Detailed Textual Analysis of the Differences Between the 1989 and 1999 Editions of Standard 90.1

Energy Standard for Buildings, Except Low-Rise Residential Buildings

Background

The Energy Conservation and Production Act provides that whenever the ANSI/ASHRAE/ IESNA Standard 90.1-1989, or any successor to that code is revised, the Secretary of Energy (Secretary) must determine whether the revised code would improve energy efficiency in commercial buildings. 42 U.S.C. 6833(b)(2)(A).

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society of North America (IESNA) approved the publication of the 1999 edition of *Energy Standard for Buildings Except Low-rise Residential Buildings*, in June 1999. After acting on several appeals the 1999 edition was published in February 2000.

The Standard was developed under American National Standards Institute (ANSI) approved consensus standard procedures. ASHRAE submitted the standard to ANSI for designation as an approved ANSI standard. In December 2000, the 1999 edition of Standard 90.1 was approved as an American National Standard.

DOE has performed both a quantitative analysis of the likely impacts of the revised code on the energy efficiency of seven categories of new commercial buildings, compared to the 1989 edition, and a non-quantitative assessment of the comparative stringency of those elements of the revised code that could not be analyzed quantitatively.

The quantitative analysis concluded that the1999 revision of the code would likely reduce the source energy consumption of new commercial buildings by approximately 5.9 percent. Site energy savings were estimated to be approximately 3.9 percent.

The comparative assessment of those elements of the 1989 and 1999 revised codes that could not be quantitatively analyzed also concluded that the 1999 standard would increase energy efficiency. The dominant factor in this comparative analysis is the 1999 edition's inclusion of alterations and renovations to existing buildings. If the value of annual investment in building alterations and renovations is a good indicator of their impact on energy use, then the expansion of this code to existing buildings could produce nearly 50% more savings than if it were applied to new buildings alone. The comparative analysis also concluded that the non-quantifiable changes affecting Lighting and Power, and Mechanical Equipment and Systems would also increase overall efficiency, although the changes to the Envelope requirements would reduce efficiency slightly.

Together, these analyses appear to indicate that the revised code will improve the energy efficiency of commercial buildings.

Request for Comment

The Secretary is not required to solicit comments from interested parties prior to reaching a determination under Section 304 of the Energy Conservation and Production Act. The sole statutory requirement is that the Secretary's determination be published in the *Federal Register*. During 1999, as a matter of policy to further the determination process, DOE solicited comments on the methodology it intended to use in performing its analysis. Prior to making its final determination, DOE is seeking further comments on its application of this methodology and the validity of its preliminary conclusions.

Comments received at:

http://www.eren.doe.gov/buildings/codes_standards/buildings/com_determinations.html

by March 9, 2001, will be considered in making the final determination.

Table of Contents

I. Summary of the Comparative Analysis

We carried out both a broad quantitative analysis and a detailed textual analysis of the differences between the requirements and the stringencies in the 1989 and the 1999 editions.

A. Quantitative Analysis

The quantitative comparison of energy codes was done using whole-building energy simulations of buildings built to each standard. We simulated seven representative building types in 11 representative U.S. climates. Note that only differences between new building requirements were considered in this quantitative analysis. Requirements in the 1999 edition that pertain to existing buildings are addressed in the detailed textual analysis. The simulations were based on a 15 zone building prototype used in previous DOE building research. The simulated Energy Use Intensities (EUI) for each zone were scaled to correctly reflect variations in building size and shapes for each representative building type. Energy use intensities developed for each representative building type were weighted by total national square footage of each representative building type to provide an estimate of the difference between the national energy use in buildings constructed to both editions. A more detailed explanation is located in Appendix B.

The scope of the 1999 edition also addresses additions and renovations to existing buildings, unlike the 1989 edition. While this difference will have a significant energy impact, we found no data available to permit us to accurately quantify this impact.

The quantitative analysis of the energy consumption of buildings built to the 1999 edition, as compared with buildings built to the1989 edition, indicates national source energy savings of approximately 5.9 percent of commercial building energy consumption. Site energy savings are estimated to be approximately 3.9 percent. These figures represent a conservative estimate of energy savings.

The quantitative analysis can be found at:

http://www.eren.doe.gov/buildings/codes_standards/buildings/com_determinations.html

B. Detailed Textual Analysis

The detailed textual analysis provides a non-quantitative assessment of the comparative stringency of those elements of the revised code that could not be analyzed quantitatively.

The lighting requirements comparison focused on the impact the different lighting requirements have on lighting energy use, as well as on building loads. The comparison looked separately at the whole building and space-by-space lighting requirements in both standards in a variety of commercial building types, as well as examined the affect of any “additional lighting power allowances.” It also looked at controls.

The mechanical requirements comparison looked at equipment efficiency requirements and system design requirements. The system design requirements affect the system efficiency, system thermal load, and also had some direct energy impacts.

In comparing the envelope requirements, we made judgements of relative stringency and frequency of occurrence of components. A positive or negative national energy impact was then estimated, based on practical application of the design requirements in each edition.

Each standard has multiple ways to demonstrate compliance. We did not perform a detailed comparison of the relative stringency of the alternate paths internal to a single standard or between standards. The large number of variables among the alternative compliance paths made such a comparison prohibitive to undertake. Further, we knew of no data on which to base the selection of representative requirements for such an analysis. Assignment of requirements would have been arbitrary. Rather we focused on the prescriptive compliance paths in each section, which we believe represent the most common approach to using the standard in question for most buildings.

II. Discussion of Detailed Textual Analysis

A. Title and Scope

The 1999 edition contains a title and text explicitly applying the standard to alterations and renovations to existing buildings, but only those portions or components of the existing building which are replaced or changed. This greatly expands the scope of the standard beyond the 1989 edition which only applied to new buildings or new portions of existing buildings (additions). While it is difficult to quantify the energy efficiency impact of alterations and renovations, we know from the U.S.

Department of Commerce Current Construction Reports that the broader category of improvements and repairs to commercial buildings in 1998 were valued at $99.9 billion, as compared to new building construction valued at $210.7 billion. While the improvements and repairs category is only half as much as new construction, it is a significant amount and alterations and renovations can be expected to be a significant part of that category.

B. Lighting and Power

1. Interior Lighting Power Exemptions

The 1989 edition entirely exempts a number of lighting categories such as display or accent lighting for galleries, and lighting in spaces designed for the visually impaired. In doing so, it also exempts controls for those lights. While the 1999 edition exempts the lighting power requirements, it retains requirements for controls in the exempted areas. Lighting for outdoor manufacturing, commercial greenhouses, and process facilities; and special lighting for research are exempt in the 1989 edition but not in the 1999 edition. These differences can be expected to result in some reduction in lighting power use as a result of the additional coverage in the 1999 edition. Conversely, there are a number of narrowly targeted exemptions in the 1999 edition that are not in the 1989 edition. These include: lighting integral to equipment installed by its manufacturer; lighting integral to open and glass enclosed refrigerator and freezer cases; lighting integral to food warming and preparation equipment; lighting in interior spaces that have been designated as a registered interior historic landmark; exit signs; lighting that is for sale or lighting educational demonstration systems; and casino gaming areas. The first three of these are not generally controlled by the 1989 edition because they are rarely known at the time the lighting plans are approved. While portions of gaming areas are often considered entertainment areas and exempt, the broader 1999 edition exemption can be expected to increase energy use in casinos. Lighting for landmark interiors might also increase in some cases. The net effect of these differences in exempted spaces is expected to be a small increase in efficiency in the 1999 edition.

2. Exterior Lighting Power

The 1989 edition prescribes maximum installed lighting power (Watts/square foot or Watts/linear foot) for exterior building and grounds areas that, when added together, become the allowed exterior wattage. The 1999 edition sets similar criteria for exits, entrances, and surface areas or facades, but also adds an efficacy requirement of 60 Lumens per Watt in luminaries of over 100 Watts . There is a three Watts/linear foot increase in allowable wattage for entrances without canopies in the 1999 edition. However, there is a decrease in allowable wattage for all exits (5 Watts/linear ft), and for high traffic canopied entrances (7 Watts/square foot), and for light traffic canopied entrances (1 Watts/square foot). The net impact is an overall energy savings with the 1999 edition.

For loading areas, loading doors, storage and non-manufacturing work areas, and driveways, walkways, and parking lots, the 1999 edition deviates from the 1989 edition by eliminating any Watts/square foot or Watts/linear foot maximums and instead sets an efficacy requirement of 60 Lumens per Watt (over 100 Watts per luminaire). This requirement in the 1999 edition eliminates the use of low efficiency technologies, such as incandescent lamps, and allows the economics of fixture and energy cost to restrict the exterior lighting use to the minimum needed. We are aware of no data on which to make a judgement as to net decrease or increase in energy use from this change.

3. Lighting Controls – Interior

The 1989 edition requires control points for each task or group of tasks within a 450 square foot area. It "counts" control "points" (1 for manual , 2 for occupancy sensor, etc.) to show compliance with this requirement, giving credit to automatic controls versus manual ones. It further sets a minimum of one control for each 1,500 Watts of lighting. In place of this task control requirement, the 1999 edition requires all buildings over 5,000 square feet in size to have automatic lighting shutoff in all spaces using time of day, occupancy sensor, or similar methods. Buildings over 5,000 square feet make up approximately half the number of commercial buildings built and over 89 percent of the floor area constructed. This should save energy in these buildings during unoccupied hours. Where occupancy sensors are used to comply with the requirement the savings should be greatest, since this will shut off lights in unoccupied individual spaces, even during regular business hours.

The 1999 edition adds control requirements for six specific lighting functions: all task lighting, hotel/motel guest rooms, display/accent lighting, case lighting, nonvisual (plant growth, food warming), and demonstration (for sale or for lighting demonstration). Furthermore, the 1999 edition requires that spaces up to 10,000 square feet in size have at least one control per 2,500 square feet and that larger spaces have one control per 10,000 square feet. In buildings with large open areas with multiple task areas lit by general lighting, the 1989 edition would require more (total manual or automatic) switching than the 1999 edition. The 1999 edition instead reduces lighting use in unoccupied spaces with automatic controls that do not require human intervention. The 1999 automatic control requirements are more likely to reduce lighting energy use in these spaces than the manual controls permitted in the 1989 edition.

The 1989 edition provides lighting control credits for use in calculating interior lighting power densities to encourage the use of automatic controls. For each area or group of lights that are controlled by an occupancy sensor, lumen maintenance sensor, daylight sensor, or combination of sensors, the design connected lighting power value used in showing compliance can be reduced by from 10 percent to 40 percent, depending on the controls used. This allows more lighting power to be used in the space in trade of the use of an automatic lighting control. The 1999 edition requires the use of automatic controls without allowing an increase in connected power.

The 1989 edition requires permanently wired lighting fixtures and switched receptacles in hotel suites of rooms to be controlled at the entrance to each room. The 1999 edition further requires this control to be at the entrance of the entire suite area. The 1999 edition should save energy by making it easier to turn off all the lights on the way out.

4. Ballast Efficacy Factor

The 1989 edition includes a minimum ballast efficacy factor. The 1999 edition does not. However, new ballast manufacturing standards required under the Energy Policy and Conservation Act serve the same purpose and no longer make it necessary to include such criteria in the 1999 edition. There will be no change in energy use as a result of this difference.

5. Exit Signs

The 1999 edition includes an additional section specifying a minimum efficiency (35 lm/W) for all exit signs operating at greater than 20 watts that is intended to eliminate the use of standard incandescent lamps in exit signs. This will essentially eliminate the use of incandescent exit signs thereby reducing energy consumption.

6. Interior Lighting Power – Whole Building

The 1999 edition provides greater clarity in specifying the calculation of luminaire or lighting system wattage that covers self ballasted, remote ballasted, track lighting systems and other miscellaneous lighting. This could eliminate some under-estimation of installed lighting power. For example, it is not uncommon for a fluorescent lighting fixture to be described by builders (with respect to power consumption) as the simple sum of the lamp wattages while ignoring ballast energy use.

The 1989 edition presents a set of whole building lighting power density requirements for 11 building types in six different building size ranges (0 – 2,000; 2,001 – 10,000; 10,001 – 25,000; 25,001 – 50,000; 50,001 – 250,000; and greater than 250,001 square feet). The 1999 edition presents a single set of whole building lighting power density requirements for 31 building types without building size variation. For four of the building types where there is a reasonable match between 1989 and 1999 editions, the 1999 allowance is higher by 0.06 to 0.64 Watts per square foot. Seven other matched building types show the 1989 edition having lighting power allowances 0.20 to 0.80 Watts per square foot higher than in the 1999 edition. Over all 11 matched building types there is an average reduction of 0.11 Watts per square foot with the 1999 edition. Within the two building types representing the largest percentage of building floor area in the commercial sector (office and retail) the reductions with the 1999 edition are 0.40 Watts per square foot for office and 0.60 Watts per square foot for retail buildings. Because there is an average reduction of lighting power densities from the 1989 edition to the 1999 edition in all matching building types, and also a reduction in the lighting power densities allowed in the two largest building types (office and retail), the overall effect of the whole building lighting power density requirements in the 1999 edition will be to provide increased energy efficiency in most building types. However, it should be noted that there is a significant increase in the lighting power allowance for warehouse and storage type buildings, which are significant in terms of total commercial building area. We expect a net reduction in energy use with the whole building requirements.

7. Interior Lighting Power – Space-By-Space

Both the 1989 and 1999 editions present individual building space lighting power allowance values for use in applying a space-by-space compliance method where individual space lighting power is aggregated to arrive at a building total power allowance. The 1989 edition's tabulated space-by-space allowances are used in the compliance process only after they have been adjusted by an Area Factor (AF) ranging from 1.0 to 1.8. This factor is used to increase the allowed lighting power when the shape of the room (the size and height) necessitates the use of additional lighting power to achieve certain levels of illuminance. The area factor that can be used to calculate some space type allowances is limited. For example, the allowance for sports playing areas, corridors, open offices, and mechanical rooms cannot be modified by an area factor, while the allowance for enclosed offices can be modified by an area factor of up to 1.55. Spaces that are used for multiple functions, such as auditoriums, conference, banquet, and meeting rooms, are allowed an additional lighting power adjustment factor of 1.5. By contrast, this adjustment for room dimensions is already built into the 1999 edition's space lighting power values, so adjustments for space dimensions are not permitted. The 1999 edition does allow some additional lighting power allowances to accommodate specific lighting needs. These include additional power for decorative lighting (1.0 Watts/square foot), additional power for VDT terminal lighting (0.35 Watts/square foot), and additional power for retail display lighting. In the latter case, either 1.6 Watts/square foot of specific display area is allowed for general merchandise highlighting, or 3.9 Watts/square foot of specific display area is allowed for valuable merchandise highlighting. This additional power is only allowed if the specified luminaries are installed and can only be used for the specific purpose noted.

It is difficult to assess the actual impact from the use of the 1999 edition's space-by-space method versus the 1989 edition's. This is because the allowed power density for a building will depend greatly on the space makeup of the building, the individual room dimensions (affecting the area factor adjustment) and any additional allowances that may apply. However, the average of all matching 1989 and 1999 edition power density space values shows a 0.36 Watts/square foot decrease in the 1999 edition's values from those in the 1989 edition. Identical room geometry configurations (based on those used in the development of the 1999 edition's lighting power densities) were taken into account in reaching this conclusion. Furthermore, it is important to consider the items in both editions that can modify these lighting allowances. For example, the 1989 edition would allow the use of a 1.5 additional lighting power adjustment factor for multi-purpose spaces, such as "Auditorium," "Conference/Meeting Room," and "Banquet/Multi-Purpose Space", whereas the 1999 edition would be even more energy efficient because there is no such area factor adjustment.

Determining the impact of the additional power allowances in the 1999 edition make direct comparison with values in the 1989 edition difficult, since any comparison using either example buildings or lighting models requires many assumptions regarding what is "typical" in this type of space and how it is used. For example, in the 1989 edition the base lighting power density for a mass merchandise store in a warehouse-type setting is 3.3 Watts/square foot. With the application of an appropriate area factor (1.05), the 1989 edition's adjusted power allowance is 3.46 Watts/square foot. The 1999 edition starts with a base lighting power density for all retail establishments of 2.1 Watts/square foot. The 1999 edition allows additional lighting power for certain lighting activities including retail sales lighting. These come in the form of an additional 1.6 Watts/square foot of lighted area for merchandise highlighting and 3.9 Watts/square foot of specific fine merchandise display. The application of these allowances will depend on the layout of the retail space and how and for what height the lighting is employed. This is not unlike how the area factor in the 1989 edition depends on the geometry of the individual space.

Office space lighting has a similar difference in that the 1999 edition offers an additional power allowance for visual display terminal lighting. No such allowance is included in the 1989 edition's values. Spaces with decorative lighting similarly are allowed extra power only for the decorative lighting used.

To make some assessment of the possible impact of these additional allowances, we developed characteristics of a space under the 1999 edition whose total space lighting power allowance would match that of the 1989 edition. For this comparison, we selected what we believed to be reasonable amounts of additional lighting power needed for merchandise display areas, office space used for computer work, and decorative lighting. Table 1 presents comparisons for a variety of representative cases.

Table 1. Additional lighting power allowance in the 1999 edition needed to match the 1989 edition lighting power allowance.

Space Type [Additional Lighting Type]	1989 Edition Adjusted Total Power (W/ft^2)	1999 Edition Base Power (W/ft^2)	Possible Scenarios of use of additional power in 1999 edition to equal 1989 edition value
Hotel Lobby [Decorative]	2.51	1.8	Requires 71 percent of entire space with decorative lighting
Office - enclosed [Visual Display Terminal]	2.38	1.5	Cannot reach the 1989 edition's value (Max 1999 value = 1.85 W/ft^2)
Office - open [Visual Display Terminal]	2.51	1.3	Cannot reach the 1989 edition's value (Max 1999 value = 1.65 W/ft^2)
Jewelry Retail [Highlight Merchandise]	7.40	2.1	Cannot reach the 1989 edition's value (Max 1999 value = 6.00 W/ft^2)
Fine Merchandise Retail [Highlight Merchandise]	4.23	2.1	55 percent of space dedicated to spotlighted fine merchandise displays – OR – 50 percent of space dedicated to spotlighted general displays and an additional 34 percent to spotlighted fine merchandise displays
Mass Merchandise (big box) Retail [Highlight Merchandise]	3.30	2.1	75 percent of space dedicated to spotlighted general displays – OR – 30 percent of space dedicated to spotlighted fine merchandise displays
Department Store Retail [Highlight Merchandise]	4.10	2.1	51 percent of space dedicated to spotlighted fine merchandise displays – OR – 50 percent of space dedicated to spotlighted general displays and 30 percent to spotlighted fine merchandise displays
Food and Misc. Retail [Highlight Merchandise]	2.80	2.1	43 percent of space dedicated to spotlighted general displays
Service Retail	3.57	2.1	92 percent of space dedicated to spotlighted

[Highlight Merchandise]			general displays
Mall Concourse [Highlight Merchandise]	1.85	1.8	3 percent of space dedicated to spotlighted general displays

In the case of the hotel lobby and the mall concourse examples, little use of additional lighting power allowances is required for the 1999 edition lighting power allowance to equal or exceed the 1989 edition value. By contrast, the office and jewelry store examples show that the 1989 edition lighting value cannot be achieved, even with the maximum allowance possible applied. In the remaining examples the 1989 edition lighting values cannot be achieved without additional lighting power scenarios that are generally unreasonable for the space type. This indicates to us that the 1999 edition lighting values are more stringent, with the additional lighting power allowances more than compensated for by the reduction in base lighting power in the 1999 edition.

C. Building Envelope

1. Air Leakage

The 1989 edition provides a series of air-leakage standards or requirements that individual components must meet. The 1999 edition replaces all these standards with a requirement to use the National Fenestration Rating Council's, *Procedure for Determining Fenestration Product Air Leakage*, NFRC 400, as the test procedure. Table 2 compares the air leakage requirements for envelope openings in the two editions.

Table 2. Comparison of air leakage requirements in the 1989 and 1999 editions.			
Product	1989 Edition	1999 Edition	1989 - 1999 Difference
Windows			
Aluminum Framed, Operable	0.37 cfm/lin ft	0.4 cfm/ft^2	+0.03
Aluminum Framed, Jalousie	1.5 cfm/ft^2	0.4 cfm/ft^2	-1.10
Aluminum Framed, Fixed	0.15 cfm/ft^2	0.4 cfm/ft^2	+0.25
Vinyl Framed	0.06 cfm/ft^2	0.4 cfm/ft^2	+0.34
Wood Framed, Residential	0.37 cfm/ft^2	0.4 cfm/ft^2	+0.03
Wood Framed, Light Commercial	0.25 cfm/ft^2	0.4 cfm/ft^2	+0.15
Wood Framed, Heavy Commercial	0.15 cfm/ft^2	0.4 cfm/ft^2	+0.25
Skylights	0.05 cfm/ft^2	0.4 cfm/ft^2	+0.35
Doors			
Aluminum Sliding	0.37 cfm/ft^2	0.4 cfm/ft^2	+0.03
Vinyl Sliding	0.37 cfm/lin ft	0.4 cfm/ft^2	+0.03
Wooden, Residential	0.34 cfm/ft^2	0.4 cfm/ft^2	+0.06
Wooden, Light Commercial	0.25 cfm/ft^2	0.4 cfm/ft^2	+0.15
Wooden, Heavy Commercial	0.10 cfm/ft^2	0.4 cfm/ft^2	+0.30
Commercial Entrance, glazed	1.25 cfm/ft^2	1.0 cfm/ft^2	-0.25
Commercial Entrance, opaque	1.25 cfm/ft^2	0.4 cfm/ft^2	-0.85
Residential Swinging	0.50 cfm/ft^2	0.4 cfm/ft^2	-0.10
Aluminum Wall Sections	0.06 cfm/ft^2	Not covered	+

The impact of these changes on energy efficiency is hard to evaluate. Air leakage requirements for windows are more stringent for four window types, about the same for two window types and less stringent in one window type in the 1999 edition. Skylight requirements are more stringent in the 1999 edition than in the 1989 edition. Doors are more stringent for two types, less stringent for two other types, and about the same stringency for three types, in the 1999 edition. We have no data as to the prevalence of each different type of component and without this data, we have determined that the overall impact on energy efficiency is minimal.

The 1999 edition does include additional requirements for loading dock weather seals in colder climates (greater than 3,600 heating degree days, base 65 degrees Fahrenheit) and also a requirement for vestibules in commercial building entrance doors. These requirements are not present in the1989 edition. These new requirements should improve energy efficiency in buildings where they are required.

2. Insulation Installation

The 1999 edition requires that insulation be installed in substantial contact with the inside surface of cavities. It also requires that lighting fixtures, heating, ventilating, and air-conditioning, and other equipment not be recessed in such a manner as to affect the insulation performance. Finally, the 1999 edition bans installation of insulation on suspended ceilings with removable ceiling panels. The 1989 edition does not address this subject at all. These 1999 edition insulation installation requirements are expected to save energy in commercial buildings.

3. Speculative Building Envelopes

Buildings constructed on speculation that they will be leased or occupied by as yet unknown occupants are referred to as “speculative” buildings in the 1999 edition. Speculative buildings are often designed and the envelope constructed prior to the final occupancy being known. Both the 1989 and 1999 editions cover this issue, albeit in somewhat different fashion. The 1989 edition sets the most stringent envelope requirements likely to be encountered to be installed in the building from the start, while the 1999 edition allows a less stringent envelope to be installed to accommodate a less demanding occupancy (such as a semi-heated warehouse), but then requires an upgrade to the envelope efficiency if the building use changes to a more demanding occupancy (such as office space). While these approaches differ, we do not believe the difference will impact the overall energy use of commercial buildings.

4. Envelope Thermal Transmittance in Cold Climates

The 1989 edition has an explicit set of requirements for the building envelope (wall, roof, and fenestration) for climates with more than 15,000 heating degree days, base 65 degrees Fahrenheit. The 1999 edition addresses these climates in bins, or groupings of ranges of degree days, that are slightly different than the 1989 edition (see Table 3). The U-factor requirements in the 1999 edition are generally less stringent. However, in reality there are very few locations in the United States (including Alaska) that have heating degree days, base 65 degrees Fahrenheit, greater than 15,000.

Table 3. Differences in building envelope thermal requirements in cold climates between the 1989 and 1999 editions.

Envelope Element	1989 Edition Cold Climate (>15,000 HDD65) Requirements	1999 Edition Bin 25 (16,201-19,800 HDD65) Requirements
Opaque Wall	U-0.053 for large buildings U-0.040 for small buildings	U-0.045 to 0.071, depending on type of wall)
Fenestration	U-0.52 (for window to wall ratios of less than 0.2 for large buildings and 0.15 for small buildings)	U-0.43, for the corresponding WWR values
Roof	U-0.024	U-0.027 to 0.049, depending on type of roof
Floor Over Unconditioned Space	U-0.023	U-0.033 to 0.064, depending on type of floor
Slab on Grade Insulation	R-15 for 48 inches	R-15, for 24 inches
Skylight	Not allowed	U-0.95

The predicted impact on national commercial building energy use is negligible since there is little or no construction in areas with heating degree days, base 65 degrees Fahrenheit, greater than 15,000.

5. Skylight Thermal Transmittance and Solar Heat Gain

For buildings whose overall roof U-factor including skylights is less than the 1989 edition's requirements, no separate skylight requirements must be met. For buildings that cannot meet this requirement, the 1989 edition contains skylight thermal transmittance requirements that are a function of heating degree days, base 65 degrees Fahrenheit, as well as provides credit towards the overall roof U-factor requirement where lighting controls are used to reduce lighting consumption. The 1999 edition has separate requirements for glass skylights with curbs, plastic skylights with curbs, and skylights without curbs, which vary by climate bin. The least stringent of these are for glass skylights with curbs. The 1999 edition provides no envelope credits for using lighting controls in conjunction with skylights. A comparison of the 1989 and 1999 editions requirements is shown in Table 4. The 1989 edition U-factors are those incorporated in Addenda F to that edition to show the whole window U-factors.

Table 4. Comparison of skylight U-factor requirements in the 1989 and 1999 editions.

Climates with:	1989 Edition	1999 Edition
HDD65 <8000	U-0.7	U-1.17 to 1.98 (glass)
HDD65 $8000	U-0.52	U-0.88 to 1.17 (glass)
Skylight curbs all climates	U-0.21	Included in U-factor for skylights with curbs

The 1989 edition limits the maximum allowable percent of skylight area based on skylight visible light transmittance, number of heating degree days, base 65 degrees Fahrenheit, number of cooling degree hours, base 80 degrees Fahrenheit, foot candle level, and interior lighting power density. The allowable percent of roof area in skylight ranges from about 2 percent to 12 percent for specific combinations. The 1999 edition limits skylights to 5 percent of roof area.

The 1989 edition is more stringent than the 1999 edition in terms of required skylight U-factor. On the other hand, the total area of skylight that can be installed is less in the 1999 edition. In other words, the 1999 edition has greater restriction on the total roof area in skylights, but does allow skylights with a higher U-factor to be used. This essentially allows the user of the 1999 edition to put in a smaller amount of less efficient skylight than the 1989 edition.

The 1989 edition does not have any requirements for skylight solar heat gain. The 1999 edition does include specific solar heat gain coefficient (SHGC) requirements for skylights. SHGC values for glass skylights range from 0.16 in very warm climates to “No Requirement” in very cold climates. Implicit in the1989 edition’s thermal transmittance requirements, however, are SHGC values associated with the required glass. With required U-factors at 0.7 and 0.52 for skylights, skylights would have to be constructed with glazing similar to double pane and double low-emissivity glazing. Such construction would have SHGC values of 0.68 and 0.59. Using this logic, a comparison of skylight SHGC values is constructed in Table 5. Values are taken for 5 percent of the roof area in skylights, as this is the maximum prescriptive level in the 1999 edition. The upper range of SHGC values in the 1999 edition column is for cooler climates within each range.

Table 5. Comparison of solar heat gain coefficients (SHGC) in the 1989 and 1999 editions.

Climates With	1989 Edition SHGC	1999 Edition SHGC
HDD65 #7500	0.68	0.16 to 0.62*
HDD65 $7500 <10801	0.59	0.36 to 0.64*
HDD65 >10801	0.59	No requirement

The 1999 edition SHGC requirement is more stringent for virtually all locations in the US. The 1989 edition does have lower SHGC requirements in very cold climates, but since solar gain is a net benefit in these climates, restricting solar gain provides no benefit.

6. Slab-On-Grade and Below Grade Wall Insulation

Slab-on-grade insulation requirements are non-existent in both editions in warm climates. For cooler climates, the1989 edition requires between R-7 to R-8 for vertical insulation, extended 24 inches deep, whereas there are effectively no requirements for slab insulation in the 1999 edition in the continental U.S. For heated slabs the 1989 edition requires an additional insulation level of R-2 above the level required for unheated slabs in all cases. For below grade walls the 1989 edition requires insulation levels from R-7 to R-16 for the first story below grade, depending on location, whereas there are effectively no requirements for below grade wall insulation in the 1999 edition until above 9000 heating degree days, base 65 degrees Fahrenheit (much of Alaska and some northern Minnesota locations). The reduction of slab-on-grade and below grade wall insulation requirement in the 1999 edition will result in higher heating loads in cold climates, particularly for small buildings. However, the magnitude of the impact will be tempered by the insulating effect of the surrounding earth.

7. Roof Thermal Transmittance

We looked at roof thermal transmittance requirements by comparing the U-factor criteria in 11 representative climate locations. For each climate, the 1989 edition provides a single prescriptive U-factor for roofs, while the 1999 edition provides 9 possible U-factors (or R-values) depending on building type and roof type.

Table 6. Comparison of roof U-factor criteria in the 1989 and 1999 editions.

		1989 Edition	**1999 Edition**		**1989 - 1999 Non-Residential Difference**
City	**Roof Type**	**All roofs**	**Non-Residential (U-Factor)**	**Semi-Heated (U-factor)**	
Denver	Buildings with Attics	0.051	0.034	0.053	0.017
	Insulation Above Deck		0.063	0.173	-0.012
	Metal Buildings		0.065	0.097	-0.014
Detroit	Buildings with Attics	0.053	0.034	0.053	0.019
	Insulation Above Deck		0.063	0.173	-0.010
	Metal Buildings		0.065	0.097	-0.012

Table 6. Comparison of roof U-factor criteria in the 1989 and 1999 editions.

City	Roof Type	1989 Edition All roofs	1999 Edition Non-Residential (U-Factor)	1999 Edition Semi-Heated (U-factor)	1989 - 1999 Non-Residential Difference
Fresno	Buildings with Attics	0.059	0.034	0.081	0.025
	Insulation Above Deck		0.063	0.218	-0.004
	Metal Buildings		0.065	0.167	-0.006
Knoxville	Buildings with Attics	0.11	0.034	0.081	0.076
	Insulation Above Deck		0.063	0.218	0.047
	Metal Buildings		0.065	0.097	0.045
Los Angeles	Buildings with Attics	0.1	0.034	0.081	0.066
	Insulation Above Deck		0.093	0.282	0.007
	Metal Buildings		0.072	0.167	0.028
Minneapolis	Buildings with Attics	0.045	0.027	0.053	0.018
	Insulation Above Deck		0.063	0.173	-0.018
	Metal Buildings		0.065	0.097	-0.020
Orlando	Buildings with Attics	0.063	0.034	0.614	0.029
	Insulation Above Deck		0.063	1.282	0.000
	Metal Buildings		0.065	1.28	-0.002
Phoenix	Buildings with Attics	0.046	0.034	0.081	0.012
	Insulation Above Deck		0.063	0.218	-0.017
	Metal Buildings		0.065	0.167	-0.019
Providence	Buildings with Attics	0.053	0.034	0.053	0.019
	Insulation Above Deck		0.063	0.173	-0.010
	Metal Buildings		0.065	0.097	-0.012

Table 6. Comparison of roof U-factor criteria in the 1989 and 1999 editions.					
		1989 Edition	**1999 Edition**		**1989 - 1999 Non-Residential Difference**
City	**Roof Type**	**All roofs**	**Non-Residential (U-Factor)**	**Semi-Heated (U-factor)**	
Seattle	Buildings with Attics	0.064	0.034	0.081	0.030
	Insulation Above Deck		0.063	0.218	0.001
	Metal Buildings		0.065	0.097	-0.001
Shreveport	Buildings with Attics	0.066	0.034	0.081	0.032
	Insulation Above Deck		0.063	0.218	0.003
	Metal Buildings		0.065	0.167	0.001

The 1999 edition tends to be more stringent than the 1989 edition for buildings with attic insulation and less stringent for buildings with insulation above deck or metal buildings. Roof insulation requirements for semi-heated buildings are also less stringent in the 1999 edition. (Semi-heated buildings are defined as being heated by a heating system with output greater than 3.4 Btu per hour for each square foot, but with an output less than in Table 3.2. Output in this table ranges from 5 to 30 Btu per hour for each square foot for climates with heating degree days, base 65 degrees Fahrenheit, ranging from none to over 16,201.) Because of the predominance of built-up roofs (insulation-above-deck) in commercial buildings, as well as the ever-increasing use of metal-building construction, particularly for semi-heated warehouse-type structures, we believe that the sole roof type that is more stringent in the 1999 edition loses much of its impact. Overall, we believe there is a moderate decrease in roof U-factor with the 1999 edition, with a significant decrease in requirements for semi-heated type structures.

8. Floors Over Unconditioned Spaces

For each climate, the 1989 edition provides a single prescriptive U-factor for floors, while the 1999 edition provides 9 possible U-factors (or R-values) depending on building type and floor type. The range of requirements for the 1999 edition addresses wood framed, steel framed, and mass (concrete) floor construction separately. Typically, wood framed floors have the lowest (most stringent) U-factor requirement, while mass floors have the highest (least stringent) U-factor. The 1999 edition is typically more stringent for wood framed and steel framed floors, and less stringent for mass floors in non-residential (and residential) buildings. The 1999 edition is less stringent for semi-heated buildings (see Table 7.)

Table 7. Comparison of floor over unconditioned space U-factor criteria in the 1989 and 1999 editions.

		1999 Edition						1989 - 1999 Difference		
		Non-Residential			Semi-Heated			Non-Residential		
City	1989 Edition All Floors	Wood Frame & Other	Steel Joists	Mass	Wood Frame & Other	Steel Joists	Mass	Wood Frame & Other	Steel Joists	Mass
Orlando	0.28	No Requirement			No Requirement			0.280		
Phoenix	0.19	0.051	0.052	0.137	No Requirement			0.139	0.138	0.053
Los Angeles	0.17							0.119	0.118	0.033
Shreveport	0.11							0.059	0.058	-0.027
Fresno	0.10							0.049	0.048	-0.037
Knoxville	0.074	0.051	0.052	0.107	0.066	0.069	0.322	0.023	0.022	-0.033
Seattle	0.056							0.005	0.004	-0.051
Denver	0.049	0.033	0.052	0.087	0.066	0.069	0.322	0.016	-0.003	-0.038
Detroit	0.048							0.015	-0.004	-0.039
Providence	0.048							0.015	-0.004	-0.039
Minneapolis	0.040							0.007	-0.012	-0.047

Overall, there will be a net decrease in energy use under the floor criteria in the 1999 edition.

9. Opaque Wall Thermal Transmittance

The 1989 edition provides a single prescriptive U-factor for lightweight walls and a range of possible U-factors for mass walls (depending on thermal mass), while the 1999 edition provides 12 possible U-factors (or R-values) depending on building type and wall construction. The maximum thermal transmittance requirements for mass walls in the 1999 edition generally fall within the range of allowable values in the 1989 edition, except for semi-heated buildings where in all cases the 1999 criteria is less stringent. However, since buildings in the semi-heated category are expected to have relatively low heating loads (due to the low internal temperature and limited heating capacity) and no cooling loads, the reduction in stringency is expected to have a minimal impact.

The difference in criteria for lightweight walls between the 1989 and 1999 editions varies, with some wall types being more stringent in some locations and other less stringent. In general, wood framed wall requirements in the 1999 edition are most likely to be more stringent than corresponding requirements in the 1989 edition.

To compare requirements for mass walls in the1989 edition, we used the Alternate Component Packages tables to determine U-factor requirements for 8 inch solid concrete and solid grouted concrete block mass walls (Heat Capacity > 15 Btu/ft^2-F) as well as for 8 inch unfilled or insulated concrete block walls (10 Btu/ft^2-F < Heat Capacity < 15 Btu/ft^2-F). We did this for insulation on the inside of the wall, integral with the wall, and on the outside of the wall, under each of the three internal load density (ILD) ranges in the Alternate Component Packages tables. This was done for the 11 locations and for 18 percent and 38 percent window to wall area ratios. The requirements used were based on interpolation across the tabulated fenestration levels. For each internal load density range, we averaged together all calculated U-factor requirements. These results are shown in Table 8. In addition, we show the 1999 edition's U-factor requirements by that edition's three space-type categories (non-residential, residential, and semi-heated).

Table 8. Mass wall requirements comparison.

Location	1989 Edition Mass Wall Requirements			1999 Edition Mass Wall Requirements			U-Value Difference		
	Interior Load Density								
	Low	Medium	High	Non-Residential	Residential	Semi-heated	Non-Residential[a]	Residential[b]	Semi-heated[c]
ORL	0.624	0.649	0.636	0.58	0.151	0.58	-0.062	-0.473	-0.044
PHX	0.404	0.403	0.400	0.58	0.151	0.58	0.179	-0.253	0.176
LOS	0.737	0.791	0.793	0.58	0.151	0.58	-0.212	-0.586	-0.157
SHR	0.301	0.327	0.328	0.58	0.123	0.58	0.252	-0.178	0.279
FRS	0.293	0.307	0.311	0.58	0.151	0.58	0.271	-0.142	0.287
KNX	0.166	0.185	0.188	0.151	0.104	0.58	-0.036	-0.062	0.414
SEA	0.123	0.140	0.147	0.151	0.104	0.58	0.007	-0.019	0.458
DET	0.100	0.107	0.109	0.123	0.09	0.58	0.015	-0.010	0.480
DEN	0.131	0.144	0.144	0.123	0.09	0.58	-0.021	-0.041	0.449
PRV	0.100	0.107	0.109	0.123	0.09	0.58	0.015	-0.010	0.480

MNP	0.078	0.087	0.088	0.104	0.09	0.58	0.017	0.012	0.502

[a] Non-Residential versus average of Medium and High Interior Load Density cases
[b] Residential versus Low Interior Load Density case
[c] Semi-heated versus Low Interior Load Density case

The difference in required U-factors for typical buildings is also shown. For this comparison, we have assumed that most non-residential buildings in the 1999 edition would fall into either the medium or high interior load density ranges of the 1989 edition. The average U-factor for both of these interior load density ranges was used in the comparison. Most residential buildings would fall into the low interior load density range of the 1989 edition. Most semi-heated building spaces (assumed to be similar to warehouse buildings) would likely fall under the low interior load density range of the 1989 edition. As can be seen from the table, the requirements of the 1999 edition are more stringent for residential buildings in almost all climates. This is particularly so in moderate to warm climates. The 1999 edition is considerably less stringent for semi-heated buildings in all but Orlando and Los Angeles, where heating losses are not expected to be significant anyway. The 1999 edition is generally less stringent for non-residential construction in moderate to warm climates and slightly less stringent for cool or cold climates. Overall, it is expected that the reduced U-factor requirements for mass walls in the non-residential and semi-heated category will result in increased heating energy use over the 90.1-1989 mass wall requirements.

10. Window Thermal Transmittance and Solar Heat Gain

The 1989 edition does not specifically provide a prescriptive approach to window thermal transmittance or solar heat gain, but rather treats windows as a component of the building wall where the wall must have certain overall heating and cooling performance to show compliance. However, the ACP (Alternate Component Packages) tables which set out prescriptive requirements for the building envelope provide tables of maximum percentage of wall glazing as a function of window U-factor, shading coefficient, projection factor, and building internal gains. The 1999 edition, by contrast, provides prescriptive U-factor requirement and Solar Heat Gain Coefficient requirements for particular combinations of percentage of glazing and building category (non-residential, residential, semi-heated), simplifying use and enforcement. Both editions require the use of an energy tradeoff methodology for buildings with very high percentages of window area (typically greater than 50 percent).

For typical levels of internal gains, the requirements for window thermal transmittance in residential and non-residential buildings are very similar in both editions. The 1989 edition is somewhat more stringent in cold climates in buildings with a high percentage of glazing. The 1999 edition is marginally more stringent in the rest of the country. For semi-heated buildings, the requirements in the 1999 edition are less stringent except in warm climates where both editions require single pane glass.

Window solar heat gain requirements in the 1999 edition are typically more stringent in buildings with lower glazing areas (less than 30 percent), but often less stringent in buildings with higher glazing areas (38 percent or 45 percent). Maximum solar heat gain requirements do not exist for semi-heated buildings in the 1999 edition. However, limiting solar heat gain does not reduce energy use for a building that is only heated.

For windows with northern orientations, the 1999 edition generally allows greater solar heat gain per window area than the 1989 edition. Overall the 1999 edition is more energy efficient in reducing solar heat gain in most buildings, but somewhat less efficient with regard to window thermal transmittance particularly in cold climates.

11. Opaque Doors

The 1999 edition contains explicit U-factor requirements for both swinging and non-swinging doors, with requirements ranging from a U-factor of 0.5 (for both door types in cold climates) to 1.45 for uninsulated doors of both types. An insulated metal door or a solid wood door require U-factors of 0.5. Glass doors that are more than one-half glass are considered to be equivalent to vertical fenestration and would need to meet vertical glazing requirements. The 1989 edition does not explicitly deal with either opaque or glazed doors, but instead treats them as part of the overall wall requirement. Opaque doors are part of the opaque wall, glass doors are part of the glazed area. Since the required thermal performance of opaque doors in the 1999 edition is generally worse than that of the surrounding opaque wall area, and the opaque door requirements are included in the overall wall requirements of the 1989 edition, the requirements of the 1999 edition are less stringent. Doors represent a small percentage of the wall area of multi-story buildings. They also represent a fairly small percentage of the wall area of many large single story buildings. Most commercial entrance doors are glazed, reducing the impact of the difference in opaque door requirements. We therefore conclude that the energy impact of this change is likely to be small for most buildings. However, in individual buildings with a significant number of doors, the impact may be significant.

D. Mechanical Equipment and Systems

1. Load Calculations and Sizing

The 1999 edition has no explicit sizing requirements for heating, ventilation, and air-conditioning systems. The 1989 edition requires the use of a computational procedure for load calculations, and it details selection of indoor and outdoor design temperature, the use of Standard 62-89 for minimum ventilation, and a selection of allowed sources for internal gain data. The 1989 edition also explicitly allows a 10 percent safety factor for steady-state design loads and additional 30 percent and 10 percent multipliers beyond that to account for heating and cooling pick-up loads. However, these additional parameters represent typical values or sources for sizing calculation data. Their omission in the 1999 edition is not expected to result in a significant reduction in energy efficiency.

2. Separate Air Distribution Systems

The 1989 edition requires that zones with special process, temperature, and/or humidity requirements, either be served by air distribution systems separate from those used to satisfy zones conditioned for comfort only, or have provisions to allow control for comfort conditioning only. An exception to this allows up to 25 percent of the air flow serving primarily process systems to be directed for comfort cooling-only needs with no system design modification. This exception might be used for office space in an industrial facility. This requirement provides the ability to operate the primary heating, ventilation, and air-conditioning systems for comfort conditioning only when processes are not operating. The 1999 edition has no requirements explicitly for systems and equipment used for process applications. However, where systems would also serve spaces conditioned for comfort only, the equipment and system requirements of the 1999 edition would apply. In particular, requirements referring to zone isolation, dehumidification, and simultaneous heating and cooling would address most of the issues addressed by the separate air distribution system requirement in the1989 edition. This will result in a minor reduction in stringency in a limited number of buildings.

3. Temperature Controls

The 1999 edition has an additional requirement that all zone and loop controllers shall incorporate control error correction. In addition, it explicitly requires a set point overlap restriction when the heating and cooling to a zone are controlled by separate thermostats within that zone. The additional requirements make the 1999 edition better at controlling room temperature and will limit reheating and recooling done by separate systems, which will provide improved efficiency over the1989 edition.

4. Off-Hour Controls and Setback

The 1999 edition requirements for off-hour controls are limited to systems with heating or cooling capacity greater than 65,000 Btu per hour and fan system power greater than 3/4 horsepower. The requirement for off-hour controls in the 1989 edition are for systems greater than two kilowatts. Exceptions are also made for heating ventilation and air-conditioning systems serving hotel or motel guest rooms. In these cases the 1999 edition is less stringent. However, the optimum start controls required in the 1999 edition for large systems should reduce the number of hours needed to bring the building to operating temperature.

The 1989 edition allows either independent shut-off controls or set-back controls to reduce heating and cooling to the zone. The 1999 edition requires automatic shutoff controls for the supply of conditioned air, outside air, and exhaust air to each independent isolation area, as well as automatic shutdown controls. However, it specifically allows substitution of a system air flow reduction in the non-occupied zones, but limits the total volume of air to those zones to 14 percent of the system airflow. The 1999 edition, by requiring maximum setback air volumes, has more stringent off-hour requirements. These would be achieved by simple thermostat setback. Both editions incorporate different exceptions to these off-hour requirements for multi-zone systems, but our limited data on commercial building multi-zone systems and operating schedules is insufficient to evaluate these exceptions.

5. Dampers

The 1999 edition requires motorized dampers in stair and elevator shafts and in all outdoor air supply exhaust hoods, vents, and ventilators. Gravity dampers are acceptable on buildings less than three stories and of any height in buildings in climates with less than 2700 heating degree days, base 65 degrees Fahrenheit. These damper performance requirements are more stringent than similar requirements in the 1989 edition. However, the requirements in the 1999 edition pertain to fewer systems (only to systems larger than 65,000 Btu per hour). The 1989 edition requires dampers (motorized or gravity) or other means of volume shut-off or reduction. It exempts supply and exhaust systems less than or equal to 3000 cfm for warm climates (less than or equal to 3000 heating degree days, base 65 degrees Fahrenheit). Overall, the 1999 edition is considerably more stringent on large systems, but is less stringent on small systems in climates above 3000 heating degree days, base 65 degrees Fahrenheit.

6. Humidity Control

The 1989 edition had a requirement that any humidity control device (humidistat) be capable of limiting the use of fossil fuel or electric energy to provide relative humidities of greater than 30 percent or less than 60 percent. This range limit of setpoint requirements for zone humidification is not included in the 1999 edition. Instead, a requirement for having the capability to prevent simultaneous humidification or dehumidification was added, with an exception for zones with tight humidity requirements approved by local authorities, or for desiccant systems used in series with evaporative cooling. Minimum impact is expected from this change as both editions effectively require systems with both humidification and dehumidification to have the controls to limit waste from abuse of these systems.

7. Radiant Heating

The requirement in the 1999 edition that radiant heating be used on unenclosed spaces such as loading docks without air curtains will save energy compared to the use of warm-air heating systems allowed in the 1989 edition.

8. Ventilation

The 1989 edition requires ventilation systems be designed capable of providing the ventilation levels prescribed in Standard 62-1989. The 1999 edition omits this requirement. However, the 1989 edition did not set the ventilation rate, but rather specified a minimum operational ventilation rate that the system must be designed to provide. Operation of a system at higher or lower ventilation rates is allowed under the 1989 edition. Therefore no savings or loss in efficiency should occur from this specific change. Furthermore, minimum ventilation rates are generally specified in the mechanical code and not including them in the 1999 edition of the energy code will reduce any conflict between the two codes.

The requirements in the 1999 edition for automatic ventilation controls for high occupancy areas increase the stringency of that edition and should provide some energy savings.

9. Pipe and Duct Insulation

The 1999 edition has slightly less stringent pipe insulation requirements than the 1989 edition for most building applications. The 1999 edition does not require insulation of piping unions in heating systems or hot water piping between the shutoff valve and coil (up to 4 feet of pipe) in conditioned spaces. It also requires more insulation on higher temperature (> 250 F) piping, and less insulation on lower temperature heating system and service hot water piping. The 1989 edition requires more insulation on low temperature cooling system piping. These differences should have minimal impact.

The 1999 edition has significantly less stringent duct insulation requirements for some categories of ducts. For cooling-only ducts, the 1999 edition requires generally lower insulation levels for ducts located outside the building and insulation levels at or lower than required in the 1989 edition for most spaces inside the building. The 1999 edition generally requires higher insulation levels for ventilated attics and for unvented attics with non-insulated attic decks, which can be high temperature areas of the building. It requires no insulation for indirectly conditioned spaces including return air plenums.

For heating-only ducts, the 1999 edition requires somewhat less insulation on exterior heating ducts, except in the most extreme heating climates where it requires more. It requires very little insulation on heating-only ductwork located inside the building envelope.

For return ducts located exterior to the building, the 1999 edition requires lower insulation levels. The lower duct insulation requirements are likely to be most significant for heating-only ducts in climates where insulation is not required for particular attic or unconditioned spaces. The reduction in the minimum insulation level for cooling-only ductwork is significant for central systems that rely on year round cooling availability (such as variable air volume or dual duct systems). Both insulation reductions will decrease energy efficiency of the 1999 edition.

Finally, the 1999 edition does not restrict the use of pressure sensitive tape at seal level C for supply pressures up to 2 inches of pressure, whereas the 1989 edition restricts its use for seal class C above 1 inch. Research is ongoing regarding the impact of this, however it is likely to show a reduction in energy efficiency.

10. Heat Recovery

New requirements in the 1999 edition for exhaust air heat recovery for systems of 5,000 cfm or greater with 70 percent or greater outside air will have significant impact on energy efficiency in heating, ventilation, and air-conditioning systems with high outside air requirements. However, the number of buildings of this type that are exempted is significant. Requirements have also been added that condenser heat recovery be used to provide heating of service hot water for buildings with a combination of continuous operation, high water heating loads (greater than 1,000,000 Btu per hour) and high cooling loads (approximately 400 tons). Primary examples are large hotel facilities. These requirements significantly increase efficiency, but in a relatively small percentage of buildings.

11. Completion Requirements

Both editions have requirements for testing and balancing of heating, ventilation, and air-conditioning equipment. The 1999 edition requires a written balancing report for zones over 5,000 square feet in area, as well as requires the ability to measure differential pressure across pumps greater than 10 horsepower in size. For buildings larger than 50,000 square feet conditioned area, detailed commissioning instructions for heating, ventilation, and air-conditioning systems are required to be provided by the designer in plans and specifications. An exception to this requirement is made for warehouses and semi-heated spaces. The more detailed and extensive documentation requirements have the potential to provide long-term energy efficiency beyond what would be expected under the minimum completion requirements of the 1989 edition.

12. Simultaneous Heating and Cooling Controls

The 1989 and 1999 editions have essentially identical text requiring that zone thermostatic and humidistatic controls shall be capable of operating in sequence the supply of heating and cooling energy to prevent reheating, recooling, or mixing of previously heated and cooled air; or other simultaneous operating of heating and cooling systems in the same zone. Similar exceptions are provided for both editions regarding: zones with special pressurization or cross-contamination requirements, zones where at least 75 percent of the reheat energy is provided from a site-recovered or site-solar source, and where the reheated volume of supply air to a zone is no greater than the maximum of several defined limits. In the latter case, however, the 1999 edition either removes or provides additional stipulations that limit the use of most of these maximum reheated-air exceptions. This should result in significant reduction in building energy use for many common multizone heating, ventilation, and air-conditioning system designs.

13. Economizer Controls

The 90.1-1999 edition requires economizers in fewer locations than the 1989 edition, but requires them in the locations of the country where they are expected to be most beneficial. The 1989 edition requires economizers on 7 ½ ton or larger equipment in climates not excepted from economizer requirements altogether. The 1999 edition uses a sliding scale of economizer requirements that depend on climate and system size, going down to 65,000 Btu per hour equipment for some climates and up to 135,000 Btu per hour equipment in climates where economizers provide less benefit. In addition, the 1999 edition requires air economizers to be capable of providing 100 percent of the design supply air quantity (versus only 85 percent in the 1989 edition), as well as specifying 1) allowed economizer control types to maximize economizer savings in specific climates, 2) leakage rates for outside air dampers, and 3) that economizer dampers in multi-zone systems shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature. In general, 90.1-1999 attempts to provide more economizer savings where economizers are most beneficial, and to not require them in climates where they provide less benefit.

14. Fan System Design Criteria

Both editions will result in similar levels of allowed fan power per CFM of airflow, although the 1999 edition has expressed those requirements using motor nameplate horsepower in order to make them more easily inspected. In addition, the 1999 edition places those requirements on fan motors down to 5 horsepower, whereas the fan system power requirements are on motors 10 horsepower and above in the 1989 edition. The 1999 edition also has more stringent unloading requirements for VAV fans, and places those requirements on VAV systems down to 30 horsepower, versus 75 horsepower in the 1989 edition. Both the constant volume and variable volume fan power requirements will be extended to far more system types in the 1999 edition. Overall, there is expected to be a significant reduction in fan power using the 1999 edition, particularly for multi-zone systems.

15. Pumping System Design

Both editions require that pumping systems designed for variable flow be designed to allow flow variation down to 50 percent of design flow rates, but the 1999 edition also has a requirement that pump power at 50 percent flow be no more than 30 percent of design flow power for systems with over 100 feet of pumping head or motors greater than 50 horsepower. This will effectively require variable speed pump drives on these large pumping systems. Exceptions are made for pumps under 75 horsepower where reduction of flow would be below the minimum flow requirements for heating, ventilation, and air-conditioning equipment, and for systems that include no more than 3 control valves. Significant energy savings will result from application of the 1999 edition in larger systems due to these part-load performance requirements.

16. Temperature Reset Controls

The 1989 edition requires system temperature reset controls on both multizone air systems and large, non-variable-flow hydronic systems. These controls shall be capable of providing a reset of at least 25 percent of the design supply to room air temperature difference, with some exceptions, most notably for low zone flow rates or for systems not capable of providing reheat. The primary purpose of this requirement is to reduce reheat in air systems. Supply water temperatures must also be capable of a reset equivalent to 25 percent of the design supply-to-return water temperature difference except for hydronic systems that can provide a 50 percent reduction in system flow, or are less than 600,000 Btu per hour in capacity, or for which reset controls would cause improper operation of heating, cooling, humidification, or dehumidification systems. The 1999 edition requires reset on chilled and hot water temperature controls used for heating, ventilation, and air-conditioning systems over 300,000 Btu per hour design capacity. Direct energy savings are expected from the reset of the supply water temperature from chiller and boiler, and the air supply temperatures in the system are assumed to follow the water temperature reset. An exception is made for hydronic systems that use variable flow to reduce pumping energy, or for systems where reset would cause improper operation of heating, cooling, humidification, or dehumidification systems. Overall, there is little net change in the reset requirements for hydronic systems other than the 1999 edition applying them to more systems. The 1999 edition does remove the air reset requirements, but addresses simultaneous heating and cooling more directly by better limiting the amount of air reheated or recooled in a new section of the standard (see Simultaneous Heating and Cooling Controls above). Some minimal degradation in efficiency is expected from removal of the air-side reset requirements, but this is likely to be offset by the increase in efficiency from requiring reset on smaller hydronic systems.

17. Hot Gas Bypass Restriction

The 1999 edition introduces a new requirement that restricts the use of hot gas bypass in cooling equipment unless the equipment is designed with multiple steps of unloading. In the latter case, hot gas bypass is allowed, but maximum hot gas bypass levels are specified as a fraction of total capacity for different sizes of cooling equipment. This requirement will provide an improvement in part-load performance for cooling equipment, where not already done by manufacturers.

18. Heating, Ventilation, and Air-conditioning Equipment

The 1999 edition provides updated equipment efficiency requirements which come into effect in October 29, 2001. Tables 6.2.1A - 6.2.1G of the 1999 edition show the existing 1989 edition's heating, ventilation, and air-conditioning equipment efficiency requirements (shown in the "Minimum Efficiency" column) with the 90.1-1999 update requirements shown in the "Efficiency as of October 29, 2001" column in each table across heating and cooling product categories. A summary of the shipped capacity weighted efficiency improvement across generic product categories is shown in Table 9.

Table 9. Shipped capacity weighted efficiency improvement across generic product categories, including equipment shipments to commercial buildings covered by Federal manufacturing standards.

Equipment Category	Estimated Full Load Efficiency Improvement
Unitary Air Conditioners and Condensing Units	~ 7.6%
Unitary and Applied Heat Pumps	~9.2%
Electrically Operated Water Chillers	~16.8%
Absorption Chillers	~5.2+%
Packaged Terminal Air Conditioners and Heat Pumps	~22.4%
Room Air Conditioners	~10.1%[c]
Furnaces, Duct Furnaces, Unit Heaters	~0+%[d]
Boilers	~0%[e]

The absorption chillers 5.2 percent estimated full-load efficiency improvement is based on double effect chillers. The 1989 edition had no efficiency requirement for absorption chiller equipment, but the market baseline for double effect chiller is a coefficient of performance of 0.95 and rises to a coefficient of performance of 1.0 in the 1999 edition. Improvements of up to 25 percent above market minimums are estimated for single effect equipment.

The change in room air-conditioner efficiency was driven by manufacturing standards requirements effective October 1, 2000 (10 CFR 430). These will occur without the requirements of the 1999 edition.

For furnaces, duct furnaces, and unit heaters, changes were made to test procedures and efficiency descriptors for unit heaters, but no net change was made in efficiency. Improved prescriptive requirements in the 1999 edition for warm-air furnaces such as requirements for intermittent ignition or interrupted device and jacket loss limits, will improve annual efficiency.

For boilers, the full load descriptor was improved, but not the boiler efficiency requirements.

In addition to providing updated efficiency requirements for most commercial equipment, the 1999 edition subdivides several of the original 1989 edition product categories and adds new efficiency requirements for heat rejection equipment which were not covered under 1989 edition. The 1999 edition provides coefficient of performance and integrated part-load value requirements for centrifugal chillers operating at other than nominal test conditions. It also expresses efficiency requirements for boilers less than or equal to 2.5 million Btu per hour input rating using true thermal efficiency, as opposed to combustion efficiency requirements in the 1989 edition. The 1999 edition provides separate efficiency requirements for packaged terminal air conditioner and packaged terminal heat pump equipment used for replacements in existing buildings and used for new construction. It also updates efficiency requirements to reflect changing test procedures and mandates the use of intermittent or interrupted ignition devices and either power venting or flue dampers on forced air furnaces. Finally, the 1999 edition restricts jacket losses on gas and electric furnaces located outside conditioned space.

The 1999 edition provides significant improvement to cooling equipment efficiencies, and minor increases in average oil or gas space heating equipment efficiency due to changes in efficiency designator or shell loss requirements. It also provides for moderate increases in heat pump heating side efficiency. All of these requirements will improve the general efficiency of commercial space conditioning products beyond that required in the 1989 edition, and will thus contribute to energy savings with the 1999 edition.

19. Service Water Heating Equipment Efficiency

The 1999 edition sets service water heating (SWH) equipment efficiencies for gas- and oil-fired equipment at, or moderately higher than, the 1989 edition levels. It improves thermal efficiencies from 2 to 3 percentage points for gas water heaters with integral storage and improves thermal efficiencies 1 percent for oil-fired instantaneous water heaters with integral storage, as well as for the similarly defined category of "hot water supply boiler".

The general form of the equations for standby loss were recast between what is required under the 1989 edition and what is required by the 1999 edition. With the 1989 edition, the standby loss was purely a function of volume. With the formulation in the 1999 edition, standby loss is a function of both volume and input rating. For gas and oil water heaters, the stringencies of each standard are roughly the same within each of the individual product categories. This allows somewhat more standby loss for large input rating products and allows somewhat less standby loss for smaller input rating products. Without very detailed information about the shipment of products within a size category, it is unknown whether there is a net change in efficiency. For electric water heaters greater than 12 kilowatt input, the 1999 edition does appear to allow marginally greater standby loss, as the formula is based on rated as opposed to measured contents, and allows a ten percent variation from the rated value. However, since this product is covered by a Federal national manufacturing standard that is more stringent than the requirements of the 1999 edition and the federal standard preempts state or local regulation, unless a waiver is granted, the reduced stringency in the 1999 edition should result in no reduction in efficiency.

20. Service Water Heating Controls

Both the 1989 and 1999 edition have requirements for a minimum service hot water temperature control capability set point, as well as a maximum control temperature requirement for public restrooms, of 110 degrees Fahrenheit. Since these are only capability and not set point requirements, no change in net building energy use is expected or assured. The 1989 edition also has a requirement that booster heaters be installed where outlet temperatures of over 120 degrees Fahrenheit were required, which is absent in the 1999 edition. The energy impact of dropping this requirement is highly dependent on the fuel source used by the booster heater. Generally, a slight increase in site energy use in specific applications might be expected, however there may also be a corollary reduction in source energy use occurring from the reduced use of electric booster heaters (a cheap first cost alternative to meeting the 1989 edition requirement). The net impact on hot water energy use is expected to be minimal.

21. Conclusion About Detailed Textual Analysis

The predominate factor identified in the detailed textual analysis is that the scope of 1999 edition includes alterations and renovations to existing buildings. The scope of 1989 edition does not include existing buildings. A significant increase in energy efficiency of commercial buildings will occur due to this change in scope.

Our assessment of seven areas of change in the Lighting and Power sections of the two editions leads us to conclude that there will be a net positive increase of efficiency in commercial buildings from these revisions. Conversely, our assessment of the 11 areas of change in the Envelope section of the two editions leads us to conclude that there will be a net decrease in efficiency of commercial buildings due to these changes. Finally, our review of the 22 areas of change in the Mechanical Equipment and Systems sections of the two editions leads us to conclude that these revisions will produce a net positive increase in the efficiency of commercial buildings.

We therefore conclude from our detailed textual analysis that there will be a significant positive increase from the change in scope and a modest net gain from the other changes.