Energy Efficiency: Building on Standard 90.1

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Energy Efficiency, Section 7, addresses six major categories: envelope requirements, on-site renewable energy systems, mechanical equipment efficiencies, energy consumption data collection, peak load control and lighting. Each of these areas has been identified as a critical component in addressing the efficient use of energy in the design of high-performance buildings.

The energy requirements include a set of mandatory requirements that must be met for all projects, and the choice of either a prescriptive set of requirements or a performance path to demonstrate full compliance with the energy chapter.

The energy requirements in Standard 189.1 build upon those in Standard 90.1. During the development of Standard 189.1, a general goal was determined of setting design requirements that would result in an overall *average* of 30% energy use savings compared to Standard 90.1-2007. Based on energy modeling results by the National Renewable Energy Lab and the U.S. Department of Energy, this goal was achieved based on an overall average of building stock and climate zones across the U.S. Unless specifically exempted or otherwise addressed in the energy efficiency section, the building project must meet all of the requirements of the Standard 90.1 Chapters 5 through 10 (building envelope, HVAC,

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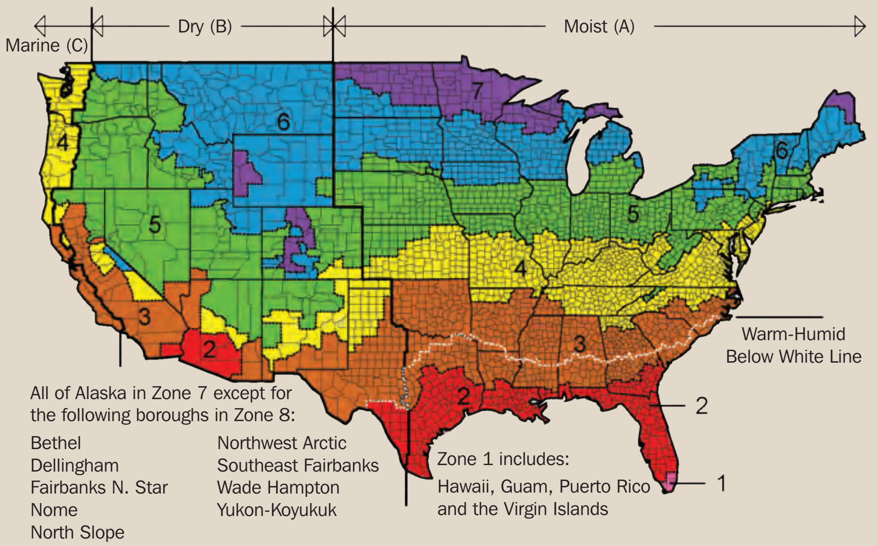
Section 7:

Energy Efficiency

Unless specifically exempted or otherwise addressed in the energy efficiency section, the building project must meet all of the requirements of the Standard 90.1. In general, Standard 189.1 provides requirements that are more stringent than Standard 90.1.

Figure 1 U.S. climate zone map.



service water heating, power, lighting, and motors). In general, Standard 189.1 provides requirements that are more stringent than Standard 90.1.

Prescriptive Envelope Requirements

Insulation and Fenestration

The prescriptive building envelope requirements in Standard 189.1 include additional energy-saving measures to those in Standard 90.1. The thermal insulation requirements for opaque assemblies, as well as the U-factor and solar heat gain coefficient (SHGC) fenestration requirements for Standard 189.1 are presented in Appendix A using the same format as those for Standard 90.1. These criteria vary by climate zone (*Figure 1*), and these are the same climate zones used in Standard 90.1 and the International Energy Conservation Code (IECC).

For nonresidential spaces, the building envelope criteria are generally based on the most stringent of the criteria in E-Benchmark 1.1 (now Core Performance as of July 2007) and the *Advanced Energy Design Guide for Small Office Buildings* and the *Advanced Energy Design Guide for Small Retail Buildings*, provided that those criteria were more stringent than the requirements in Standard 90.1-2007. Where the criteria in Standard 90.1-2007 were equal or more stringent, the requirement for Standard 189.1 was raised by an increment with a few exceptions in some milder climate zones.

For residential spaces, where the criteria are the same as those for nonresidential spaces in Standard 90.1, they are the same in Standard 189.1. Where the residential criteria are more stringent than the nonresidential criteria in Standard 90.1-2007, they have also been made more stringent in Standard 189.1.

The prescriptive requirements can only be used when vertical fenestration is less than 40% of gross wall area. When using greater amounts of vertical fenestration, the energy performance path in Section 7.5 of the standard must be used.

Continuous Air Barrier

The prescriptive requirement for a continuous air barrier can be met using any one of three criteria:

Materials. Using individual materials that have an air permeability not to exceed 0.004 cfm/ft^2 under a pressure differential of 0.3 in. water (1.57 lb/ft^2) (0.02 L/s·m^2 under a pressure differential of 75 Pa). The requirement can be met using the list of the materials provided in Appendix B of the standard or by testing other materials.

Assemblies. Using assemblies of materials and components that have an average air leakage not to exceed 0.04 cfm/ft^2 under a pressure differential of 0.3 in. water (1.57 lb/ft^2) (0.2 L/s·m^2 under a pressure differential of 75 Pa). The requirement can be met using the list of the assemblies provided in Appendix B of the standard or by testing other assemblies.

Building. Testing the completed building and demonstrating that the air leakage rate of the building envelope does not exceed 0.4 cfm/ft^2 under a pressure differential of 0.3 in. water (1.57 lb/ft^2) (2.0 L/s·m^2 under a pressure differential of 75 Pa).

Note that the requirement for assemblies is 10 times more stringent than for whole buildings. This is because of the added air leakage that occurs due to penetrations and gaps that occur when whole buildings are tested compared to individual assemblies. Similarly, the requirement for materials is 10 times more stringent than that for assemblies because of the air leakage that occurs when materials are taped or pieced together to form assemblies.

Fenestration Shading

The standard requires that there be permanent shading projections on the west, south, and east walls of buildings in Climate Zones 1 through 5 unless the vertical fenestration receives direct solar radiation for fewer than 250 hours per year because of shading by nearby structures or topography. This requirement is intended to reduce the solar heat gain to the buildings in these climate zones. Since the requirement is for an area-weighted projection factor of 0.5, not every window is required to have a permanent shading projection or overhang. Requirements also can be met by recessed windows, the use of balconies, building shapes that shade themselves or other architectural features. A projection on the west face of a building in Climate Zone 5 is shown in *Photo 1.*

Building and Fenestration Orientation

The prescriptive fenestration orientation requirement for Climate Zones 1 through 6 encourages design that orients the building with the longest façades on the north and south. This discourages large amounts of fenestration on the east and west facades, which are subject to the most solar gains in the summer months due to the lower angle of the sun on these faces. Lower SHGCs on the east and west façades can be used to meet these requirements in Climate Zones 1 through 4. A similar requirement is in place for Climate Zones 5 and 6, but only restricts fenestration on the west face. This recognizes the benefits of solar gains on the east façade for morning warm-up in colder climates.

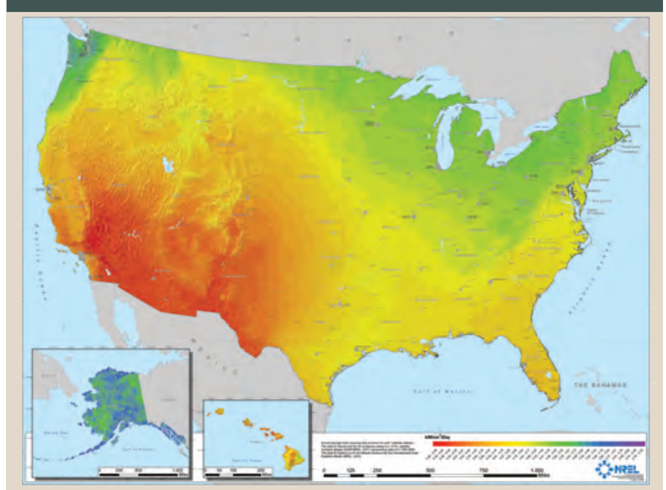
On-site Renewable Energy

The project committee recognized that today, renewable energy systems are not always cost effective. However, the committee also realized that once a building is constructed, the opportunity for future installation of such systems is often lost forever. Meanwhile, the capital cost for such systems is expected to decline as their use increases.

To enable the future installation of such systems as they become more cost effective, the standard has a mandatory requirement that the building design provide for the future installation of a photovoltaic, solar thermal, geothermal energy (but not including ground-source heat pumps) or wind system with a minimum rating of 13 Btu/h·ft^2 (3.7 W/ft^2) multiplied by the total roof area. Provision for future installation means to show allocated space

Photo 1 Overhang on west face of building in Climate Zone 5 (photo courtesy of CTLGroup).

Figure 2 U.S. photovoltaic solar resource map: Flat plate tilted at latitude. (NREL: www.nrel.gov/gis/solar.html.)



for solar collectors, pathways for conduit, piping and associated equipment on the construction documents.

This minimum requirement was based on the assumption that a typical photovoltaic array generates 8 to 10 watts of power per square foot of photovoltaic panel when operating at peak capacity and that roofs on most building can allocate 50% of their roof area for these systems. The only exception for the installation of such systems is if the building is in a location with poor incident solar radiation, defined as 4 kW/m^2·day on a collector oriented due south and tilted at an angle equal to the site's latitude and as illustrated in *Figure 2*. This exempts the upper Midwest and New England states, as well as portions of the Pacific Northwest. Sites with adequate permanent shade also will often meet the exemption.

Under the prescriptive requirements, buildings that do not qualify for the same incident solar radiation exception must install on-site renewable energy systems at the time of construction. These systems must be capable of providing annually at least either 4 or 6 kBtu/ft^2 (45 to 68 MJ/m^2)of conditioned space, depending on other criteria that are used for compliance. Since this requirement is in terms of conditioned space rather than roof area, compliance will be easier for low-rise buildings or buildings with surrounding space that can be used for on-site renewable energy systems. Sites that meet the poor incident solar radiation exception must purchase a specified amount of renewable energy complying with the Green-e Energy National Standard for Renewable Electricity Products. This requirement corresponds to a purchase of renewable energy certificates (RECs) for about 10 years. When these prescriptive requirements are not met, the energy performance path in Section 7.5 of the standard must be used.

Mechanical Equipment

The minimum mechanical equipment efficiencies are those required by the National Appliance Energy Conservation Act (NAECA), the Energy Policy Act (EPACT), and the Energy Independence and Security Act (EISA). As a high performance green building standard, Standard 189.1 seeks to encourage the installation of higher than minimum efficiencies not only in mechanical equipment but throughout the standard.

The requirements for mechanical equipment are based on Section 6 of Standard 90.1 except as modified. In the case of mechanical equipment for HVAC, two options exist for compliance within the prescriptive compliance path (*Figure 3*). The first option is to comply with the energy-efficiency requirements of the NAECA, EPACT and EISA, which are the values listed in Standard 90.1 and the renewable energy and peak load reduction provisions as outlined in the prescriptive sections. The second option allows a reduction by one-third in the amount of on-site renewable energy required and a less stringent peak load reduction if mechanical equipment efficiencies are increased to meet ENERGY STAR requirements and the requirements in Appendix C of Standard 189.1.

Figure 3 Complying with the HVAC equipment minimum efficiency requirements.

EPAct Baseline

Use equipment with EPAct baseline efficiency levels, and:

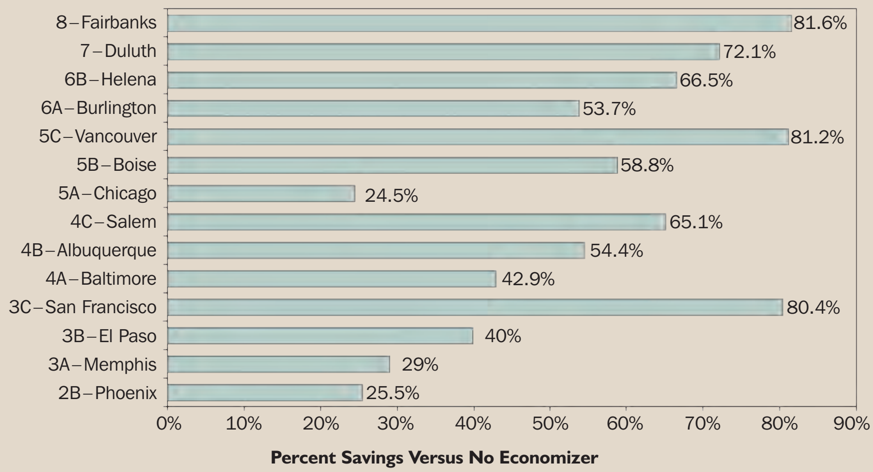
- Renewable energy system producing 6.0 kBtu/ft^2 conditioned floor space annually
- Peak electrical load reduction of 10%

Higher Efficiency

Use higher efficiency of ENERGY STAR requirements and Appendix C, and:

- Renewable energy system producing 4.0 kBtu/ft^2 conditioned floor space annually
- Peak electrical load reduction of 5%

Figure 4 Air economizer HVAC cooling energy savings.



There are also lower occupant density thresholds associated with demand control ventilation requirements and increased duct sealing requirements. To avoid providing outside ventilation air to a space during periods of less than design occupancy, demand control ventilation is required except in certain cases. Not only does this result in additional energy savings, but this may help avoid mold and other excess moisture problems that occur, resulting in a healthier environment, as well as a more efficient building.

With the increased envelope requirements and higher internal commercial building loads, the use of air and water economizers for free cooling can offer significant energy savings for a typical office building. Standard 189.1 modifies the minimum size requirements for economizers from those of Standard 90.1 and requires rooftop units with a capacity of less than 60,000 Btu/h (17 584 W) to have two stages of capacity control with the first stage relying on the economizer and the second stage adding the mechanical cooling. It also requires integrated economizers for all economized units such that the economizer and mechanical cooling can be used together. For most systems with cooling capacity exceeding 33,000 Btu/h (9671 W), either an air or water economizer is required except in certain circumstances (for example, Climate Zones 1A, 1B and 2A). The changeover control for economizers must be either differential enthalpy or differential dry bulb.

To reduce the energy waste associated with simultaneous operation of heating and cooling equipment, zone controls are required. These controls are intended to prevent reheating, recooling and the mixing or simultaneous supply of air that has been previously heated with air that has been previously cooled either by mechanical systems or by an economizer. Limited simultaneous heating and cooling of air is allowed, based on the larger of the *design outdoor airflow rate* or 15% of the supply airflow to the zone.

Indoor fan power in commercial buildings can be a significant portion of the overall HVAC energy use due to ventilation requirements that require the fan to operate continuously. Standard 189.1 has reduced maximum allowable fan power by 10% versus Standard 90.1. It also requires all constant volume DX units with a capacity greater than 110,000 Btu/h (32 238 W) and all fan coils with a motor horsepower greater than 5 hp (3.7 kW) to have at least a two-speed fan or variable speed fan to allow for reductions in fan power at lower loads.

Standard 189.1 also expands the requirements for exhaust air energy recovery devices to be used to transfer energy from the exhaust air to the return air in heating and from the outdoor ventilation air to the exhaust air in cooling. The requirements are a function of the region, supply air volume and outside air volume.

To reduce energy in unoccupied hotels and motel guest rooms, controls must be installed that set back the HVAC system and turn off plug loads when the rooms are unoccupied. Plug loads, including lighting, switched outlets, and television, must be turned off when occupants are not in the room. In Europe and Asia this is often accomplished by inserting a room key card in a device that activates power to these items when entering the room.

Energy Consumption Data Collection

An important part of ensuring the sustainable performance of an energy-efficient building is establishing that it continues to perform as designed. To better facilitate that performance, energy consumption data must be captured and retained. For energy sources meeting certain size or capacity thresholds, Standard 189.1 requires that measurement devices with remote communication capability be installed to collect energy consumption data. If building energy metering is required for an energy source, then energy subsystems such as the total HVAC system, people moving system and so on, are also required to collect and electronically store data if the subsystems' collective load exceeds specified thresholds.

The data storage system must also be capable of producing reports summarizing the data so that building performance can be assessed at least monthly. For example, if the natural gas service to the building exceeds the equivalent of 1,000,000 Btu/h (293 kW), then the natural gas service must be metered and data retained. Gas subsystems such as

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boilers, water heating systems, etc., exceeding a capacity of 500,000 Btu/h (146 kW) must be submetered, and the data retained as well. The meter or the reporting system should be calibrated to account for the heating value content of the fuel used, the pressure of the fuel and the atmospheric pressure at the location of the mater installation. Data collected must be at a minimum, daily data with hourly energy use profiles and must be retained for at least three years. Buildings with low energy use thresholds and residential portions of buildings are exempted from these requirements.

Section 10 of Standard 189.1 requires plans to use the data to assess the energy use at least every three years. This key portion of the standard will help identify increases in energy above what is expected.

While utility-grade metering is not required, building owners may take advantage of utility "smart" metering where it exists for whole-building metering.

Service Water Heating

Minimal changes from those in Standard 90.1 are incorporated in Standard 189.1. There are requirements for increases in the amount of piping insulation and, in many cases, water heating equipment efficiencies to be more stringent than those required in Standard 90.1. Insulation on the sides and bottoms of pools used primarily as spas or for physical therapy is required.

Peak Load Reduction

Standard 189.1 requires that building projects contain automatic systems, such as demand limiting or load shifting, that are capable of reducing electrical peak demand of the building by not less than 10% exclusive of any demand reduction that may be provided by standby power generation. As described in *Figure 3*, this peak load reduction requirement is lowered to 5% if all the mechanical equipment efficiencies meet the ENERGY STAR requirements and those in Normative Appendix C. Automatic peak load reduction can be accomplished through demand limiting in which load use is curtailed or reduced or through load shifting as load use is moved to off-peak hours.

Lighting

Standard 189.1 requires compliance with Standard 90.1 lighting levels and further reduces lighting power allowances in Sections 9.5 and 9.6 by 10%. Occupancy sensors, automatic controls for egress and security lighting, automatic controls for lighting in daylight zones and controls for outdoor lighting are also required with appropriate exceptions where necessary. Users may use either the Building Area method of Section 9.5 of Standard 90.1 or the Space-by-Space method defined in Section 9.6 to determine the allowable amount of lighting for Standard 189.1. Even though the lighting power density requirements are reduced in Standard 189.1 the intent is not to result in illumination levels below those recommended by IES.

The standard requires occupancy sensor controls to have "manual on" and "automatic off" controls. All outdoor lighting controls must meet the requirements of Section 9 of Standard 90.1 with the following modifications. For lighting of building façades, parking lots, garages, canopies (sales and non-sales), and all outdoor sales areas, automatic controls must be installed to reduce the sum of all lighting power by a minimum of 50% within one hour after normal business closing and to turn off outdoor lighting within 30 minutes after sunrise except in certain circumstances.

Performance Options

As an alternate compliance path, rather than meeting the requirements of the mandatory and prescriptive sections of Standard 189.1, (sections that begin with 7.3 and 7.4), users may demonstrate compliance if their buildings meet the mandatory requirements of Section 7.3 plus the performance requirements in Section 7.5. In the performance path, compliance is demonstrated in three ways. First, buildings must have an annual building energy cost less than or equal to the annual building energy cost of a baseline building constructed meeting the mandatory and prescriptive requirements of Sections 7.3, 7.4, and seven other sections of the standard.

Second, buildings using the performance option must also have an annual CO_2e (CO_2 equivalent) less than or equal to the level achieved by compliance with Sections 7.3, 7.4, and seven other sections of the standard. To determine CO_2e, the energy use by energy source (such as electricity or natural gas) is multiplied by the factors in Table 7.5.3. Third, buildings must have the same or less peak electrical demand than that achieved by compliance with the mandatory and prescriptive requirements of Sections 7.3, 7.4, and seven other sections of the standard. The building also must have a minimum electrical annual load factor of 0.25 or more.

Compliance with the performance option requires the use of Appendix D. This appendix is similar to Appendix G in Standard 90.1 and requires a whole building, computer-based, energy simulation tool capable of modeling annual energy use on an hourly basis. Rules for this analysis are presented in Appendix D.

Summary

The intent of the energy efficiency section is to significantly reduce the energy consumption of new buildings through reductions in energy losses through the building envelope, increased efficiencies in mechanical systems, reduced lighting loads, and other energy saving measures. Standard 189.1 requires that buildings comply with Standard 90.1-2007 and then, in general, adds more stringent requirements. Standard 189.1 requires that either on-site renewable energy is used as a prescriptive option, that renewable energy certificates are purchased (only allowed in some cases), or that the building complies with the performance option and uses additional energy-saving measures to make up the deficiency from not using on-site renewable energy. ■