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NORMATIVE APPENDIX A FORMS

For Oregon state compliance, Normative Appendix A forms are adopted as modified and published in Normative Appendix Z, Section Z6 "Compliance Forms" for *Tier 1 covered buildings* and Normative Appendix Y, Section Y6 "Compliance Forms" for *Tier 2 covered buildings*.}

NORMATIVE APPENDIX B ALTERNATIVE ENERGY INTENSITY TARGETS

NOT ADOPTED

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX C OPERATIONS AND MAINTENANCE IMPLEMENTATION

Informative Note: This appendix is based on ANSI/ASHRAE/ACCA Standard 180 [N18], Section 4, "Implementation," with application to the operations and maintenance of all *building* systems.

C1. INTRODUCTION

This standard is intended to serve all segments of *building* ownership and all methods of delivering inspection and maintenance work. This standard applies to facilities with no maintenance program as well as facilities with state-of-the-art maintenance programs. Requirements are described in terms consistent with a minimum standard. Implementation methods chosen to achieve compliance with this standard are left to the responsible party and/or an authorized implementation partner. All parties may exceed these standard requirements as they see fit.

This standard is implemented by defining the party responsible for compliance and then defining a minimum maintenance program and the elements of the program. These program elements are described and defined to allow compliance to be achieved across the widest range of owners and maintenance delivery systems as reasonably possible.

C2. RESPONSIBLE PARTY

The *building owner* shall be responsible for meeting the requirements of this standard. The owner may designate other parties that shall be authorized and contractually obligated to fulfill the owner's responsibility.

C3. MAINTENANCE PROGRAM

There shall be a maintenance program that preserves the condition and capability of all *building* systems and equipment to enable each to provide the intended *performance* (e.g., thermal and visual comfort, energy efficiency, and indoor environmental quality) required for the facility. At a minimum, the maintenance program shall contain the elements in Sections C3.1 through C6.2.

C3.1 Inventory of Items to be Inspected and Maintained. All *building* systems and equipment that impact *building* envelope *performance*, thermal and visual comfort, energy efficiency, indoor environmental quality, and other services shall be listed in an equipment and component inventory of items to be inspected and maintained. This list shall include manufacturer information, location, capacity, maintenance program identifier, and other data relevant to the equipment or component and agreed upon by the responsible party and implementing party.

C3.2 Maintenance Plan. A plan of inspection and maintenance work shall be established. The maintenance plan shall document the work to be accomplished at scheduled intervals on the inventory of work to be maintained. The maintenance plan shall be developed specifically for the size, design, scope, criticality, and complexity of the systems and equipment serving the facility. The plan shall describe each required task, the frequency of each task, and task schedule; identify the party responsible for performing the task; and specify the authorizing party, task completion documentation procedure, plan monitoring procedures, and procedures for evaluation and feedback. The plan shall include the information described in Sections C3.2.1 through C3.2.4.

C3.2.1 Minimum Required Inspection and Maintenance Tasks. The minimum required inspection and maintenance tasks shall be determined from codes, regulations, and manufacturer recommendations. In any of the aforementioned, all of the tasks that apply to the equipment or components in the maintenance program shall be included in the list of required inspection and maintenance tasks to comply with this standard.

C3.2.2 Inspection and Maintenance Task Frequencies. The baseline frequencies of inspection and maintenance tasks for equipment and systems shall be determined from the sources listed in Section C3.2.1. These frequencies are the minimum required for compliance.

Refer to Section C5 for requirements for revising inspection and maintenance task frequencies.

Informative Note: Inspection serves to monitor and document the condition of equipment and components over time with regard to appearance, functionality, and *performance*. Maintenance serves to preserve equipment and component condition and *performance* as required by the facility.

C3.2.3 Condition Indicators. Condition indicators for systems and equipment shall be developed. These indicators are measurements or observations of physical condition and delivery of thermal and visual comfort, indoor environmental quality, and energy efficiency that are learned during the *performance* of the related inspection tasks and compared to the condition standard. The comparisons serve to determine the level of

degradation and subsequent responsive action. The responsible party and the maintenance program implementer shall mutually agree on the condition indicators and standards used in the maintenance program.

Informative Note: The intent of this standard is to (a) monitor changes in the condition indicators over time as a measure of the efficacy of the maintenance program in meeting *performance* objectives and (b) provide advance indication of pending equipment or component failures. Unacceptable condition indicators could lead to equipment failure or *performance* degradation. When condition indicators reach unacceptable levels, additional preservative or restorative action is required.

C3.2.4 Maintenance Program Objectives. Program objectives shall be established to define desired outcomes for the maintenance program for all *building* systems and equipment that impact *building* envelope *performance*, and that deliver required thermal and visual comfort, energy efficiency, and indoor environmental quality, and other services. Program objectives shall be measurable quantities that can be trended over time, and shall, when achieved define maintenance program success. Program objectives shall be based on responsible party requirements and operating procedures. The responsible party and the implementing party shall mutually agree on the program objectives. The program objectives shall be documented. Status of program objectives shall be reviewed periodically.

Informative Note: The following sources may assist in establishing specific program objectives based on the Basis of Design and operational criteria specific to a particular system or component:

a. Design documents for the *building* and its systems, with the provision that those documents still reflect the current loads, space utilization, and other system requirements
b. A duly licensed professional authorized to perform design work for the relevant system or component
c. Manufacturers' technical material or generally accepted industry criteria
d. Guidance from ASHRAE Standards 55 [N4], 62.1 [N3], and 90.1 [N2]
e. Authorities having jurisdiction
f. Licensed contractor with expertise in the relevant system or component
g. Owner's program requirements

C4. MAINTENANCE PLAN AUTHORIZATION AND EXECUTION

The maintenance plan shall be approved by the responsible party with concurrence by the implementing party. Approval shall authorize performing the work included in the plan.

C4.1 Inspection and maintenance tasks shall be performed at the established frequency or upon documented observance of an unacceptable condition. Whether or not authorized by written or verbal instructions, execution of the task shall be documented and archived for future reference.

Informative Notes:

1. The maintenance plan should include provisions for responding to unplanned inspection and maintenance events.
2. Response to discovery of unacceptable conditions found between task intervals should require authorization to perform the required work with proper documentation. Good practice, once unacceptable conditions are found, is to take action to return equipment to its required condition or *performance* capability. The responsible party and the implementing party must agree on the resource requirements for the work.
3. Unplanned events where additional work beyond the scope of this standard is required, such as repair or replacement, may require additional approval, funding, or authorization by the responsible party and the implementing party for the work to proceed.

C5. REVISION OF THE MAINTENANCE PROGRAM AND MAINTENANCE PLAN

The maintenance program shall be capable of continuous improvement. Improvement in this context shall be manifest when changes in equipment condition or status, changes to the facility, or acquisition of new maintenance technology warrant review and revision of the maintenance plan. The intent of the standard is to enable tasks and/or frequencies to be changed in order to deliver proper preservative action in response to actual conditions.

Informative Notes: The following list contains examples of changes to the facility, its components or operating systems, and equipment that require review of the maintenance plan:

1. Modifications to the *building* that impact system capacities or configuration
2. Changes to *building* function or *building* use that impact the design intent or configuration of components or systems
3. Changes to *building* systems or components

4. One or more systems found incapable of achieving their design intent or owner requirements
5. Documented, agreed upon recommendations from the responsible party or maintenance provider
6. Miscellaneous changes:
    a. Changes to equipment condition
    b. Changes to equipment status
    c. Changes to the facility
    d. Acquisition of new maintenance technology
    e. Revision to task frequencies in response to actual conditions may result in improved condition or reduced inspection and maintenance work

C5.1 Degradation of Condition and Performance. Degradation of equipment condition or *performance* that is observed while performing scheduled inspection and maintenance tasks or on other occasions shall be documented.

C5.2 Response to Changes. Upon initial discovery or observation of the degraded state, the situation shall be resolved through appropriate corrective or preservative action. If preservative action cannot resolve the degraded status, then further action outside the scope of this standard may be required.

C5.3 If unacceptable condition indicators or unacceptable *performance* are found on a system or component during two successive inspections, the maintenance plan and condition history of the system or component shall be reviewed to determine if the inspection frequency or the maintenance task frequency should be increased. Further, maintenance tasks should also be reviewed for improvement opportunities. Results of the review, and revisions to the maintenance plan, shall be documented and implemented.

C5.4 If acceptable condition indicators or acceptable *performance* are observed during three successive inspections, the maintenance plan shall be reviewed for opportunities to reduce task frequencies or work procedures without compromising condition or *performance*. Revisions to task frequencies and work procedures shall be documented.

C5.5 Climate-related or facility operational requirements may impact execution of the maintenance plan. These circumstances shall be reviewed along with the maintenance plan for opportunities to revise task frequencies or work procedures. Revisions to task frequencies and work procedures shall be documented.

Informative Note: Some of these circumstances may interrupt the delivery of inspection and maintenance care. These deferrals of the maintenance plan provide an opportunity to review existing inspection and maintenance tasks and frequencies and make appropriate adjustments considering the impact of the deferral. Each adjusted frequency should be documented and include the reason for the adjustment.

C5.6 Equipment Warranty. This standard's requirements shall not supersede equipment manufacturers' warranty terms and conditions and other guidance that may require different tasks or task frequencies.

C6. PROGRAM REVIEW

The responsible party and the implementing party shall periodically review the maintenance program. There shall be at least two formal review meetings between the responsible party and the implementing party, one at the beginning of the *performance* period and one at the end of the *performance* period.

C6.1 Beginning Review. The responsible party and the implementing party shall define scope, expectations, and desired outcomes for the maintenance program. Initial review shall consist of developing program objectives, condition standards, and measures to be used to evaluate program *performance* that are mutually acceptable to the responsible party and the implementing party. These factors shall be established before the work commences. Creating *performance* objectives and condition standards ahead of implementation, both authorizing party and implementing party align expectations based on knowledge of the goals and evaluation measures established for the program and maintenance plan.

C6.2 End Review. The end review shall consist of comparing maintenance program results with the program results and condition standards. The responsible party and the implementing party shall review the measurements and observations collected during the evaluation period. The actual results shall be compared to the program requirements, desired outcomes, and *performance* of *building* systems and components. The comparison shall serve to evaluate the maintenance program *performance*. The information shall be used to develop a plan for improving the maintenance program. Program improvement actions shall be mutually agreeable between the responsible party and the implementing party.

INFORMATIVE APPENDIX D TIMELINE

NOT ADOPTED

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard.)

INFORMATIVE APPENDIX E CLIMATE ZONES

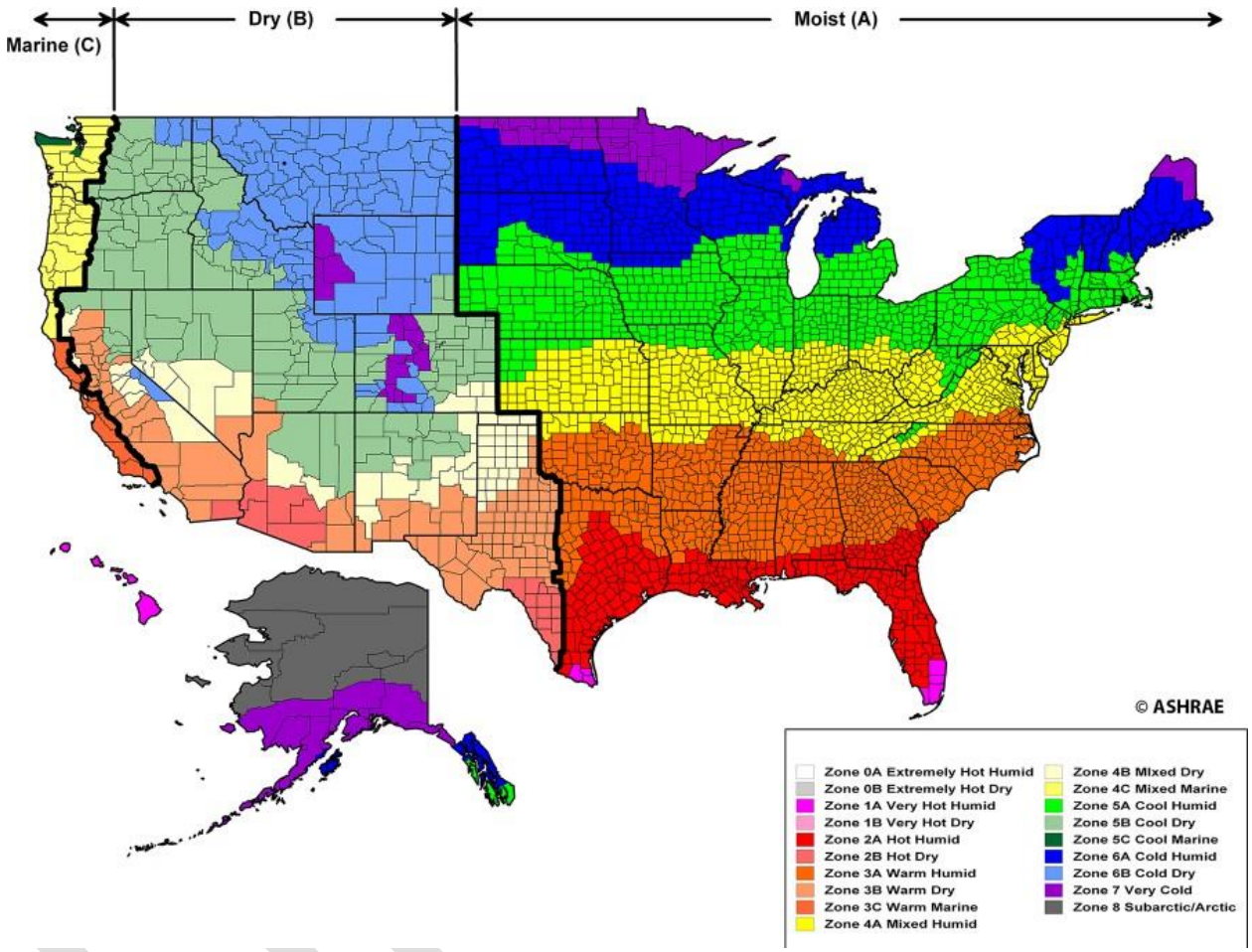

Figure E-1 U.S. climate zone map.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard.)

INFORMATIVE APPENDIX F BUILDING ENERGY MODELING

F1. BUILDING ENERGY MODELING

F1.1 General. *Building* energy simulation plays a valuable role informing the design and operation of existing *buildings* undergoing energy *performance* renovations and in analyzing alternative *energy efficiency measures* (*EEMs*) or for *optimized bundles of EEMs*. *Building* energy simulation can also help prioritize investment strategies and identify the most cost-effective measures.

ANSI/ASHRAE Standard 209, *Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings* N9 was created to define reliable and consistent procedures that advance the use of timely energy modeling to quantify the impact of design decisions at the point in time at which they are being made. The committee believes such an approach will improve modeling effectiveness, realize greater savings, and support achieving increasingly aggressive energy savings targets.

Data from the existing *building* can be used to develop the *baseline* reference *building* model, and that model should be validated against current annual utility costs. The validated model can then be modified to reflect proposed *EEMs*, either individually or collectively, in order to create the proposed *building* model.

Unless specifically impacted by the proposed *EEMs*, the proposed *building* model should be identical to the reference *building* model for all elements, including *building* classification, location, utility rate structure, annual weather data, design-day weather data, and internal design conditions (e.g., summer and winter, form, shape, orientation, envelope, infiltration, interior lighting, *HVAC systems*, ventilation requirements, receptacle load, process loads, occupancy, and operating schedules).

The models can be documented by reports generated by the modeling software or by manually completing relevant compliance forms. Sample compliance forms are included with past editions of the *Standard*

90.1 User's Manual. Simulation software varies in sophistication and detail and includes freeware applications, such as eQUEST (DOE-2) and EnergyPlus, as well as commercial software. End-use-specific tools are available for pumping systems from the DOE's Advance Manufacturing Office.

Utility rate structures and tariffs are published by the Energy Information Agency or can be obtained from your local utilities and energy suppliers.

The energy simulations of the reference *building* and the proposed *building* models must use the same annual hourly weather file, and that file must represent a typical weather year for the current *building* location. The weather file should be selected from the climate zone that most closely represents the typical weather conditions at that location (see Figure E-1). Many simulation programs provide specially formatted versions of the TMY2 or other similar weather files for use with their programs.

ANSI/ASHRAE/IES Standard 90.1 N2, Normative Appendix G, "Performance Rating Method," provides background modeling and simulation guidance.

Energy models should be developed by qualified professionals and meet the minimum eligibility requirements under the ASHRAE Building Energy Modeling Professional (BEMP) certification program.

The design-day weather data used for sizing equipment represents 99.6% annual cumulative frequency dry-bulb temperature for heating conditions and the 1% annual cumulative frequency dry-bulb and wet-bulb temperatures for cooling conditions. Tables F-1 and F-2 list sources of weather data.

Table F-1 Annual Weather File Sources

Weather File
TMY2—Typical Meteorological Year 2 CTZ2—California Climate Zone 2

Table F-2 Design-Day Weather Data Sources

Weather File	Source
ANSI/ASHRAE Standard 169	See Informative Reference N10.

ASHRAE Handbook—Fundamentals	See Informative Reference N11.

INFORMATIVE APPENDIX G DERIVATION OF ENERGY INTENSITY TARGETS FOR STANDARD 100

NOT ADOPTED

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard.)

INFORMATIVE APPENDIX H ENERGY EFFICIENCY MEASURES

This informative appendix provides categorized listings of typical *energy efficiency measures* (*EEMs*) that can be applied to enable *buildings* to meet the set *energy use intensity (EUI) targets*. It identifies commonly applied elements that can improve *building performance* but is not intended to suggest specific requirements, nor does it comprehensively covered all of the options available to an owner.

Measures included in these listings are intended to improve energy efficiency and reduce overall energy use. They are not intended to encourage fuel switching unless actions such as installation of cogeneration, trigeneration, or combined heating and cooling plants would result in overall reduction in total energy used. Some measures, such as demand response/control, may also save energy as an incidental benefit. Other measures may result in extension of the capacity of given infrastructure systems and/or the ability for energy efficiency to defer or eliminate the need for plant expansions. Such results can be factored into the resulting

return on investment or life-cycle cost analysis.

H1. BUILDING ENVELOPE

H1.1 Walls

H1.1.1 Insulate Walls. Retrofit insulation can be external and internal.

H1.1.1.1 External post insulation makes large savings possible, as this type of insulation contributes not only to a reduction of the heat loss through large wall surfaces but also eliminates the traditional thermal bridges where floor and internal wall are anchored in the exterior wall.

H1.1.1.2 Internal insulation is typically used when external insulation is not allowed, such as for historical *buildings*.

H1.1.2 Insulate cavity walls using spray-in insulation.

H1.1.3 Consider converting internal courtyard into an atrium to reduce external wall surface.

H1.2 Roofs

H1.2.1 Use cool roof (high-reflectance roofing material) with reroofing projects. **H1.2.2** Determine roof insulation values and recommend roof insulation as appropriate. **H1.2.3** Insulate ceilings and roofs using spray-on insulation.

H1.2.4 Where appropriate, exhaust hot air from attics.

H1.3 Floors

H1.3.1 Insulate floors.

H1.3.2 Insulate floors using spray-on insulation.

H1.3.3 Insulate basement wall with a slab over unheated basement.

H1.4 Windows

H1.4.1 Replace single-pane and leaky windows with thermal/operable windows to minimize cooling and heating loss.

H1.4.2 Install exterior shading, such as blinds or awnings, to cut down on heat loss and to reduce heat gain.

H1.4.3 Install storm windows and multiple glazed windows.

H1.4.4 Use tinted or reflective glazing or energy control/solar window films.

H1.4.5 Replace existing fenestration (toplighting and/or sidelighting) with dual-glazed low-e glass wherever possible to reduce thermal gain.

H1.4.6 Adopt weatherization/fenestration improvements.

H1.4.7 Consider replacing exterior windows with insulated glass block when visibility is not required but light is required.

H1.4.8 Landscape/plant trees to create shade and reduce air-conditioning loads.

H1.5 Doors

H1.5.1 Prevent heat loss through doors by draft sealing and using thermal insulation.

H1.5.2 Install automatic doors, air curtains, or strip doors at high-traffic passages between conditioned and unconditioned spaces.

H1.5.3 Use self-closing or revolving doors and vestibules if possible.

H1.5.4 Install high-speed doors between heated/cooled *building* space and unconditioned space in the areas with high-traffic passages.

H1.6 Install separate smaller doors for people near the area of large vehicle doors.

H1.6.1 Seal top and bottom of *building*.

H1.6.2 Seal vertical shafts, stairways, outside walls, and openings.

H1.6.3 Compartmentalize garage doors and mechanical and vented internal and special-purpose rooms.

H1.7 Moisture Penetration H1.8 Reduce air leakage.

H1.9 Install vapor barriers in walls, ceilings, and roofs.

H2. HVAC SYSTEMS

H2.1 Ventilation

H2.1.1 Reduce *HVAC system* outdoor airflow rates when possible. Minimum outdoor airflow rates should comply with ANSI/ASHRAE Standard 62.1 N3 or local code requirements.

H2.1.2 Reduce minimum flow settings in single-duct and dual-duct variable-air-volume (VAV) terminals as low as is practical to meet ventilation requirements.

H2.1.3 Minimize exhaust and makeup (ventilation) rates when possible by complying with the most stringent federal, state, and/or local code requirements.

H2.1.4 When available, use operable windows for ventilation during mild weather (natural ventilation) when outdoor conditions are optimal. Confirm that the facility has been designed for natural ventilation and that control strategies are available to operate the facility in the natural ventilation mode.

H2.1.5 Eliminate outdoor air ventilation during unoccupied *building* morning warm up.

H2.1.6 Convert mixing air supply systems into displacement ventilation systems to create a temperature stratification in spaces with high ceilings and predominant cooling needs.

H2.1.7 Consider replacement of all-air *HVAC system* with a combination of a dedicated outdoor air system (DOAS) coupled with radiant cooling and heating systems.

H2.1.8 Convert constant-air-volume (CAV) central exhaust systems into demand-based controlled central exhaust systems when possible.

H2.1.9 Convert *HVAC systems* to provide ventilation in accordance with ASHRAE Standard 62.1 N3.

H2.2 HVAC Distribution Systems

H2.2.1 Convert a CAV (including dual-duct, multizone, and constant-volume reheat systems) into a VAV system with variable-frequency drives (VFDs) on fan motors. A VAV system is designed to deliver only the volume of air needed for conditioning the actual load.

H2.2.2 Control VAV system VFD speed based on the static pressure needs in the system. Reset the static pressure set point dynamically as low as is practical to meet the *zone* set points.

H2.2.3 Reset VAV system supply air temperature set point when system is at minimum speed to provide adequate ventilation.

H2.2.4 If conversion to VAV from CAV systems is impractical, reset supply air temperatures in response to load. Dynamically control heating duct temperatures as low as possible, and cooling duct temperatures as high as possible, while meeting the load.

H2.2.5 Use high-efficiency fans and pumps; replace or trim impellers of existing fans if they have excessive capacity relative to peak demand.

H2.2.6 Install higher-efficiency air filters/cleaners in the *HVAC system*. Size ducts and select filter sizes for low face velocity to reduce pressure drop where available space permits.

H2.2.7 Insulate HVAC ducts and pipes, particularly where they are outside the *conditioned space*. Ensure that duct insulation and vapor barrier are maintained or enhanced to ensure thermal *performance* and avoid water vapor intrusion.

H2.2.8 Check for air leaks in HVAC duct systems and seal ductwork as indicated.

H2.2.9 Rebalance ducting and piping systems.

H2.2.10 Provide cooling effect by creating air movement with fans.

H2.2.11 Select cooling coils with a face velocity range of 300 to 350 fpm (1.5 to 1.75 m/s) to reduce the air pressure

drop across the cooling coil and increase the chilled-water system temperature differential across the system.

H2.2.12 Replace standard fan belts with fan belts designed for minimum energy losses, such as cog belts.

H2.2.13 Eliminate or downsize existing HVAC equipment in an existing *building* or group of *buildings* when improvements in *building* envelope, reductions in lighting or plug loads, and other *EEMs* that reduce cooling or heating loads have been implemented.

H2.2.14 Eliminate HVAC use in vestibules and unoccupied spaces.

H2.2.15 Minimize direct cooling/heating of unoccupied areas by system *zone* controls, *occupancy sensors*, or by turning off fan-coil units and unit heaters.

H2.2.16 Replace forced-air heaters with low- or medium-temperature radiant heaters.

H2.2.17 Replace inefficient window air conditioners with high-efficiency (i.e., high SEER rating) modular units or central systems.

H2.2.18 Employ heat recovery from exhaust air and processes for preheating or precooling incoming outdoor air or supply air.

H2.2.19 Install transpired air heating collector (solar wall) for ventilation air preheating.

H2.2.20 Modify controls and/or systems to implement night precooling to reduce cooling energy consumption the following day.

H2.2.21 Use waste heat, such as hot gas, return air heat, or return hot water, as an energy source for reheating for humidity control. (Often air is cooled to dew-point to remove moisture and then must be reheated to desired temperature and humidity.)

H2.2.22 Avoid temperature stratification with heating, either by proper air supply system design or by using temperature destratifiers such as ceiling fans.

H2.2.23 In humid climates, supply air with a temperature above the dew point to prevent condensation on cold surfaces.

H2.2.24 Insulate fan-coil units and avoid their installation in unconditioned spaces.

H2.2.25 Clean heat exchangers (to *maintain* heat exchange efficiency) in the evaporators and condensers of refrigeration equipment on a seasonal basis.

H2.2.26 Use high-efficiency dehumidification systems based on either DOASs or VAV systems.

H2.2.27 Identify whether there are any rogue *zones* (i.e., *zones* that determine the cooling or heating demand on the entire system) in a multiple-*zone* air-handling system, and modify them to eliminate their negative impact.

H2.2.28 Modify supply duct systems to eliminate duct configurations that impose high friction losses on the system.

H2.2.29 Convert three-pipe heating/cooling distribution systems to four-pipe or two-pipe systems. Eliminate simultaneous heating and cooling through mixed returns.

H2.2.30 Convert steam or compressed air humidifiers to ultrasonic or high-pressure humidifiers.

H2.2.31 Replace mechanical dehumidification with desiccant systems using heat-recovery regeneration.

H2.2.32 Consider small unitary systems for small *zones* with long or continuous occupancy. Avoid running large distribution systems to meet needs of small, continuously occupied spaces.

H2.2.33 Install thermostatic control valves on uncontrolled or manually controlled radiators. **H2.2.34** Replace unitary systems with newer units with high efficiency and high SEER ratings. **H2.2.35** Install evaporative precooling for direct-expansion (DX) systems.

H2.2.36 Install air-side heat recovery for systems using 100% makeup air, such as run-around piping or energy exchange wheels.

H2.2.37 In reheat systems, make adjustments as necessary to minimize reheat energy consumption while maintaining indoor environmental quality.

H2.2.38 In multiple-*zone* systems, identify any rogue *zones* that consistently cause the reset of system- level set points in order to satisfy that one *zone*'s heating or cooling demands.

H2.3 Building Automation and Control Systems

H2.3.1 Create *building*/*conditioned space zones* with separate controls to suit solar exposure and occupancy.

H2.3.2 Use night setback, or turn off HVAC equipment when *building* is unoccupied.

H2.3.3 Install *occupancy sensors* with VAV systems; set back temperatures and shut off boxes.

H2.3.4 Install system controls to reduce cooling/heating of unoccupied space.

H2.3.5 Lower heating and raise cooling temperature set points to match the comfort range prescribed in ANSI/ASHRAE Standard 55 N4.

H2.3.6 Install an air-side and/or water-side economizer cycle with enthalpy switchover when compatible with the existing equipment, space occupancy, and distribution system.

H2.3.7 Schedule off-hour meetings in a location that does not require HVAC in the entire facility.

H2.3.8 Retrofit multiple-*zone* VAV systems with *direct digital controls* (*DDC*) controllers at the *zone* level, and implement supply air duct pressure reset to reduce supply air duct pressure until at least one *zone* damper is nearly wide open.

H2.3.9 Eliminate duplicative *zone* controls such as multiple thermostats serving a single *zone* with independent controls.

H2.3.10 Adjust hot-water and chilled-water temperature to develop peak-shaving strategies based on an outdoor air temperature reset schedule.

H2.3.11 Adjust housekeeping schedule to minimize HVAC use.

H2.3.12 Install programmable *zone* thermostats with appropriate deadbands.

H2.3.13 Use VFDs and *DDC* on water circulation pump and fan motors and controls.

H2.3.14 Reduce operating hours of complementing heating and cooling systems. Ensure proper location of thermostat to provide balanced space conditioning.

H2.3.15 Implement an energy management system designed to optimize and adjust HVAC operations based on environmental conditions, changing uses, and timing.

H2.3.16 Install a fault detection and diagnostic (FDD) system and address identified faults. A FDD system should utilize *building* analytic algorithms to convert data provided by sensors and devices to automatically identify faults in *building* systems and provide a prioritized list of actionable resolutions to those faults based on cost or energy avoidance, comfort, and maintenance impact.

H3. REFRIGERATION

H3.1 Reduce Loads

H3.1.1 Install strip curtains or automatic fast open and close doors on refrigerated space doorways.

H3.1.2 Replace open refrigerated cases with reach-in refrigerated cases.

H3.1.3 Replace old refrigerated cases with new high-efficiency models (improved glazing, insulation, motor efficiency, and reduced antisweat requirements).

H3.1.4 Replace worn door gaskets.

H3.1.5 Replace broken or missing automatic door closers.

H3.1.6 Check defrost schedules and avoid excessive defrost.

H3.1.7 Repair/install refrigeration piping insulation on suction lines.

H3.1.8 Install humidity-responsive antisweat heating (ASH) controls on refrigerated case doors.

H3.1.9 Install refrigerated case, walk-in, or storage space lighting controls (scheduled and/or *occupancy sensors*).

H3.1.10 Install night covers to reduce infiltration in open cases.

H3.1.11 Install low/no ASH refrigerated case doors.

H3.1.12 Replace lights with LED strip lights with *motion sensors* in refrigerated cases and spaces.

H3.1.13 Increase insulation on walk-in boxes and storage spaces that have visible moisture or ice on walls, corners, etc. Ensure that insulation and vapor barrier are maintained or enhanced to ensure thermal *performance* and avoid water vapor intrusion.

H3.2 Improve System Operating Efficiency H3.2.1 Clean condenser coils.

H3.2.2 Check the refrigerant charge and add when needed.

H3.2.3 Reclaim heat from hot-gas line for domestic water heating or space heating.

H3.2.4 Install floating-head pressure controls, adjustable-head pressure control valve, and balanced port expansion valves for DX systems.

H3.2.5 Install floating suction pressure controls on DX systems.

H3.2.6 Install evaporator fan motor VSDs and controllers in walk-ins and refrigerated storage spaces. **H3.2.7** Replace single-phase, <1 hp (746 W) evaporator fan motors with electrically commutated motors. **H3.2.8** Replace three-phase evaporator and condenser motors with premium efficiency motors.

H3.2.9 Replace single compressor systems with multiplex systems and control system.

H3.2.10 Install mechanical subcooling.

H3.2.11 Install mechanical unloaders on appropriate multiplex reciprocating semihermetic compressors.

H3.2.12 Install VFDs on ammonia screw compressors.

H3.2.13 Install high specific-efficiency condensers.

H3.2.14 Install hybrid air-cooled/evaporative-cooled condensers.

H4. WATER SYSTEMS

H4.1 Domestic Hot-Water Systems

H4.1.1 Lower domestic water set-point temperatures to 120°F (49°C).

H4.1.2 Install point-of-use gas or electric water heaters.

H4.1.3 Install water-heater blankets on water heaters.

H4.1.4 Where permitted by the manufacturer, and in conjunction with the manufacturer's control system, install automatic flue dampers on fuel-fired water heaters.

H4.1.5 Insulate hot-water pipes.

H4.1.6 Reclaim heat from waste water, refrigeration systems, cogeneration, or chillers.

H4.1.7 Install solar heating where applicable.

H4.1.8 Replace dishwashers by installing low-temperature systems that sanitize primarily through chemical agents rather than high water temperatures.

H4.1.9 Retrofit dishwashers by installing electric-eye or sensor systems in conveyor-type machines so that the presence of dishes moving along the conveyor activates the water flow.

H4.1.10 Reduce operating hours for water heating systems.

H4.1.11 Install gray-water heat recovery from showers, dishwashers, and washing machines.

H4.1.12 Install low-flow dishwashing prewash spray nozzles.

H4.1.13 Replace outdated laundry equipment with newer models.

H4.2 Water Conservation

H4.2.1 Replace faucets with units that have infrared sensors or automatic shutoff.

H4.2.2 Install water flow restrictors on shower heads and faucets.

H4.2.3 Install covers on swimming pools and tanks.

H4.2.4 Install devices to save hot water by pumping water in the distribution lines back to the water heater so that hot water is not wasted. Install industrial waste/sewage metering.

H4.2.5 Install water metering.

H4.2.6 Install landscape irrigation timers to schedule sprinkler use to off-peak, night, or early morning hours when water rates are cheaper and water used is less likely to evaporate.

H4.2.7 Use low-flow sprinkler heads for landscape irrigation instead of turf sprinklers in areas with plants, trees, and shrubs.

H4.2.8 Use sprinkler controls for landscape irrigation that employ soil tensiometers or electric moisture sensors to help determine when soil is dry and gage the amount of water needed.

H4.2.9 Use trickle or subsurface drip systems for landscape irrigation that provide water directly to turf roots, preventing water loss by evaporation and runoff.

H4.2.10 Install low-flow toilets and waterless urinals.

H4.2.11 Use water reclamation techniques.

H5. ENERGY GENERATION, DISTRIBUTION, AND MONITORING

H5.1 Boiler System

H5.1.1 Install air-atomizing and low NOx burners for oil-fired boiler.

H5.1.2 Investigate economics of adding insulation on presently insulated or uninsulated lines. If pipe or duct insulation is missing, replace it with new material. Ensure that the pipe insulation and vapor barrier are maintained or enhanced to ensure thermal *performance* and avoid water vapor intrusion.

H5.1.3 Review mechanical standby turbines presently left in idling mode.

H5.1.4 Review operation of steam systems used only for occasional services, such as winter-only tracing lines.

H5.1.5 Review pressure-level requirements of steam-driven mechanical equipment to consider using lower exhaust pressure levels.

H5.1.6 Survey condensate presently being discharged to waste drains for feasibility of reclaim or heat recovery.

H5.1.7 Reduce boiler operating pressure to minimize heat losses through leakage.

H5.2 Chiller System

H5.2.1 Chiller retrofits with equipment that has high efficiency at full and part load.

H5.2.2 Cooling-tower retrofits, including high-efficiency fill, VSD fans, fiberglass fans, hyperbolic stack extensions, fan controls, VSD pump drives, and improved distribution nozzles.

H5.2.3 Install economizer cooling systems (heat exchanger between cooling-tower loop and chilled-water loop before the chiller).

H5.2.4 Install evaporative cooled, evaporative precooled, or water-cooled condensers in place of air- cooled condensers.

H5.2.5 Isolate offline chillers and cooling towers.

H5.2.6 Reduce overpumping on chilled-water systems.

H5.2.7 Replace single compressor with multiple different-size staged compressors.

H5.2.8 Install two-speed, mechanical unloading, or VFD on compressor motors.

H5.2.9 Use an absorption chiller when there is cogeneration system, waste heat, or solar thermal available.

H5.2.10 Install double-bundle chillers for heat recovery.

H5.2.11 Free-cooling cycle by piping chilled water to condenser during cold weather.

H5.2.12 Prevent chilled water or condenser water flowing through the offline chiller. Chillers can be isolated by turning off pumps and closing valves.

H5.2.13 For equipment cooling, control makeup water and reduce blowdown by adding temperature control valves to cooling water discharge lines in equipment such as air compressors and refrigeration systems.

H5.2.14 For evaporative cooling systems, install drift eliminators or repair existing equipment.

H5.2.15 For evaporative cooling systems, install softeners for makeup water, side-stream filtration (including nanofiltration, a form of low-pressure reverse osmosis), and side-stream injection of ozone.

H5.2.16 For evaporative cooling systems, install submeters for makeup water and bleed-off water for equipment such as cooling towers that use large volumes of water.

H5.2.17 Evaporative cooling systems control cooling-tower bleed-off based on conductivity by allowing bleed-off within a high and narrow conductivity range. This will achieve high cycles of concentration in the cooling system and reduce water use in cooling towers.

H5.2.18 Clean evaporator and condenser surfaces of fouling.

H5.2.19 Optimize plant controls to raise evaporator temperature as high as possible while meeting system loads. Also optimize condenser water temperature control to achieve best combination of chiller and tower efficiency.

H5.2.20 Optimize multiple chiller sequencing.

H5.2.21 Control crankcase heaters off when they're not needed. **H5.2.22** Raise evaporator or lower condenser water temperature. **H5.2.23** Optimize multiple-chiller sequencing.

H5.2.24 Use two-speed or variable-speed fans instead of water bypass to modulate the cooling-tower capacity.

H5.2.25 Balance water flow in the chilled-water system.

H5.2.26 Use VFDs for the primary chilled-water pumps above 5 hp (3.7 kW). Consult chiller and tower manufacturers' specifications to set appropriate minimum flow limits.

H5.2.27 Apply cooling load-based optimization strategies.

H5.2.28 Install water-source heat pumps to augment the capacity of the hot-water boiler and to reduce the cooling load on the existing chiller systems when heat is required.

H5.2.29 Trim impellers on all condenser water and chilled-water pumps that are oversized.

H5.2.30 Replace all pump and fan motors with premium efficiency motors.

H5.3 Thermal Storage and Heat Pumps

H5.3.1 Install cool storage to reduce peak demand and lower electric bills.

H5.3.2 Install hot-water storage to shave peaks of hot-water use or to store reclaimed energy from combined heat and power (CHP) systems or waste heat from chillers for later use.

H5.3.3 Install add-on heat pumps.

H5.3.4 Install secondary pumping systems.

H5.3.5 Install VFDs on secondary pumps and replace most three-way valves with two-way valves.

H5.3.6 With cool storage and VFDs on fans and pumps, consider use of low-temperature chilled water to reduce fan and pump energy.

H5.3.7 Replace electrically powered air conditioning and heating units with heat pumps. Consider geothermal or ground-source heat pumps.

H5.3.8 Replace electric water heaters with electric heat-pump water heaters.

H5.4 Electric and Heat Cogeneration

H5.4.1 The application of cogeneration should be considered where use of both electrical and thermal energy can be achieved on a cost-effective basis.

H5.4.2 Subject to the approval of the *authority having jurisdiction*, where CHP plants are installed as energy efficiency improvements, the energy audit and analysis of overall *building* energy use *performance* may follow the Federal Energy Management Program (FEMP) guidelines, *Reporting Guidance for Federal Agency Annual Report on Energy Management* (per 42 U.S.C. 8258), Attachment 3 N5. Energy efficiency projects may be allowed to receive a credit in the amount of the annual *source energy* savings from CHP, which would be used to offset the *building site energy* used in calculating and comparing against the *EUI targets*.

H5.5 Energy System Monitoring

H5.5.1 Install a metering system to monitor the electrical energy use for each of the major electrical energy-using loads. These loads may include, but are not limited to, *HVAC systems*, water heating systems, cooking equipment, laundry equipment, interior lighting, exterior lighting, parking lots, parking ramps, elevators, escalators, and receptacle circuits.

H5.5.2 Install a metering system to monitor the fossil-fuel energy use for each of the major fossil-fuel energy-using loads. These loads may include, but are not limited to, space heating systems, water heating systems, pool heating systems, cooking equipment, clothes drying equipment, gas lighting, outdoor equipment, and all other miscellaneous fossil-fuel end-uses.

H6. NONRESIDENTIAL LIGHTING

In implementing any of these *EEMs*, care should be taken to not compromise the photometric distribution or any required light levels.

H6.1 General. Check the current Illuminating Engineering Society (IES) recommended light levels for the tasks in the facility. They may be lower than when the original lighting system was designed. Use these current recommended light levels to help shape all future lighting decisions, including those enumerated here. **H6.2 Daylighting**

H6.2.1 In any spaces with fenestration, evaluate opportunities for *daylight harvesting* by determining the spatial daylight autonomy (sDA) in accordance with IES LM-83 N6. In spaces where sDA*300,50%* is greater than 55%, consider installing daylight switching or daylight dimming controls (and appropriate ballasts if

the lighting system is fluorescent or high-intensity discharge [HID]) to reduce use of electric lighting.

H6.2.2 In any spaces with fenestration, evaluate the need for shading by determining the annual sunlight exposure (ASE) in accordance with IES LM-83 N6. In spaces where ASE*1000,250* is greater than 10%, interior and/or exterior shading should be installed to reduce solar heat gain and cut down on heat loss and con-

trol the amount of light entering the space from the exterior.

H6.2.3 Install a skylight, tubular daylighting device, or sunlight delivery system to reduce the use of electric lighting and provide natural daylight to the internal spaces of the *building*.

H6.3 Luminaire Upgrades

H6.3.1 Upgrade incandescent *lamps* in existing *luminaires* with more effective sources, such as halogen, integrally ballasted compact fluorescent, solid state (LED), or metal halide retrofit *lamps*. Alternatively, replace incandescent *luminaires* with *luminaires* using these sources.

H6.3.2 Upgrade T12 fluorescent *luminaires* with more effective sources, such as high-performance T8 or T5 systems, by replacing *lamps* and ballasts, using *luminaire* upgrade kits, or installing new *luminaires*.

H6.3.3 If the lighting system is already a high-performance fluorescent system, consider replacing the

lamps with reduced-wattage *lamps* (where appropriate).

H6.3.4 For fluorescent lighting, install high-performance electronic ballasts that are multilevel or continuously dimmable with the appropriate controls.

H6.3.5 Replace mercury vapor or probe-start metal halide HID *luminaires* with pulse-start metal halide or high-performance T8 or T5 fluorescent *luminaires*.

H6.3.6 Upgrade task and display lighting, including lighting in refrigeration and freezer cases, to more effective sources, such as LED.

H6.4 Signage

H6.4.1 Evaluate upgrading standard fluorescent or neon signage with more effective sources, such as high-performance T8 or T5 fluorescent systems or solid-state (LED) systems.

H6.4.2 Upgrade all exit signs to solid state (LED). Supplemental lighting may need to be added if the existing exit sign also provides general lighting.

H6.5 Lighting Controls

H6.5.1 Reduce lighting use through management and controlled systems. In general, consider bringing the lighting control protocols for the *building* up to ASHRAE/IES Standard 90.1N2, Section 9.4.1 requirements; this includes the following.

H6.5.2 Reduce operating hours for lighting systems through the use of controls and *building* management systems. This includes the use of shut-off controls, such as time switches.

H6.5.3 Use reduced lighting levels—including off—when spaces are unoccupied, during *nighttime hours*, and for restocking, cleaning, and security. Whenever possible move restocking and cleaning operations to normal operating hours.

H6.5.4 Use occupancy, vacancy, or *motion sensors*. Wherever applicable, these sensors should be manual-ON, or turn lighting on to no more than 50% of *lighting power*.

H6.5.5 Use controls to provide multiple light levels or dimming where appropriate.

H6.5.6 Recircuit or rezone lighting to allow personnel to only turn on *zones* based on use rather than operating the entire lighting system.

H6.5.7 Install personal lighting controls so individual occupants can vary the light levels within their spaces.

H6.5.8 Consider installation of lighting systems that facilitate load shed requests from the electric utility or energy aggregator.

H6.5.9 Evaluate turning emergency lighting off or to a lower level when a *building* or portion of a *building* is completely unoccupied, without sacrificing safety requirements.

H6.6 Exterior Lighting

H6.6.1 Use automatic controls that can reduce outdoor lighting levels or turn lights off when either sufficient daylight is available or when lighting is not needed. All facade and landscape lighting should be off from an hour after closing until an hour before opening. All other lighting should be reduced by at least 30% during that same time frame or when a *motion sensor* detects no activity for 15 minutes. These controls are not applicable to lighting for covered vehicle entrances or exits from *buildings* or parking structures where required for safety, security, or eye adaptation.

H6.6.2 Reduce power levels or turn exterior signage off when appropriate.

H6.6.2.1 Signs that are meant to be on for some part of *daylight hours* should be reduced in power by at least 65% during *nighttime hours*. All other sign lighting should automatically turn off during *daylight hours* and reduced in power by at least 30% from an hour after closing until an hour before opening. These controls are not applicable to sign lighting using metal halide, high-pressure sodium, induction, cold cathode, or neon *lamps* that are automatically reduced by at least 30% during *nighttime hours*.

H6.6.3 When selecting new outdoor *luminaires*, consider the amount of backlight, uplight, and glare delivered by each *luminaire* type to improve functionality and minimize environmental impacts. See ANSI/ ASHRAE/ICC/USGBC/IES Standard 189.1 N7, Section 5.3.6.

H6.7 Luminaire Layout

H6.7.1 Consider using lower levels of general illumination overall and then supplement with task lighting where needed.

H6.7.2 Consider new layouts that may maximize efficiency and reduce the total connected lighting load. Consider plug-and-play systems to provide flexibility as space use changes.

H6.8 Other

H6.8.1 Implement a plan to recycle *lamps*, ballasts, and *luminaires* removed from the *building*.

H6.8.2 Consider updating lighting systems to provide for demand response capability so that lighting loads are reduced during periods of peak electricity demand. These types of systems can provide day-to-day energy savings in addition to demand response capability.

H7. RESIDENTIAL LIGHTING

H7.1 General

H7.1.1 Replace incandescent *lamps* with halogen, integrally ballasted compact fluorescent, or solid-state (LED) retrofit *lamps* in existing *luminaires*.

H7.1.2 Color temperature indicates the color appearance of the light produced by the *lamp*. Halogen *lamps* are a more energy-efficient form of incandescent technology and will deliver light similar to incandescent *lamps*. Linear fluorescent, compact fluorescent, and solid-state (LED) *lamps* are available in a variety of color temperatures. *Lamps* with color temperatures of 2700 and 3000 K deliver the most incandescent-like light.

Lamps with a color temperature of 3500 K deliver a neutral, white light. *Lamps* with color temperatures of 4000 K and higher deliver cooler, white light; the higher the color temperature number, the cooler the light.

H7.1.3 Select *lamps* appropriate for use in enclosed *luminaires*, outdoor applications, and cold temperature applications, and for use with dimming controls. Check the packaging or manufacturer's website for guidance.

H7.1.4 Use energy-efficient technologies such as fluorescent, compact fluorescent, or solid state (LED) in applications with the longest operating times.

H7.1.5 Use a whole-home lighting control system that provides energy-saving features, such as dimming, occupancy sensing, and *daylight harvesting*, and allows occupants to turn all the lights off from a single location or remotely.

H7.2 Interior

H7.2.1 Replace on/off switches with dimming controls, vacancy sensors, or countdown timers. Use dimming controls, vacancy sensors, or countdown timers for lights or fans in bathrooms. Use vacancy sensors in garages, laundry rooms, closets, and utility rooms.

H7.2.2 Replace *lamps* and ballasts or install new *luminaires*. Ballasts should be FCC rated for residential use.

H7.2.3 Evaluate replacing incandescent and halogen *luminaires* with dedicated compact fluorescent or solid-state (LED) *luminaires*.

H7.2.4 When replacing fluorescent ballasts or installing new fluorescent *luminaires*, evaluate using electronic dimming ballasts with the appropriate dimming controls.

H7.2.5 Evaluate adding daylight-sensing controls for general illumination lighting in rooms with windows or skylights. Use in combination with dimming systems so that the electric light level can be adjusted based on the amount of daylight available.

H7.2.6 Install vacancy sensors to automatically turn off lighting in closets, storage, work rooms, garages, and exterior *buildings* when the space has been vacated for 15 minutes.

H7.2.7 Add task lighting that uses energy-efficient technologies, such as fluorescent and solid state (LED), and reduce or eliminate overhead lighting.

H7.3 Exterior

H7.3.1 Install time switches and/or *motion sensors* to control outdoor lighting.

H8. ELECTRIC SYSTEMS, MOTORS

H8.1 Install energy-efficient transformers. Use infrared cameras to identify high-heat-loss transformers.

H8.2 Reduce demand charges through load shedding, operational changes, and procedural changes.

H8.3 Replace oversized electric motors with right-sized or slightly oversized motors.

H8.4 Replace existing three-phase, 1 hp (746 W) and greater electric motors with premium-efficiency motors (often a better choice than rewinding motors).

H8.5 Replace existing one-phase, 1 hp (746 W) and less motors with electrically commutated motors.

H9. APPLIANCES

H9.1 Install appliances (clothes washers, dehumidifiers, dishwashers, freezers, refrigerators, room air cleaners and purifiers, office equipment, and televisions) that are certified as ENERGY STAR® compliant.

H9.2 Reduce plug loads, using devices to shut off equipment not being used (use *occupancy sensors* or timers).

H9.3 Install vending-machine controllers.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard.)

INFORMATIVE APPENDIX I OPERATIONS AND MAINTENANCE REQUIREMENTS FOR BUILDING SYSTEMS AND ELEMENTS

I1. BUILDING ENVELOPE

I1.1 Operations and maintenance (O&M) requirements for the *building* envelope should include all applicable items in Section 6 plus the following.

I1.1.1 The *energy manager* (*EM*) should verify that a *building* envelope inspection is performed at least once every three years. Corrective action should be taken as needed, including addressing all of the following items.

I1.1.1.1 Seal all exterior joints in the *building* envelope, and all around penetrations of the *building*

envelope by utility services.

I1.1.1.2 Replace broken or missing windows.

I1.1.1.3 Repair or replace exterior door weather stripping, threshold, and door sweeps as needed.

I1.1.1.4 Seal or cap obsolete shafts, chimneys, and other air chases.

I1.1.1.5 Repair or replace existing door closers on exterior doors.

I1.1.2 The *EM* should develop, document, and distribute procedures to *building* personnel for energy- efficient operation of exterior doors, loading docks, and operable windows.

I2. DOMESTIC HOT-WATER SYSTEMS

I2.1 General Requirements. O&M requirements for domestic hot-water (DHW) systems include all applicable items in Section 6 plus the following.

I2.1.1 Securely and visibly locate a list of operating parameters, such as temperature set points, pressures, and operating schedule, at each piece of equipment.

I2.2 Hot-Water Heaters

I2.2.1 *Maintain* proper combustion efficiency—carry out a combustion analysis and carbon monoxide testing at least annually, and make necessary corrections to achieve rated efficiency and safety.

Exception to I2.2.1 The input capacity of the heater is less than 100,000 Btu/h (29,310 W).

I2.2.2 De-energize booster heaters when the serviced equipment is not in use or is in standby mode. Make allowance for warm-up time in heater schedule.

I2.2.3 Control the DHW heater so that DHW temperature is maintained between 120°F (49°C) and 125°F (52°C).

Exceptions to I2.2.3:

1. Systems dedicated to serving equipment requiring higher water temperatures.
2. Systems that use a water heater to meet both domestic hot-water needs and space heating load.

I3. HEATING, VENTILATING, AND AIR-CONDITIONING (HVAC) SYSTEMS

I3.1 Scope. The scope of Section D3 includes *HVAC systems* and components used to condition spaces within *buildings*. The O&M requirements for these systems and their components should minimize energy use over time while providing heating, ventilation, and cooling as needed for *building* operations and occupant needs. The O&M requirements for these systems should be evaluated when *building* use or other changes are made that affect system operations.

I3.2 General Requirements

I3.2.1 O&M requirements for *HVAC systems* include all applicable items in Section 6 plus the following.

I3.2.1.1 Each O&M task should be performed in a safe and professional manner by *qualified* personnel. Tasks that require specialized expertise should be performed by personnel with the requisite expertise who are certified where required by code or regulation.

I3.2.1.2 O&M tasks should be performed twice per year, unless otherwise noted in this standard, or as recommended by the manufacturer.

I3.2.1.3 Securely and visibly display a list of operating parameters, such as temperature set points, pressures, and operating schedule, for each piece of equipment in the equipment room or the equipment location.

For equipment located in other areas, the list of operating parameters should be located in a readily accessible location close to the equipment, such as the unit control panel, or at the equipment access point, such as the roof hatch.

I3.2.1.4 For systems using refrigerant, *maintain* the refrigerant charge per the manufacturer's requirements.

I3.2.1.5 Display and *maintain* a *service log* on each piece of equipment as a visible and waterproof document.

I3.2.1.6 The *EM* and/or *building operator* should schedule, verify, and record O&M evaluations of the

HVAC systems, taking corrective action where indicated. Such evaluations should include the following.

I3.2.1.6.1 Poll occupants and users of the *HVAC systems* for any observations or operational issues that have occurred.

I3.2.1.6.2 Physically inspect the maintained systems and components.

I3.2.1.6.3 Analyze occupant complaints and how these relate to system operation.

I3.2.1.6.4 *Maintain* indoor environmental quality parameters that have been established for the *building*, including temperature, humidity, and ventilation.

I3.2.1.6.5 *Maintain HVAC system* rooms and spaces for proper and safe service access. Relocate any material or debris impeding access to the HVAC equipment. *Maintain* service lighting.

I3.2.1.6.6 *Maintain HVAC system* schedules to meet current requirements, including the following.

I3.2.1.6.6.1 Occupied mode.

I3.2.1.6.6.2 Unoccupied mode, such as automatic shutdown, setup mode, setback mode.

I3.2.1.6.6.3 Start mode, such as warm-up mode, cool-down mode, optimum start mode.

I3.2.1.6.7 *Maintain HVAC system* electrical connections.

I3.2.1.6.8 *Maintain* equipment to avoid excessive mechanical noise and vibration.

I3.2.1.6.9 *Maintain* HVAC heat exchange surfaces for effective heat transfer.

I3.2.1.6.10 *Maintain* serviceable points of lubrication.

I3.2.1.6.11 Replace or clean filters in accordance with the manufacturer's recommended schedule or design pressure drop.

I3.2.1.6.12 *Maintain HVAC system* piping and duct systems against leakage.

I3.2.1.6.13 *Maintain* insulation on *HVAC system* piping and duct systems.

I3.2.1.6.14 *Maintain* the steam water heating, hot-water heating, and chilled-water cooling control valves against leakage a minimum of once every three years.

I3.2.1.7 Document periodic maintenance work and service work on *service logs*.

I3.3 Boiler Systems. The scope of this section covers the operation and maintenance of boilers, flues/vents, feed water equipment, piping, valves, steam traps, strainers, all fittings, and components comprising the entire system.

I3.3.1 O&M requirements for boiler systems include all applicable items in Section 6 plus the following.

I3.3.1.1 Boiler Burners

I3.3.1.1.1 *Maintain* proper combustion efficiency—carry out a combustion analysis and carbon monoxide testing at least annually, and make necessary corrections to achieve rated efficiency and safety.

I3.3.1.1.2 For boilers □400,000 Btu/h (117,240 W), design input, perform combustion analysis, and make adjustments to optimize boiler efficiency at least once annually.

I3.3.1.1.3 For boilers <400,000 Btu/h (117,240 W), design input, perform combustion analysis, and make adjustments to optimize boiler efficiency at least once every three years.

I3.3.1.1.4 *Maintain* burners.

I3.3.1.1.5 *Maintain* combustion chamber to avoid incomplete combustion.

I3.3.1.1.6 Inspect combustion chamber against cracks or deterioration.

I3.3.1.1.7 *Maintain* pilot and flame controls, flues, combustion air openings, and safeties.

I3.3.1.1.8 *Maintain* boiler blowdown to ensure it is functional and not excessive.

I3.3.2 Boiler Controls

I3.3.2.1 Adjust controls to cycle the boiler system through an entire heating cycle and *maintain* proper operation.

I3.3.2.2 *Maintain* reset controls.

I3.3.2.3 *Maintain* heating operations so they do not result in short or rapid cycling of the burners.

I3.3.3 Venting

I3.3.3.1 *Maintain* combustion and ventilation air openings.

I3.3.3.2 *Maintain* boiler vent discharge and intakes.

I3.3.4 Steam and Condensate Return Loop I3.3.4.1 *Maintain* condensate return systems. **I3.3.4.2** *Maintain* feed water systems.

I3.3.4.3 *Maintain* pressure relief and venting.

I3.3.4.4 *Maintain* steam traps.

I3.3.4.5 *Maintain* water treatment.

I3.3.5 Hot-Water Hydronic Loop

I3.3.5.1 *Maintain* pump operation and sequencing. **I3.3.5.2** *Maintain* water systems makeup and relief. **I3.3.5.3** *Maintain* system water pressure.

I3.3.5.4 *Maintain* system free of leaks and entrained air.

I3.3.5.5 *Maintain* water treatment and antifreeze additives.

I3.4 Chilled-Water Systems. The scope of this section covers the operation and maintenance of chillers, condensers, open- and closed-type cooling towers, pumps, valves, strainers, piping, and all fittings and components that make up the system.

I3.4.1 Chillers

I3.4.1.1 *Maintain* refrigeration system for proper temperatures and pressures.

I3.4.2 Chilled-Water-System Controls

I3.4.2.1 *Maintain* controls to cycle the chilled-water system through an entire cooling cycle and verify proper operation.

I3.4.2.2 *Maintain* flow controls, operating controls, and safeties for proper operation.

I3.4.2.3 *Maintain* reset and head pressure controls for proper operation.

I3.4.2.4 Where cooling is provided by multiple units, *maintain* proper sequencing to achieve maximum efficiency while meeting required load.

I3.4.3 Chilled-Water Hydronic Loop

I3.4.3.1 *Maintain* proper water temperatures during operation.

I3.4.3.2 *Maintain* proper pump operation and sequencing.

I3.4.3.3 *Maintain* proper system water pressure.

I3.4.3.4 *Maintain* the entire system and ensure the distribution system is free of leaks and entrained air.

I3.4.3.5 *Maintain* water treatment.

I3.4.4 Cooling Towers and Condenser Water Loop

I3.4.4.1 *Maintain* proper water temperatures during operation.

I3.4.4.2 *Maintain* proper pump operation and sequencing.

I3.4.4.3 *Maintain* the entire system and ensure the distribution system is free of leaks and entrained air.

I3.4.4.4 *Maintain* water treatment, bleed control, and cycles of concentration.

I3.4.4.5 *Maintain* corrosion coupon consumption.

I3.4.4.6 *Maintain* cooling-tower sump.

I3.4.4.7 *Maintain* proper fan operation.

I3.5 Air-Side Heating, Cooling, and Ventilating Systems. The scope of this section covers the operation and maintenance of air-side heating, cooling, and ventilating systems ducting; terminal units; and components that make up the system.

I3.5.1 Air-Handling Systems

I3.5.1.1 *Maintain* all airflow components, including motors, fans, variable-frequency drives, inlet vanes, drain pans, piping, ductwork, dampers, louvers, coils, energy recovery devices, and cabinets, as applicable.

I3.5.1.2 *Maintain* controls, including sensors and actuators, and proper sequence of operation.

I3.5.1.3 *Maintain* heat exchange devices, including coils.

I3.5.1.4 *Maintain* damper systems.

I3.5.2 Heat Recovery Systems Including Energy Recovery Ventilation (ERV) and Heat Recovery Ventilation (HRV)

I3.5.2.1 See Section I3.5.1 as applicable.

I3.5.2.2 *Maintain* correct physical operation, such as wheel rotation, as applicable.

I3.5.3 Humidification

I3.5.3.1 *Maintain* fill and drain systems.

I3.5.3.2 *Maintain* water compartment for proper operation.

I3.5.3.3 *Maintain* sprayers and nozzles.

I3.5.3.4 *Maintain* sumps.

I3.5.3.5 *Maintain* control valve and steam traps.

I3.6 Perform heat exchanger testing on furnace heat exchangers at a minimum of once every three years per AHRI Guideline X, *Induced Draft Furnace Heat Exchanger Inspection* N1.

I3.7 Review occupant hot/cold complaints and operator hot/cold observations. If the complaint is validated, do the following.

I3.7.1 Check the *HVAC system* equipment operation.

I3.7.2 Review draft problems.

I3.7.3 Review zoning conflicts.

I3.7.4 Test the *zone* for good and stable temperature control.

I3.7.5 Measure the humidity level to verify it is below the ASHRAE Standard 55 [8] upper dew-point limit of 62.2°F (16.8°C).

I3.7.6 Adjust diffusers and other parts of heating and cooling distribution systems to minimize overheating and overcooling of rooms and *zones*.

I3.8 *Maintain* economizer systems.

I3.8.1 Check that dampers move freely through their entire operating range. Clean, lubricate, adjust, and repair as necessary.

I3.8.2 *Maintain* damper blades and side seals.

I3.8.3 *Maintain* wiring.

I3.8.4 *Maintain* controls, including sensors, wiring, pneumatic tubing and their connections, damper actuators, damper linkages, and damper sequencing for proper operation.

I3.9 Unitary Systems and Air-Handling Systems I3.9.1 See Section I3.5.1 as applicable.

I3.9.2 *Maintain* system heating and cooling operation. **I3.9.3** *Maintain* controls for proper sequence of operations. **I3.9.4** *Maintain* condensate drain pan and piping.

I3.9.5 *Maintain* direct-expansion (DX) cooling or heating.

I3.9.6 Refer to Section I4 for DX refrigerant-based systems.

I3.10 Evaporative Cooling Systems I3.10.1 See Section I3.5.1 as applicable.

I3.10.2 *Maintain* proper fill and drain operation.

I3.10.3 *Maintain* water compartment moisture and air containment.

I3.10.4 *Maintain* sprayers, nozzles, evaporative media, and water distribution components for proper operation.

I3.10.5 *Maintain* drains and clean sumps.

I3.10.6 *Maintain* proper system heating, heat recovery, and cooling operation.

I3.10.7 *Maintain* controls for proper sequence of operations.

I3.11 Geothermal Systems

I3.11.1 See Section I3.5.1 and I3.9 as applicable.

I3.11.2 *Maintain* system heating and cooling operation.

I3.12 Terminal Systems

I3.12.1 See D3.5.1 as applicable.

I3.12.2 *Maintain* system heating and cooling operation.

I3.13 Thermal Energy Storage Systems. The scope of this section covers thermal energy storage systems, ice-storage systems, phase-change storage systems, hot-water storage systems, and heat storage systems (e.g., using thermal mass).

I3.13.1 *Maintain* all equipment in accordance with requirements for each type of equipment elsewhere in this section.

I3.13.2 Operate the thermal energy storage system through its entire cooling and/or heating cycle and verify proper operation of all controls. Perform adjustments and repairs as necessary.

I4. REFRIGERATION SYSTEMS

I4.1 Scope. The scope of Section D4 includes the operation and maintenance of refrigeration systems and equipment that do not supply comfort cooling, such as display case refrigeration systems, refrigerated warehouses, and all medium- and low-temperature-product refrigeration systems.

I4.2 Operations and Maintenance. O&M requirements for refrigeration systems include all applicable items in Section I6.1 plus the following.

I4.2.1 Monitor refrigerating systems at regular intervals, determined by the type of system and historic leakage rates, to ensure that systems are well sealed, have the correct refrigerant charge, and are operating properly. Take the following actions as applicable.

I4.2.1.1 Securely and visibly locate a list of operating parameters, such as temperature set points, pressures, and operating schedule, at each piece of equipment.

I4.2.1.2 Check for refrigerant leaks using industry standard procedures.

I4.2.1.3 Monitor and record all additions of refrigerant to, or removals from, the system, along with the reason for the action.

I4.2.1.4 *Maintain* the refrigerant charge within the manufacturer's specified range.

I4.2.1.5 *Maintain* evaporator defrost system for proper operation.

I4.3 Retail Store Product Display Refrigeration Systems I4.3.1 *Maintain* refrigeration systems.

I4.3.2 The *EM* should work with staff to ensure they know correct product loading practices for display refrigerators. Avoid uneven loading, overloading, blocked air curtains, or blocked return air paths.

I4.3.3 In stores that are not open 24 hours a day, *maintain* the use of night covers for display cases and refrigerators to minimize ambient air infiltration.

I4.4 Walk-In Coolers and Freezers I4.4.1 *Maintain* refrigeration system.

I4.4.2 *Maintain* doors, including hinges, gaskets, and closures.

I4.4.3 *Maintain* evaporator and condenser coils.

I4.4.4 *Maintain* evaporator drains lines. In freezers, *maintain* the drain line heat tape to operate properly, and *maintain* the drain line insulation in good condition.

I4.4.5 *Maintain* the defrost operation, including frequency. Schedule defrost to avoid activation during peak demand periods.

I4.4.6 *Maintain* the interior of refrigerated enclosures for punctured or broken panels and breaches around pipe or wiring penetrations; *maintain* vapor barrier integrity.

I4.4.7 Encourage users to turn lights off when the room is vacant.

I4.5 Ice-Making Machines

I4.5.1 *Maintain* refrigeration systems.

I4.5.2 *Maintain* water system, reservoir, and evaporator coil for scale or mineral build-up and proper operation.

I4.5.3 *Maintain* strainer, inlet water valve screen, and float valve for proper operation.

I4.5.4 *Maintain* air filter, condenser coil, and condenser fan.

I4.5.5 *Maintain* the bin ice control for proper operation, including drain and water overflow.

I4.6 Refrigerated Warehouses

I4.6.1 *Maintain* refrigeration systems.

I4.6.2 The *EM* should work with users so that product is located to permit air circulation, particularly near walls and ceiling.

I4.6.3 Examine walls and ceiling monthly for evidence of frost build up. Locate the source and make corrective repairs.

I4.6.4 *Maintain* doors, rollers, door travel, and threshold as needed to minimize door leakage.

I4.6.5 *Maintain* the interior of refrigerated enclosures for punctured or broken panels and breaches around ducts, pipe, or wiring penetrations; *maintain* vapor barrier integrity.

I5. LIGHTING SYSTEMS

I5.1 The O&M program should include a lighting systems section. The lighting systems plan should include, as a minimum, the requirements listed in Section D5, which should be implemented at the time of compliance with this section and at three-year intervals thereafter.

I5.2 Lighting Controls. The *EM* should inventory and verify correct operation, programming, and placement of all lighting controls. Lighting controls that have been disabled should be repaired and made functional. Functional testing should be performed on *dimmers*, *multiscene controls*, *occupancy sensors*, time switches, or *photosensors*, if present, in accordance with the requirements of ANSI/ASHRAE/IES Standard 90.1 N2, Section 9.4.4.

I5.3 Luminaire Integrity. The *EM* should survey all existing *luminaires* and create an as-built *lighting schedule*. This *lighting schedule* may be developed using a lighting survey tool. The *EM* should calculate and document the *lighting power density* and compare with any previous *lighting power density* calculation,

such as those from original design documents or from previous *lighting schedules*. Continued compliance with this section requires that the *lighting power density* does not increase with time unless there is a corresponding, documented change in use of the space.

I5.4 The current *lighting schedule* should be evaluated for opportunities for energy savings through implementation of *energy efficiency measures* (*EEMs*), such as those listed in Informative Appendix H, Section H6 (nonresidential) or Section H7 (residential), and an estimate of the energy savings should be prepared. This estimate will be included in the energy management plan (see Section 5.1.2.13 if an energy management plan is required).

I5.5 Occupant Training

I5.6 Lighting Maintenance. The O&M program should specify the following.

I5.6.1 Replacement of failed *lamps* and ballasts.

I5.6.2 Replacement of failed *luminaires*.

I5.6.3 Periodic cleaning of all optical surfaces, including lenses, reflectors, louvers, and shielding mechanisms, as well as *lamps*. Individual luminaries should be cleaned whenever *lamps* or ballasts are replaced, and all luminaries as a group should be cleaned at least once every three years. All such cleaning should be performed in accordance with manufacturer's instructions if available.

I5.6.4 Any *lamp* or ballast replacement within the existing *luminaires* in a space should not increase the installed interior *lighting power density* of the space unless the previous light levels were less than the IES recommended levels as specified in the IES *Lighting Handbook* [4] or in the IES *Recommended Practices* title for that space type. If the exact space type cannot be found, then the space type with the closest functional activities should be used.

I5.6.5 For exterior residential lighting, all replacement *lamps* should be *high-efficacy lamps* unless controlled to automatically limit power use to less than 2200 total hours of full-power operation per year.

I5.6.6 For nonresidential exterior lighting, turn off all exterior lighting during *daylight hours*.

Exceptions to I5.6.6:

1. Signage.
2. Lighting needed for safety.
3. Lighting needed for operational necessity.

I5.7 Interior Lighting in Nonresidential Buildings. A lighting satisfaction survey should be conducted at least every three years and key issues identified and corrected as necessary.

I6. CONTROLS SYSTEMS

I6.1 Scope. The scope of Section D6 includes all types of control and energy management systems and components used to control *conditioned spaces* within *buildings*.

The O&M requirements for these systems and their components should minimize energy use over time while providing control of equipment and systems as needed for *building* operations and occupant needs. The O&M requirements for these systems should be re-evaluated when *building* use or other changes are made that negatively affect the systems' operations.

I6.2 All equipment should be maintained according to the manufacturer's instructions.

I6.2.1 Each O&M task should be performed safely and in accordance with good trade practice by *qualified* personnel. Tasks that require specialized expertise should be performed by personnel with the requisite expertise and who are appropriately certified where required by code or regulation.

I6.2.2 O&M tasks should be performed twice per year, unless otherwise noted in this standard, or as recommended by the manufacturer.

I6.2.3 The *EM* and/or *building operator* should schedule and perform evaluations of the control systems twice per year. System evaluations should include the following.

I6.2.3.1 Reviewing recorded trouble calls and occupant complaints and analyzing how these relate to control

operation.

I6.2.3.2 Physically inspecting maintained systems and components.

I6.2.3.3 Checking that all set points are correct per efficiency requirements, design, or the owner's needs.

I6.2.3.4 Checking to ensure seasonal control changes are adjusted.

I6.2.3.5 Checking that time of day and holiday schedules are optimized to meet current occupied hours.

I6.2.3.6 Making calibration checks of all system-level sensors, including hot-water, chilled-water, and multiple-*zone* air-handling units, at least every three years.

I6.2.3.7 Making calibration checks of all space sensors showing small drift or offset over time at least once every five years.

I6.2.3.8 Checking whether controls are overridden or in manual operation and making corrections as necessary.

I6.2.3.9 Checking the control of minimum outdoor air ventilation and making adjustments where necessary to avoid either excessive or inadequate minimum outdoor airflows.

I6.2.4 Correct all issues found during the control system evaluations.

I6.3 Pneumatic Controls (including Pneumatic Sensors and Actuators)

I6.3.1 Check for properly operating receivers controllers and transducers and calibrate as required.

I6.3.2 Check for oil in the air lines and clean lines and any affected components as required.

I6.3.3 Check filters on air dryer and clean or replace as necessary.

I6.3.4 Check condenser coil on the air dryer and clean as necessary.

I6.3.5 Check pressure reducing valves (PRV or regulator) operation and calibrate as required.

I6.3.6 Check for leaks in air storage tank.

I6.3.7 Check tank condensate drain operation.

I6.3.8 Check thermostat for proper operation and calibrate as required.

I6.3.9 Check system for leaks in the high pressure lines.

I6.3.10 Check compressor run time; it should run less than 50% of the time. If runtime is excessive, check for leaks or other causes of high demand for control air and take corrective action as needed.

I6.3.11 Correct all issues found during the pneumatic control system evaluations.

I6.4 Analog Controls

I6.4.1 Check differential pressure gages operation. **I6.4.2** Check differential pressure switches operation. **I6.4.3** Check air pressure switches operations.

I6.4.4 Check thermostat operation.

I6.4.5 Check transformer input and output voltages.

I6.4.6 Check system's back-up batteries.

I6.4.7 Correct all issues found during the *analog control* system evaluations.

I6.5 Direct Digital Controls (DDC) (including Electronic Sensors and Actuators)

I6.5.1 Review *DDC* system applications programs and verify the system is working in accordance with the design sequence of operation.

I6.5.2 Confirm component readings are in range through audits, calibration, or comparison to *performance* standards.

I6.5.3 If the *DDC* system has back-up batteries, check system's back-up batteries.

I6.5.4 Inspect, clean, and *maintain* all sensors and meters in conformance with the manufacturer's recommendations.

I6.5.5 Verify the most recent calibration report of CO_2 sensors and recalibrate as recommended by the manufacturer.

I6.5.6 Check whether outdoor devices have adequate enclosures and whether the enclosures are in good conditions.

I6.5.7 Verify input and output transformer voltages.

I6.5.8 Verify control actuation, linkage attachment, stroke timing, and torque required for motor actuators.

I6.5.9 Correct all issues found during the *DDC* system evaluations.

I7. ELECTRIC POWER DISTRIBUTION AND ON-SITE GENERATION SYSTEMS

I7.1 Scope. The scope of Section D7 covers aspects of O&M for the *building* electrical power system that relate to the facility's energy efficiency.

I7.2 O&M requirements for electric power distribution and on-site generation systems include all applicable items in Section I6.1 plus the following.

I7.2.1 Each piece of on-site electrical generation equipment or built-up system should be maintained to the manufacturer's instructions.

I7.2.2 Metering and Submetering. Meters and submeters owned by the facility should be calibrated at least once every five years per the manufacturer's instructions.

I7.2.3 On-Site Electricity Generation

I7.2.3.1 Fuel-Fired Cogeneration. A monthly record of cogeneration operating hours and heat recovery should be maintained and reported annually. Annual energy generated and useful heat recovered should be compared to the design estimates for these values.

I7.2.3.2 Photovoltaic (PV) Systems. PV system *performance* should be reported on an annual basis. The annual output should be compared to the system's designed output or output during previous operating periods. Shortfalls in annual system *performance* should be analyzed for cause and possible system defects, and troubleshooting and corrective work should be performed as necessary.

I7.2.3.3 Fuel Cells. Fuel-cell *performance* should be reported on a monthly basis. Shortfalls in monthly system *performance* should be analyzed for cause and possible system defects, and troubleshooting and corrective work should be performed as necessary.

INFORMATIVE APPENDIX J GUIDANCE FOR LOCALLY DERIVED BUILDING PERFORMANCE TARGETS

NOT ADOPTED

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard.)

INFORMATIVE APPENDIX K FUEL HEAT CONTENT CONVERSION VALUES—"OTHER" FUELS

ANSI/ASHRAE Standard 105 [N15], Table G-1, has been reproduced here as Table K-1 and can be used to determine the heating value of fuels other than those listed in Table 5-1 of this standard.

Table K-1 Higher Heating Values

Coals		**Btu/lb**		**kWh/kg**	
Anthracite		12,700		8.2	
Semianthracite		13,600		8.8	
Low-volatile bituminous		14,350		9.3	
Medium-volatile bituminous		14,000		9.0	
High-volatile bituminous A		13,800		8.9	
High-volatile bituminous B		12,500		8.1	
High-volatile bituminous C		11,000		7.1	
Subbituminous B		9000		5.8	
Subbituminous C		8500		5.5	
Fuel Oils		**Btu/U.S. gal [a]**		**kWh/L [a]**	
#1 (Kerosene)		See Table 5-1		See Table 5-1	
#2		See Table 5-1		See Table 5-1	
#4		See Table 5-1		See Table 5-1	
#5L		148,000		11.5	
#5H		150,000		11.6	
#6		See Table 5-1		See Table 5-1	
Gas	Natural gas	See Table 5-1		See Table 5-1	
	Propane	See Table 5-1		See Table 5-1	
Bagasse (Moisture Free)		8900 Btu/lb		5.8 kWh/kg	
Sawdust, Peat, Bark		9000 Btu/lb		5.8 kWh/kg	
Woods		**Mass lb/cord [b], kg/m^3**		**Million Btu/Cord [b], kWh/m^3**	
Species		**Green [c]**	**Air-Dry [d]**	**Green [c]**	**Air-Dry [d]**
Ash		3840 (480)	3440 (430)	16.5 (1300)	20.0 (1600)
Aspen		3440 (430)	2160 (270)	10.3 (800)	12.5 (1000)
Beech, American		4320 (540)	3760 (470)	17.3 (1400)	21.8 (1800)
Birch, yellow		4500 (560)	3680 (460)	17.3 (1400)	21.3 (1700)
Douglas fir		3200 (400)	2400 (300)	13.0 (1100)	18.0 (1500)
Elm, American		4320 (540)	2900 (360)	14.3 (1200)	17.2 (1400)
Hickory, shagbark		5040 (630)	4240 (530)	20.7 (1700)	24.6 (2000)
Maple, red		4000 (500)	3200 (400)	15.0 (1200)	18.6 (1500)
Maple, sugar		4480 (560)	3680 (460)	18.4 (1500)	21.3 (1700)
Oak, red		5120 (640)	3680 (460)	17.9 (1400)	21.3 (1700)
Oak, white		5040 (630)	3920 (490)	19.2 (1600)	22.7 (1800)
Pine, eastern white		2880 (360)	2080 (260)	12.1 (1000)	13.3 (1100)
Pine, eastern yellow		4000 (500)	2600 (330)	14.2 (1100)	20.5 (1700)

a. "Table 5-1" in this column refers to Standard 105.

b. Based on 80 ft^3 of solid wood stacked in a 128 ft^3 cord, for a void fraction of 37.5%. Cubic metres apply to the gross volume of a stacked pile of wood with this void fraction.

c. 40% to 60% moisture
d. 20% moisture

INFORMATIVE APPENDIX L SIMPLE PAYBACK AND LIFE-CYCLE COST ANALYSIS

NOT ADOPTED

INFORMATIVE APPENDIX M GUIDANCE ON BUILDING TYPE DEFINITIONS

NOT ADOPTED

INFORMATIVE APPENDIX N INFORMATIVE REFERENCES

NOT ADOPTED

INFORMATIVE APPENDIX O STANDARD 100-2024 CROSSWALK

NOT ADOPTED

INFORMATIVE APPENDIX P ADDENDA DESCRIPTION INFORMATION

NOT ADOPTED