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ASHRAE Standard 189.1-2011

ANSI/ASHRAE/USGBC/IES Standard 189.1-2011, *Standard for the Design of High-Performance Green Buildings*,[1] embodies a collaborative effort to establish a design standard for high-performance green-building projects. Written in mandatory, code-intended language, the standard was first published in 2009 and has recently been revised to incorporate new provisions and to include updated references to other ASHRAE standards. The 2011 version has been adopted by the International Green Construction Code (IgCC) as an optional compliance path, so it's becoming more and more important to know what the standard covers and some of its key provisions.

This EN provides an overview of the standard, with a more detailed discussion of the HVAC-related provisions in the Energy Efficiency category.

Paraphrasing the ASHRAE definition, high-performance green buildings (HPGBs) are designed, constructed, and operated in a manner that increases environmental performance and economic value over time, while establishing an indoor environment that supports the health, comfort, and productivity of occupants; they do this by integrating environmentally preferable building sites and materials with water-efficient and energy-efficient systems.

The standard presents provisions in six major categories:

- Site sustainability
- Water use efficiency
- Energy efficiency
- Indoor environmental quality
- Impact on atmosphere, materials, and resources
- Construction and plans for operation

Most sections include mandatory, prescriptive, and performance-related provisions. The mandatory provisions must be met in all cases, along with either the prescriptive-option provisions or corresponding performance-option provisions.

Site Sustainability

Building projects occupy land or building area, making it unavailable for other uses. HPGB sites must be in "low impact" locations, such as brownfield or greyfield sites (see inset, p. 2, for definitions). This helps project teams "repurpose" previously developed land. Greenfield sites may also be used provided they meet additional provisions; for instance, they must be located near basic services or public transportation.

This section of the standard also addresses urban heat island effect, urban light pollution, and stormwater runoff.

Urban heat island effect. Urban heat island effect increases cooling energy use, greenhouse gas emissions, and air pollution; causes adverse health effects due to elevated temperature; and negatively impacts local water quality (the stormwater runoff is heated from the pavement and other surfaces, increasing the temperature of streams and rivers).[2]

To reduce the urban heat island effect, HPGB sites must use materials, surfaces, and other techniques to reflect more solar heat than traditional building sites. Site shading, landscaped (that is, vegetated) surfaces, porous hard surfaces, and building materials with a high solar reflectance index all help reduce site heat island effect.

Urban light pollution. Urban light pollution not only obscures the night sky, but also negatively impacts human health, air quality, and insect and animal behavior, and it wastes energy, which increases greenhouse gas emissions.[3] To reduce urban light pollution, HPGB sites must limit exterior lighting power and control exterior lights to minimize unnecessary lighting at night. The standard includes requirements related to backlight (light cast in the direction opposite to the intended direction), uplight (light cast to the night sky), and glare (blinding light that impairs vision, especially at night).

For many sites, the same building automation system that coordinates HVAC operation also controls exterior lighting, turning lights off during daylight hours, turning some exterior signs off after midnight, and reducing some exterior sign lighting to no more than 35 percent of full power between sunset and sunrise.

Stormwater runoff. Stormwater runoff can result in both physical and thermal pollution of streams, rivers, and lakes. It can also prevent stormwater from reaching the local water table.[4] To reduce stormwater runoff, HPGB sites must be developed to meet either prescriptive-option requirements for water management (such as covering site surfaces with vegetation, permeable pavement or porous pavers), or performance-option requirements, which set a minimum percentage of annual rainfall to be managed on specific sites—demonstration of rainfall management usually requires water-management computer simulation.

Water Use Efficiency

As global population increases, ground water levels decrease.[5] Pumping water out of the aquifer faster than it can be replaced by rain and snow fall, reducing the aquifer replacement rate by increasing stormwater runoff, and/or polluting the aquifer due to human activities—any of these can trigger a potential ground water crisis. A sustainable future includes intelligent management of ground water,[6] so all HPGB projects must reduce and manage both exterior (site) and interior (building) water use.

Site water use. To reduce site water use, HPGB projects must limit the use of turfgrass—a dense, thick layer of non-native, non-diverse grass that requires both fertilization and irrigation to thrive—to less than 40 percent of the improved site landscape. And, irrigation systems for the improved landscape must be designed and controlled using hydro-zoning, so that the irrigation level in each zone matches the current needs of the plantings in that zone.

Building water use. To reduce building water use, an HPGB must use efficient water fixtures. The standard includes mandatory minimum efficiency levels for water closets, urinals, faucets, and showerheads. For instance, clothes washers and dishwashers in dwelling units must meet maximum Water Factors set by ENERGY STAR requirements, while clothes washers with public access must not exceed a Water Factor of 7.5 gal/ft^3 of drum capacity per cycle.

HVAC systems must not use once-through potable-water cooling systems. Cooling towers and evaporative coolers must use blowdown and makeup water meters, conductivity controllers, and overflow alarms. Cooling towers must be designed to limit drift to a maximum percentage of the recirculated water volume. In locations where the mean-coincident wet-bulb temperature at the 1 percent design condition equals or exceeds 72°F, mechanical cooling equipment (5 tons or greater) must include a condensate-collection system to recover condensate for reuse (usually for irrigation or tower makeup water).

Potable water must not be used for water-spray roof-cooling systems or to irrigate established vegetated roofs.

Monitor water use. Both potable and reclaimed domestic water flow in some systems (for instance, those wherein potable water flow exceeds 1000 gal/day) must be monitored using measurement devices with remote communication capability. Rented or leased spaces 50,000 ft^2 or larger must include separate sub-metering. Subsystem water flow within the building project must include separate sub-metering when such subsystem water flow exceeds specific thresholds (for instance, 500 gpm for cooling towers and 1000 gal/day for processes such as a car washer or aquarium).

A data acquisition system must store the collected water-use data and must include the capability to generate hourly, daily, monthly and annual water consumption reports. As with exterior lighting, in many buildings, the BAS that coordinates HVAC operation may also act as the data acquisition system for water-flow meters.

Other requirements. In addition to the mandatory requirements discussed above, HPGB projects must be designed to meet either prescriptive- or performance-option requirements for site and building water-use reduction.

As an example, one prescriptive requirement for building water use sets a minimum makeup-rate to blowdown-plus-drift-rate ratio of 5 for cooling towers in areas with hard water—a requirement that HVAC system designers must take into account. Another requirement limits fixture water use in food service facilities and laboratories.

The performance-option, on the other hand, limits annual building water use to no more than the water use that would have been achieved by meeting

Definitions

brownfield site. A site documented as contaminated by means of an ASTM E1903 Phase II Environmental Site Assessment or a site classified as a brownfield by local, state, or federal government agency.

greenfield site. A site of which 20 percent or less has been previously developed with impervious surfaces.

greyfield site. A site of which more than 20 percent is already developed with impervious surfaces.

Source: ANSI/ASHRAE/USGBC/IES Standard 189.1-2011[1] all mandatory plus all prescriptive requirements. This approach implicitly requires demonstration of annual building water use by computer simulation.

Energy Efficiency

Energy efficiency is probably the most obvious and perhaps the most important element of high-performance green buildings. Since residential and commercial buildings account for about 40 percent of the energy used in the US, reducing building energy use tends to reduce the use of fossil fuels, dependence on foreign energy sources, and greenhouse gas emissions.

Energy efficiency, of course, applies to HVAC systems, and this section of the standard contains several HVAC-related provisions. We'll cover some of those in greater detail in the "HVAC System Energy Use" inset (p. 4). First, let's examine the mandatory provisions of this section.

Mandatory Standard 90.1 provisions. HPGB projects must reduce energy use to lower levels than those resulting from compliance with the requirements of the energy standard, Standard 90.1-2010.[7] By reference, the mandatory requirements of Standard 90.1 (Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4) become the basis for most of the mandatory provisions in Standard 189.1.

Renewable energy. Beyond energy use, HPGB projects must facilitate renewable energy use, by including the infrastructure necessary for the future installation of renewable-energy systems—6 kBtu/ft^2 of roof area for single-story buildings and 10 kBtu/ft^2 for taller buildings.

Monitor energy use. To help manage energy use and ensure that design goals are met during building operation, each energy-supply source must be monitored using measurement devices with remote communication for systems that exceed specific threshold levels. Some subsystems must be monitored separately, depending upon type of system and the magnitude of energy used (for instance, HVAC system electrical energy use must be monitored if the connected electric load exceeds 100 kVA).

A data acquisition system must store the collected energy-use data and must include the capability to generate hourly, daily, monthly, and annual energy-use reports. Again, the BAS that coordinates HVAC operation may become the data acquisition and reporting tool in many buildings.

Other requirements. In addition to the mandatory requirements discussed above, HPGB projects must be designed to meet either prescriptive- or performance-option requirements for energy-use reduction.

Prescriptive requirements are extensive, since they include *all* Standard 90.1 prescriptive provisions with additional stringency in some cases and with new provisions in other cases. Prescriptive requirements cover many areas including renewable energy production, building envelope, HVAC systems, service water heating, power, lighting, and other equipment. All prescriptive requirements cannot possibly be addressed in detail in this newsletter, but the "HVAC System Energy Use" inset (p. 4) focuses on some of the HVAC-related provisions.

Performance-option building energy-use requirements, on the other hand, address predicted annual energy cost, annual carbon dioxide emission rate, and annual peak electric demand. Each of these parameters must be no higher than the levels that would have been achieved by meeting all mandatory plus all prescriptive-option provisions. This approach explicitly requires demonstration of annual energy cost, emission rates, and peak electric demand using the comparison procedures in Appendix D of the standard. Appendix D builds on the requirements of Appendix G in Standard 90.1, specifying how the proposed building is to be compared to a baseline building using computer simulation software, such as TRACE™.

Indoor Environmental Quality

Indoor environmental quality (IEQ) impacts human health and comfort, which in turn impact occupant productivity. IEQ encompasses not only indoor air quality (IAQ) but also thermal comfort, acoustics, daylighting, and the entry of pollutants from the soil. HPGB occupants are expected to be healthier, more comfortable, and more productive than occupants of traditional buildings, although compliance with the standard cannot always ensure these outcomes.

Indoor air quality. Standard 189.1 mandates that HPGBs must meet all requirements in Sections 4 through 7 of Standard 62.1,[8] as well as any superseding requirements, such as:

- The minimum outdoor air intake flow must be found using the ventilation rate procedure (Standard 62.1, Section 6.2).
- The outdoor airflow rate must be monitored.
- MERV 8 (rather than MERV 6) filters must be used upstream of coils and in PM10 non-attainment areas.
- MERV 13 (rather than MERV 11) filters must be used in PM2.5 non-attainment areas.
- Forty percent ozone air cleaners must be used in all ozone non-attainment areas (rather than in those few areas with very, very high levels of ozone, as required by Standard 62.1).

Thermal comfort. HPGB projects must meet thermal comfort requirements by complying with Standard 55, Sections 6.1 and 6.2. "Typical" ranges for comfort parameters cannot be given because too many factors (such as occupant activity and size, building envelope design, mechanical system design, and so on) differ for each building. However, compliance with comfort requirements clearly requires accurate and responsive capacity control for mechanical cooling and heating systems.

HVAC System Energy Use

What does Standard 189.1-2011 require specifically for the design of energy-efficient HVAC systems? As stated in the Energy Efficiency section, all HPGB projects must meet the Standard 90.1-2010 mandatory requirements, so HVAC systems must meet the requirements of Section 6.4.

Note that the requirements found in Standard 90.1, Section 6.3—an optional compliance path for simple systems—are not included here because Section 7.3.1 of Standard 189.1 already requires compliance with the prescriptive path in Standard 90.1, Section 6.4. In other words, only one Standard 90.1 compliance path—namely Sections 6.1, 6.4, 6.7, and 6.8 compliance—is available for Standard 189.1 projects.

In addition to the Section 6.4 mandatory requirements, HVAC systems complying with the Standard 189.1-2011 prescriptive option must meet the requirements in Section 7.4.3, most of which supersede Standard 90.1 requirements. Table 1 summarizes the Standard 189.1 requirements. The key provisions include:

- Both single-zone and multiple-zone systems (MZS) must include demand-controlled ventilation (DCV) for zones with 25 or more people per 1000 ft^2. Although multiple-zone VAV systems can be complex, ventilation reset approaches (also required by Standard 90.1) that solve the MZS equations in real time have been used successfully in many VAV systems that use direct digital controls.
- Smaller systems (down to 2¾ tons) must include economizer cooling, which directly impacts HVAC system selection, design, and control.
- Elimination of reheat exceptions results in VAV system design challenges and more sophisticated controls.
- Increased requirements for exhaust-air energy recovery make equipment selection and exhaust air capture more important.

Overall, HVAC systems in HPGB projects save energy compared with traditional systems, but not without cost.

Table 1. HVAC-Related Mandatory and Prescriptive Provisions of Standard 189.1, Section 7

Standard 189.1 Section	Summary of Provisions
Mandatory	
7.3.1 General	For HVAC systems, comply with the mandatory requirements of Standard 90.1, Section 6.4.
7.3.2 On-site Renewable Energy Systems	Allocate space in single-story buildings for at least 6 kBtu/ft^2 (roof area) for on-site renewable energy systems. For some HVAC systems, allowance for solar thermal heating can contribute to meeting this requirement.
7.3.3 Energy Consumption Management	Provide measurement devices with remote communication capability to collect energy consumption data for each energy supply source. In some buildings, the BAS coordinating HVAC operation can be used to collect and report this energy consumption data.
Prescriptive (for HVAC systems)	
7.4.3 Heating, Ventilating and Air Conditioning	Comply with all of Section 6 of Standard 90.1, except as noted in section 7.4.3. The prescriptive provisions of Standard 189.1 include all provisions in Section 6.1, 6.4, 6.7, and 6.8 of Standard 90.1.
7.4.3.1 Minimum Equipment Efficiencies (addresses Standard 90.1-2010, Section 6.4.1 and Tables 6.8.1A through 6.8.1G)	Use products that comply with either: a) EPAct baseline: minimum efficiencies addressed in NAECA, EPAct, and EISA; or b) Higher efficiency: the greater of the ENERGY STAR requirements in Section 7.4.7.3 or the values listed in Appendix C, which *supersede* and exceed the values in Standard 90.1, Tables 6.8.1A through 6.8.1G. Also, for systems using higher efficiency equipment, the minimum renewable energy production requirement of Section 7.4.1.1 is reduced to 4.0 kBtu/ft^2 of roof area annually for single-story buildings and 7.0 kBtu/ft^2 of roof area annually for other buildings, and electric peak demand requirement is reduced from 10% to 5%. (*Note: Standard 90.1 has no renewable energy requirements or electric peak demand limits.*)
7.4.3.2 Ventilation Controls for Densely Occupied Spaces (addresses Standard 90.1-2010, Section 6.4.3.9)	Provide DCV for any area with 25 or more people per 1000 ft^2. Standard 90.1 requires DCV in spaces with 40 or more people per 1000 ft^2.
7.4.3.3 Economizers (addresses Standard 90.1-2010, Section 6.5.1)	Provide economizer cooling in all climate zones (except 1A and 1B) for any system with cooling capacity of 33,000 Btu/h or greater (with exceptions). Standard 90.1-2010 requires economizer cooling in the same climates but only for systems with cooling capacity of 54,000 Btu/h or greater.
7.4.3.4 Zone Controls (addresses Standard 90.1-2010, Section 6.5.2.1)	Provide controls to limit simultaneous heating and cooling in more cases than required by Standard 90.1.
7.4.3.5 Fan System Power Limitation (addresses Standard 90.1-2010, Table 6.5.3.1.1A)	Limit fan power to values 10% lower than those required by Standard 90.1.
7.4.3.6 Exhaust Air Recovery (addresses Standard 90.1-2010, Table 6.5.6.10)	Use energy recovery systems with at least 60% effectiveness. Standard 90.1-2010 requires at least 50% energy recovery effectiveness.
7.4.3.7 Variable-Speed Fan Control for Commercial Kitchen Hoods (addresses Standard 90.1-2010, Section 6.5.7.1)	Use commercial kitchen hoods with variable-speed exhaust-air and makeup-air fans. Standard 90.1-2010 allows constant airflow exhaust hoods.
7.4.3.8 Duct Insulation (addresses Standard 90.1-2010 Tables 6.8.2A and 6.8.2B)	Use duct insulation with higher minimum R-values than required by Standard 90.1.
7.4.3.9 Automatic Control of HVAC and Lights in Hotel/Motel Guest Rooms (adds a provision not found in Standard 90.1-2010)	In hotels/motels with more than 50 guest rooms, provide automatic controls in each guest room to raise the cooling setpoint by at least 5°F in the cooling mode and lower the heating setpoint by at least 5°F in the heating mode, within 30 minutes of occupant departure from the room.

Acoustics. Acoustical control is required for both exterior and interior sound. Perimeter walls and roof/ceiling assemblies must achieve a minimum sound transmission class. Inside the building, interior walls must also achieve a minimum sound transmission class.

Daylighting. To increase the introduction of light from outside the building to improve visibility and visual comfort for occupants, designs must use sufficient fenestration to ensure minimum daylighting by toplighting. In a 20,000 ft^2, three-story space, for instance, overhead or high side-wall fenestration must provide adequate lighting for at least 50 percent of any floor area directly beneath a roof.

Soil gas. To reduce the likelihood of soil gas intrusion, especially carcinogenic radon, building projects on brownfield sites and those in high radon regions (designated "Zone 1" areas by the EPA) must include a soil gas retarding system.

Other requirements. In addition to the mandatory requirements discussed above, HPGB projects must be designed to meet either prescriptive- or performance-option requirements to ensure minimum daylighting and to reduce indoor contaminants from building materials.

Prescriptive requirements for daylighting by sidelighting apply to most office spaces and classrooms. The sidelighting openings must meet minimum requirements for area and most offices must also meet minimum window shading requirements.

Performance-option requirements for daylighting by sidelighting include a minimum illuminance level for surfaces. Daylighting computer simulation models must be used to demonstrate that the design meets the minimum specified requirements.

Prescriptive requirements for specific building materials include either minimum VOC emissions or minimum VOC content.

The performance-option for materials requires computer simulation to show that contaminant emission rates result in acceptable space contaminant concentrations; these concentrations must comply with maximum levels for each contaminant, as established by California Section 01350.

Building Impact on Atmosphere, Materials, and Resources

The construction of buildings impacts natural resources, the atmosphere, and the ultimate fate of materials. HPGB projects address these issues.

Construction waste management. To reduce the quantity of construction materials discarded to landfills or incinerators, HPGB projects must divert at least 50 percent of construction materials by recycling and/or reuse. Total construction waste generated must not exceed 12,000 lbs per 10,000 ft^2 of building floor area.

Materials. All materials, products, and assemblies installed must comply with the appropriate regulations in the country of origin, and wood products must not include wood from endangered tree species.

Refrigerants. To reduce the impact of the building project on atmospheric ozone, HVAC equipment must not use CFC-based refrigerants, and fire suppression systems must not use ozone-depleting substances.

Recycling or disposal. Each building must have areas designated for the collection and storage of: recyclable materials, reusable materials, and in some buildings, fluorescent and high-intensity discharge (HID) lamps and ballasts.

Other requirements. In addition to the mandatory requirements discussed above, HPGB projects must be designed to meet either prescriptive- or performance-option requirements to promote the use of reduced-impact materials.

To meet prescriptive requirements, the design must meet one of the following options:

- at least 10 percent of the building's total materials must be recycled materials (with a minimum recycled content); or
- at least 15 percent of building's total materials must be extracted, harvested, recovered, or manufactured within 500 miles of the building site; or
- at least 5 percent of the building's total materials must be biobased materials.

Performance-option provisions, on the other hand, require a life-cycle assessment (LCA) to analyze at least two alternative designs, using at least the materials considered for the prescriptive option (above). The LCA must show that one approach results in at least a 5 percent improvement over the other approach(es) in at least two of the following impact categories: land use, resource use, climate change, ozone layer depletion, human health effects, ecotoxicity, smog, acidification, and eutrophication (i.e., the depletion of oxygen in water).

Construction and Plans for Operation

Building construction, operation, and maintenance has often been cited as the source of more problems than improper building design. Although this standard primarily addresses the *design* of high-performance green buildings, these buildings must also be properly constructed, operated, and maintained to help them attain the results envisioned by the design team.

Project construction. Construction requirements include acceptance testing, project commissioning, site erosion control, IAQ management during construction, moisture control and local vehicle exhaust control.

Buildings of 5,000 ft^2 or less must be acceptance tested in accordance with a specification, rule, guide, or procedure generally accepted as authoritative. Buildings larger than 5,000 ft^2 must be commissioned in accordance with a specification, rule, guide, or procedure generally accepted as authoritative, or a handbook.

An erosion and sediment control plan ensures that soil remains in place during construction. A plan for IAQ management during construction and a moisture control plan help protect workers, building materials, and future occupants. And a construction pollution-control plan protects workers from exhaust fumes from vehicles on the construction site.

Project operation. Operation requirements include a building operation plan, a maintenance plan, a service-life plan, and a transportation management plan.

A Master Building Plan for Operations covers all aspects of the design requirements in Sections 5 through 9, to ensure that the systems in each category continue to operate as designed after building occupancy. A maintenance plan requires periodic inspection and maintenance of key systems. A service life plan helps the owner plan (and budget) for future periodic repair and replacement of materials and systems. Finally, a transportation plan helps reduce the energy used by building occupants to travel to and from the building.

All provisions in this section are mandatory.

Summary

ASHRAE Standard 189.1 defines high-performance green buildings by stipulating minimum building project requirements. Similar to building rating systems, it covers many aspects of high-performance projects, ranging from site selection to water and energy use to material selection, without ignoring indoor environmental quality. When adopted into building codes, either directly or as an IgCC compliance path, this standard will help project teams consistently design the high-performance green buildings of the future.

By Dennis Stanke, applications engineer, and Jeanne Harshaw, information designer, Trane. Dennis is the current committee chairman for Standard 189.1. You can find this and previous issues of the Engineers Newsletter at www.trane.com/engineersnewsletter. To comment, e-mail us at comfort@trane.com.

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ASHRAE Standard 189.1-2011

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