BSR/ASHRAE/IES Addendum ag
to ANSI/ASHRAE/IES Standard 90.1-2019

Public Review Draft

Proposed Addendum ag to Standard 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings

First Public Review (July 2021)
(Draft Shows Proposed Changes to Current Standard)

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ASHRAE, 180 Technology Parkway NW, Peachtree Corners, GA 30092

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FOREWORD

This addendum adds an optional Mechanical System Performance path. Currently this path is restricted to HVAC system efficiency tradeoffs only in Section 6. It is anticipated that it will be expanded in the future to include service water heating systems in Section 7 to allow heat recovery efficiency to be credited.

While easy to use and understand, the prescriptive path limits design flexibility and fails to acknowledge individual building characteristics or system improvements that can optimize a buildings energy performance with integrated solutions. Because prescriptive requirements are typically established at an individual component level and limited by cost effectiveness requirements, the rate of improvement of each subsequent code has slowed down based on economic considerations and limits of technological feasibility. In addition, such component efficiency ratings are based on standard rating conditions that may not reflect actual building conditions and the climate of the building site. The HVAC System Performance approach accounts for all of these system parameters to provide a comprehensive evaluation of a building’s HVAC system.

Improvements in prescriptive requirements may limit design flexibility. To continue progress, code developers have increasingly focused on performance paths to help maintain the design flexibility desired by the architectural and engineering community.

In some cases, prescriptive requirements require systems that may not be practical or effective in all building situations. For example:

- Outside air economizers may not be practical for some system types in some buildings, yet they are required unless excepted.
- In some buildings the absolute fan power limits in the prescriptive path may be challenging to achieve.

Currently, to make a trade-off for any prescriptive requirements, a full building analysis is required under Section 11 or Appendix G of Standard 90.1. This can require substantial professional analysis time. A mechanical performance method would allow a simplified building input and adequately assess mechanical system efficiency tradeoffs. The mechanical system performance path is much simpler than standard whole building performance energy modeling, providing a solution more informative than a prescriptive based approach without the complexities and costs of a whole-building performance-based approach.

The Mechanical System Performance path is designed to provide tradeoffs within the mechanical system while maintaining equivalent energy efficiency to the prescriptive path. The path uses a new metric—the

Total System Performance Ratio (TSPR)—for evaluating an HVAC system. TSPR analyzes all components of the HVAC system, accounts for part-load performance and system controls, and normalizes for building loads. The TSPR metric addresses multiple issues, as it measures the amount of energy required to deliver each unit of heating and cooling to the building over the course of a typical year. The TSPR metric is larger when a system is more efficient, and is represented as follows:

$$TSPR = \frac{Delivered\ HVAC\ Loads}{HVACinput}$$

Where:

Delivered HVAC Loads = Sum of the annual heating and cooling loads met by the building HVAC system, in thousand Btu (kWh).

HVACinput = Sum of the annual HVAC energy input for heating, cooling, fans, energy recovery, pumps, and heat rejection. The HVAC energy input units are generally annual HVAC system energy cost, although jurisdictions may substitute metrics like carbon emissions, source energy, or site energy.

A larger TSPR indicates a lower heating and cooling energy cost to meet the same HVAC annual loads, and therefore indicates a more efficient HVAC system. The annual heating and cooling loads are based on proposed building envelope loads, internal loads due to lights, equipment, and occupants, as well as ventilation and infiltration loads. This metric provides a single evaluation criterion which addresses all components of the HVAC systems used to move heat and air into, out of, and within a building. It includes distribution system effectiveness, considers both full and part-load performance, and accounts for system controls. This differs from standard system efficiency ratings (such as seasonal energy efficiency ratio, coefficient of performance, or kilowatt hours per ton) that usually address part of a system and fail to account for all the system inefficiencies that may be present within a building as well as their interaction with building loads and ventilation requirements.

Systems using the same or less overall annual energy as a selected target system to meet the building's annual thermal and ventilation loads would be rated as equivalent or more efficient. This proposal defines a *TSPR* requirement, by comparing a proposed mechanical system ($TSPR_p$) with a reference mechanical system ($TSPR_r$). The reference system is generally aligned with Appendix G requirements that are roughly equivalent to 90.1-2004. Then the improvement for the proposed system would need to be greater than or equal to the improvement for a target system ($TSPR_t$). So, efficiency equivalence is demonstrated where:

$$TSPR_p \geq TSPR_t \;\; OR \;\; \frac{TSPR_p}{TSPR_r} \geq \frac{TSPR_t}{TSPR_r}$$

This is simplified by using a Mechanical Performance Factor (*MPF*) that represents the improvement in system output per cost for a target system ($TSPR_t$) compared to the reference system ($TSPR_r$). This allows the reference systems to remain stable in software, with only a table of *MPFs* updated for each edition of 90.1. The *MPFs* are unique to building type and climate zone. The target systems are selected to represent a typical prescriptive system based on consensus discussion of the Mechanical Subcommittee of SSPC 90.1.

$$TSPR_p > TSPR_r / \text{MPF}$$

Where:

$TSPR_p$	=	Proposed *TSPR*
$TSPR_r$	=	Reference *TSPR*
MPF	=	Mechanical Performance Factor based on climate zone and building use type (MPF = $TSPR_r$ / $TSPR_t$)

The Mechanical System Performance Path is implemented with a brief addition of an alternative path in Section 6, and then supported by a new normative Appendix J that provides direction to the user and simulation program developer to meet the *TSPR* calculation requirements. DOE has committed to support Pacific Northwest National Laboratory in development of one version of software that meets the requirements of Appendix J. Other software developers can create their own versions of the software or incorporate the *TSPR* calculation into existing HVAC system design software.

Cost Considerations: This addendum creates an optional performance path in the standard designed to provide increased flexibility. Since the path is optional, it does not create a code requirement for increased costs and therefore is not subject to cost effectiveness analysis.

[Note to Reviewers: This addendum makes proposed changes to the current standard. These changes are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

Addendum ag to 90.1-2019

Make the following changes to Section 3.2 (I-P and SI Units):

[…]

proposed building performance**:** the annual *energy* cost calculated for a *proposed design*.

proposed design: a computer representation of the actual proposed *building* design, or portion thereof, used as the basis for calculating the *design energy cost*.

[…]

total system performance ratio (TSPR): The ratio of the sum of a *building's* annual heating and cooling load in thousand Btu (kWh) to the sum of annual *energy* input of the *building* mechanical *systems* where the input units are in accordance with Section J5.

[…]

TSPR reference building design: a computer representation of a hypothetical *building* design based on modifications to the *proposed design* in accordance with Section J.4.3. This representation is used as the basis for calculating the mechanical *total system performance ratio* for determining alternative mechanical *system* performance in accordance with Section 6.6.2.

Make the following changes to Section 3.3

DOAS dedicated *outdoor air system*

FPTU fan powered terminal unit

HWST heating water loop supply temperature

MPF Mechanical Performance Factor

OAT *outdoor air* temperature

OSA *outdoor air*

RAT return air temperature

VSD variable speed drive

SAT supply air temperature

TSPR *total system performance ratio*

$TSPR_p$ *TSPR* of a *proposed design*

$TSPR_r$ *TSPR* of a *TSPR reference building design*

[…]

Make the following changes to Section 6 (I-P and SI):

6.2 Compliance Paths

Mechanical ~~equipment~~*equipment* and ~~systems~~*systems* providing heating, cooling, ventilating, or refrigeration shall comply with Section 6.2.1 and Section 6.2.2.

6.2.1 Requirements for all Compliance Paths

Mechanical ~~equipment~~*equipment* and ~~systems~~*systems* shall comply with all the following:

a. Section 6.1, "General"~~;~~

b. Section 6.4, "Mandatory Provisions"~~;~~

c. Section 6.7, "Submittals"~~; and~~

d. Section 6.8, "Minimum *Equipment Efficiency* Tables~~.~~"

Exception to 6.2.1(b)

When compliance is shown using Section 6.3, compliance with Section 6.4 is not required.

6.2.2 Additional Requirements to Comply with Section 6

Refrigeration *equipment* and *systems* shall comply with Section 6.5, "Prescriptive Compliance Path." ~~Mechanical equipment and~~ All *building HVAC systems* shall comply with one of the following:

a. Section 6.3, "Simplified Approach *Building* Compliance Path for *HVAC Systems*"

~~**Exception to 6.2.2(a)**~~

~~When compliance is shown using Section 6.2.2(a), compliance with Section 6.4 is not required.~~

b. Section 6.5, "Prescriptive Compliance Path"

~~**Exception to 6.2.2(b)**~~

~~*HVAC systems* only serving the heating, cooling, or ventilating needs of a *computer room* with IT *equipment* load greater than 10 kW shall be permitted to comply with Section 6.4, "Mandatory Provisions" and Section 6.6, "Alternative Compliance Path."~~

c. Section 6.6.1, "*Computer Room Systems* Path"

d. Section 6.6.2, "Mechanical *System* Performance Path"

Informative Note:

Section 6.3 requires all *HVAC systems* in the *building* to qualify for the simplified path. Section 6.6.2 requires all allowable *systems* to meet the Appendix J requirements. *HVAC systems* for larger *computer rooms* may comply with either 6.5, 6.6.1, or 6.6.2.

[…]

6.6 Alternative Compliance Paths

6.6.1 Computer Rooms Systems Path

The *Computer room System* Path is an optional path for compliance where the following conditions are met:

a. *HVAC systems* that only serve ~~ing~~ the heating, cooling, or ventilating needs of a *computer room* with IT *equipment* load greater than 10 *kW* shall comply with ASHRAE Standard 90.4, *Energy Standard for Data Centers*.

b. All other *HVAC systems* shall comply with the applicable requirements in Section 6.5.

6.6.2 Mechanical System Performance Path

6.6.2.1 Scope

The Mechanical *System* Performance Path is an optional path for compliance where the following conditions are met:

a. All *HVAC systems* in the *building* that meet the criteria in Section J1.1.1 shall comply with Section 6.6.2.2.

b. All other *HVAC systems* shall comply with one of the following:

   1. The applicable requirements in Section 6.5 or
   2. *HVAC systems* that only serve the heating, cooling, or ventilating needs of a *computer room* with IT *equipment* load greater than 10 *kW* shall be permitted to comply with ASHRAE Standard 90.4, *Energy Standard for Data Centers*.

6.6.2.2 Criteria

HVAC systems in new *buildings*, *additions*, or *alterations* shall comply with the requirements in Section J2, "Mechanical *System* Performance Method." The *proposed design Total System Performance Ratio* (*TSPR*p) of the *HVAC systems* using this method shall be greater than or equal to the *Total System Performance Ratio* of the *TSPR reference building design* (*TSPR*r) divided by the mechanical performance factor (MPF) when calculated in accordance with the following:

$$TSPR_p > TSPR_r / \text{MPF}$$

Where:

$TSPR_p$ = Proposed *TSPR* calculated in accordance with Appendix J.

$TSPR_r$ = Reference *TSPR* calculated in accordance with Appendix J.

MPF = Mechanical Performance Factor from Table 6.6.2 based on climate zone and *building* use type

Where a *building* has multiple *building* use types, MPF shall be area weighted as follows:

$$\text{MPF} = (A_1 * \text{MPF}_1 + A_2 * \text{MPF}_2 + \ldots + A_n * \text{MPF}_n) / (A_1 + A_2 + \ldots + A_n)$$

Where:

MPF_1, MPF_2 through MPF_n = Mechanical Performance Factors from Table 6.6.2.2 based on climate zone and *building* use types 1,2, through n

A_1, A_2 through A_n = Conditioned *floor* areas for *building* use types 1, 2, through n

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Informative note:

The Mechanical *System* Performance Method is a simplified performance trade-off approach for *HVAC systems* that does not require using the whole *building* trade-off approaches in Section 11 or Appendix G. *HVAC systems* that are allowed to use this approach will not need to comply with all of the prescriptive requirements in Section 6.5. For example, an *HVAC system* without a required outside air economizer can show compliance with Section 6 by demonstrating improved cooling *efficiency* or reduced fan *energy* use compared to a reference *HVAC system* that meets all prescriptive requirements, including outside air economizers. This approach does not allow *HVAC system efficiency* trade-offs with *building envelope* or lighting *systems*.

Table 6.6.2.2 Mechanical Performance Factors (MPF)

Climate Zone: *Building* type	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium)[a]	0.75	0.75	0.74	0.74	0.72	0.69	0.75	0.70	0.69	0.73	0.70	0.71	0.76	0.72	0.72	0.78	0.75	0.79	0.81
Office (Large)[a]	0.91	0.93	0.94	0.93	0.88	0.94	0.80	0.88	0.95	0.77	0.95	0.82	0.82	0.89	0.82	0.81	0.84	0.79	0.77
Retail	0.61	0.59	0.52	0.56	0.48	0.47	0.43	0.46	0.62	0.53	0.60	0.73	0.57	0.68	0.75	0.60	0.60	0.57	0.52
Hotel/Motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.69	0.73	0.59	0.66	0.65	0.55	0.59	0.68	0.51	0.54	0.47	0.40
Multi-Family/ Dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.60	0.54	0.59	0.57	0.52	0.58	0.53	0.48	0.57	0.53	0.55	0.52
School/ Education	0.89	0.89	0.89	0.87	0.83	0.82	0.79	0.80	0.80	0.75	0.85	0.77	0.84	0.83	0.73	0.86	0.82	0.83	0.78

[a] Office sizes defined in Section J1.1.1.1.

[…]

Add Normative Appendix J as follows:

Normative Appendix J

MECHANICAL SYSTEM PERFORMANCE METHOD

J1 GENERAL

J1.1 Scope

This appendix offers an alternative path of compliance for *HVAC systems* in accordance with Section 6.6.2. This appendix establishes the requirements for *HVAC systems* that use the Mechanical *System* Performance Method and requirements for calculating $TSPR_p$ and $TSPR_r$ to demonstrate compliance in accordance with Section 6.6.2.2. Not all *HVAC systems* are allowed to use the Mechanical *System* Performance Method as described in J1.1.1.

J1.1.1 Allowable HVAC Systems

HVAC systems are allowed to use the Mechanical *System* Performance Method if they comply with all the following criteria:

a. The *HVAC system* type is included in Table J1.1.1
b. The *HVAC system* serves a *building* use type included in Section J1.1.1.1
c. The *HVAC system* is not excluded by Section J1.1.1.2
d. The *HVAC system* is powered by grid-delivered electricity, renewable electricity, natural gas, propane, renewable thermal *energy*, or distillate fuel oil.

Informative note:
The intention of the scope is to allow most of the *building* to use the *TSPR* path and have portions of the *buildings* that cannot use the *TSPR* path use either the prescriptive path or the *computer room system* path.

Table J1.1.1: Proposed Building HVAC Systems Allowed to use the Mechanical System Performance Method

System No.	*System* Name	*System* Abbreviation
1	*Packaged Terminal Air Conditioner*	*PTAC*
2	*Packaged Terminal Air* Heat pump	*PTHP*
3	Packaged Single Zone Gas Furnace	PSZGF
4	Packaged Single Zone Heat Pump (air to air only)	PSZHP
5	*Variable-Refrigerant-Flow-System* (air source only)	-
6	Four-Pipe Fan Coil	FPFC
7	Water-Source Heat Pump (Water Loop)	WSHP
8	Ground-Source Heat Pump	GSHP
9	Packaged *Variable-air-volume system* (DX cooling)[a]	*PVAV*
10	*Variable-air-volume system* (hydronic cooling)[a]	*VAV*
11	*Variable-air-volume system* with Fan Powered Terminal Units	*VAV*FPTU
12	Dedicated *Outdoor air System* (in conjunction with *systems* 1-8)	DOAS

a. *Reheat and primary heat may be electric, hydronic, or gas furnace

J1.1.1.1 Allowable Building Use Types

HVAC systems that serve the following *building* use types are allowed to use the Mechanical *System* Performance Method:

a. large office (*gross conditioned floor area* >150,000 ft^2 (14,000 m^2) or > 5 floors)
b. medium office (*gross conditioned floor area* 5000 to 150,000 ft^2 (460 to 14,000 m^2) and ≤ 5 floors)
c. small office (*gross conditioned floor area* ≤5000 ft^2 (460 m^2) and ≤ 5 floors)
d. retail
e. multifamily (including dormitory)
f. hotel (including motel)
g. school (including education and university)
h. Other *building* use types that are <1000 ft^2 (93 m^2) and <10% of the *building* conditioned floor area unless specifically excluded by Section J1.1.1.2(a)

Informative note
Item h allows for a small sandwich or coffee counter service area but not a restaurant in an office *building* lobby or bookstore for example.

J1.1.1.2 Excluded HVAC Systems

The following *HVAC systems* are excluded from using the Mechanical *System* Performance Method:

a. *HVAC systems* serving one of the following excluded *building* areas:
   1. Data centers and *computer rooms* with *equipment* power density exceeding 20 W/ft^2 (216 W/m^2) of conditioned floor area and exceeding 10 *kW* of *equipment* load
   2. Laboratories with fume hoods

3. Locker rooms with more than 4 showers
4. Cafeterias and dining rooms
5. Restaurants and commercial kitchens with total cooking capacity greater than 100,000 Btu/h (30 *kW*) (does not include break rooms)
6. Natatoriums or rooms with saunas
7. Areas of *buildings* with commercial refrigeration *equipment* exceeding 100 *kW* of power input

b. *HVAC systems* that are not replaced in their entirety as part of an *Alteration* and are not serving initial build-out construction

c. *HVAC systems* serving *portions* of the *building* that are also served in parallel by other *HVAC systems* not allowed to use the Mechanical *System* Performance Method

Exceptions to J1.1.1.2(a and c)

1. Multiple zone *HVAC systems* in Table J1.1.1, including dedicated *outdoor air systems*, where 80% or more of *system* supply air serves allowed *building* use types in accordance with Section J1.1.1.1 and 20% or less of *system* supply air serves excluded areas in Section J1.1.1.2(a) or (c).
2. Central chiller or *boiler* plants where 80% or more of capacity serves allowed *building* use types in accordance with Section J1.1.1.1 and 20% or less of capacity serves excluded areas in Section J1.1.1.2(a) or (c).

J2 MECHANICAL SYSTEM PERFORMANCE METHOD

J2.1 Compliance

J2.1.1 Mandatory Requirements

All *HVAC systems* in the proposed *building* design shall comply with the requirements in Section 6.2.1.

Informative note:

Buildings using the Mechanical *System* Performance Method are required to meet all mandatory provisions in Section 6.4 in accordance with 6.2.1. For example, while *DCV* controlled area in the proposed *building* is one of the user entries in the simulation program, the minimum entry needs to meet the floor area where *DCV* is required in accordance with Section 6.4.3.8. The intent of this entry is to give credit for *DCV* control in more area than required, but not to allow *DCV* that is a mandatory requirement to be traded off with other *efficiency* improvements.

J2.1.2 Mechanical System Performance Method Requirements

All *HVAC systems* using the Mechanical *System* Performance Method shall demonstrate compliance using $TSPR_p$ and $TSPR_r$ in accordance with Section 6.6.2 and the following requirements:

a. $TSPR_p$ and $TSPR_r$ shall be calculated in accordance with Section J2.1.5 "Calculating *TSPR*" and the requirements of Sections J2, J3, J4 and J5.

b. *Alterations* that include replacement of the entire *HVAC system* shall be modeled as a new *building*.

c. *HVAC systems* shall comply with Section J2.1.4 "Partial Prescriptive Requirements"

d. Initial build-out construction shall be modeled in accordance with Section J2.1.3 "Core & Shell / Initial Build-Out Construction Analysis."

e. Compliance documentation and supplemental information shall be submitted in accordance with Sections 4.2.2 and J2.1.6 "*TSPR* Submittals."

J2.1.3 Core & Shell / Initial Build-Out Construction Analysis

Where the *building* permit applies to only a portion of the *HVAC system* in a *building* and the remaining components will be designed under a future *building* permit or were previously installed, the future or previously installed components shall be modeled as follows:

a. Where the *HVAC zones* that do not include *HVAC systems* in the current permit will be or are served by independent *systems*, then the block (See Section J2.2.1) including those zones shall not be included in the model.
b. Where the *HVAC zones* that do not include complete *HVAC systems* in the permit are intended to receive HVAC services from *systems* in the permit, their proposed zonal *systems* shall be modeled with *equipment* that meets, but does not exceed, the requirements of Section 6.4 and Section 6.5.
c. Where the zone *equipment* in the permit receives HVAC services from previously installed *systems* that are not in the permit, the previously installed *systems* shall be modeled with *equipment* matching the certified value of what is installed or *equipment* that meets the requirements of Section 6.4 and Section 6.5, whichever has the more efficient *energy* use.
d. Where the central plant heating and cooling *equipment* is completely replaced and *HVAC zones* with *existing systems* receive HVAC services from *systems* in the permit, their proposed zonal *systems* shall be modeled with *equipment* that meets, but does not exceed, the requirements of Section 6.4 and Section 6.5.

Informative Notes:

1. Examples of *HVAC systems* that are intended to receive HVAC services from *systems* in the permit include future zonal water source heat pumps that will receive loop water that is heated by a *boiler* or cooled by a cooling tower included in the permit, any *system* that will receive outdoor *ventilation* air from a dedicated *outdoor air system* included in the permit, and future zone terminal units that will be connected to a central *VAV system* included in the permit.

2. An initial build-out with heating coils served from a previously installed *system* with a high-*efficiency* condensing *boiler* would use the installed *efficiency* if it exceeded the current requirements. If the installed *boiler* had a lower *efficiency* than the current requirements, the current requirement would be used.

3. A partial central plant upgrade (e.g. chiller, but not *boiler* replacement) cannot use this method.

J2.1.4 Partial Prescriptive Requirements

HVAC systems using the HVAC Performance Method shall meet relevant prescriptive requirements in Section 6.5 as follows:

a. Air *economizers* shall meet the requirements of Section 6.5.1.1.5 "relief of excess *outdoor air*" and Section 6.5.1.1.6 "sensor accuracy."
b. Steam humidifiers shall meet requirements of Section 6.5.2.4.
c. *Variable-air-volume system systems* shall meet requirements of Sections 6.5.3.2.2, 6.5.3.2.3, and 6.5.3.3.
d. Hydronic *systems* shall meet the requirements of 6.5.4.2.
e. Plants with multiple chillers or *boiler*s shall meet the requirements of Section 6.5.4.3.
f. Chilled water and heating water supply temperature reset shall meet the requirements of Section 6.5.4.4 without exception.

g. Hydronic (Water Loop) Heat Pumps and Water-Cooled *Unitary Air Conditioners* shall meet the requirements of Section 6.5.4.5.
h. Cooling tower turndown shall meet requirements of Section 6.5.5.4.
i. Heating of unenclosed *spaces* shall meet the requirements of Section 6.5.8.1.
j. Hot-gas bypass shall meet the requirements of Section 6.5.9.
k. *Systems* shall meet the door switch *control* requirements of Section 6.5.10.
l. Refrigeration *systems* shall meet the requirements of Section 6.5.11.

J2.1.5 Calculating TSPR

$TSPR_p$ shall be calculated according to Equation J1:

$$TSPR_p = \frac{\text{Loads}_r}{HVAC\text{input}_p} \quad (J1)$$

Where:

Loads$_r$ = Sum of the annual heating and cooling loads for the *TSPR reference building design* met by the *building HVAC system*, in thousand Btu (kWh).

HVACinput$_P$ = Sum of the annual HVAC *energy* input for heating, cooling, fans, *energy* recovery, *pumps*, and heat rejection for the *proposed design*. The HVAC *energy* input units shall be in accordance with Section J5.

$TSPR_r$ shall be calculated according to Equation J2:

$$TSPR_r = \frac{\text{Loads}_r}{HVAC\text{input}_r} \quad (J2)$$

Where:

Loads$_r$ = Sum of the annual heating and cooling loads for the *TSPR reference building design* met by the *building HVAC system*, in thousand Btu (kWh).

HVACinput$_r$ = Sum of the annual HVAC *energy* input for heating, cooling, fans, *energy* recovery, *pumps*, and heat rejection for the *TSPR reference building design*. The HVAC *energy* input units shall be in accordance with Section J5.

Informative note:

The annual HVAC *energy* uses calculated using the Mechanical *System* Performance Method are not predictions of whole *building energy* consumption for an actual proposed *building* after construction. Actual experience will differ from these calculations due to variations such as occupancy, *building* operation and maintenance, weather, *energy* use of *systems* and *building* areas not covered by this procedure, changes in *energy* prices between design of the *building* and occupancy, and the precision of the calculation tool.

J2.1.6 TSPR Submittals

Where $TSPR_p$ and $TSPR_r$ are used to demonstrate compliance in accordance with Section 6.6.2, documentation shall be provided to the *building official* including the following:

a. A compliance report as outlined in Section J3.4 generated by the *simulation program.*
b. A mapping of the actual *building* HVAC component characteristics and those simulated in the *proposed design* showing how individual pieces of HVAC *equipment* identified above have been combined into average inputs as required by the *simulation program* including, but not limited to:
   1. Fans
   2. Hydronic *pump*s
   3. Air handlers
   4. Packaged cooling *equipment*
   5. Furnaces
   6. Heat pumps
   7. *Boiler*s
   8. Chillers
   9. Cooling towers
   10. *Electric resistance* coils
   11. Condensing units
   12. Motors for fans and *pump*s
   13. *Energy* recovery devices
c. For each piece of *equipment* identified in J2.1.6(b) above include the following along with the units specified in Table J2.2.3 as applicable:
   1. *Equipment* name or tag consistent with that found on the design documents.
   2. Rated *Efficiency* level.
   3. Rated Capacity.
   4. Electrical input power for fans and *pump*s (before any speed or frequency *control device*) at design condition and calculation of input value (W/cfm (W·s/L) or W/gpm (W·s/L))
d. A floor plan of the *building* identifying how portions of the *building* are assigned to the simulated blocks (See Section J2.2.1) and which areas of the *building* are served by *HVAC systems* required to meet the requirements of Section 6.5 or Section 6.6.1.

J2.2 Proposed Building Information Required

The simulation of *HVAC systems* and the *HVAC zones* they serve shall be modeled based on *building* information required by this Section.

J2.2.1 Simplified Block Approach

The geometry of *buildings* shall be configured using one or more simplified geometric simulation *building* blocks, referred to as “blocks” in this appendix. Each block contains one or multiple *thermal blocks.*

J2.2.1.1 Block Geometry

Each block shall define attributes including block dimensions, number of *floors*, *floor* to *floor* height and *floor* to ceiling height. The *simulation program* is permitted to allow the use of simplified shapes (such as rectangle, L shape, H Shape, U shape or T shape) to represent blocks. Where actual *building* shape does not match these pre-defined shapes, simplifications are permitted providing the following requirements are met:

a. The *conditioned floor area* and volume of each block shall match the actual *proposed design* within 10%.

b. The area of each *exterior building envelope* component from Tables 5.5-1 through 5.58 is accounted for within 10% of the actual *proposed design*.

c. The area of vertical *fenestration* and *skylights* is accounted for within 10% of the actual *proposed design*.

d. The *orientation* of each component in b and c above is accounted for within 45° of the actual *proposed design*.

The user shall create multiple blocks if necessary, to meet these requirements.

J2.2.1.2 Number of Blocks

One or more blocks shall be created per *building* based on the following restrictions:

a. Each block shall have only one *building* use type. At least one single block shall be created for each unique use type, including where one *HVAC system* serves two different use types.

b. Each block shall be served by only one type of primary or zonal *HVAC system*. A DOAS *system* shall be permitted to serve blocks served by other *systems*. A single block shall be created for each unique primary or zonal *HVAC system* type and *building* use type combination. Multiple HVAC units of the same type are permitted to be represented in one block in accordance with Section J2.2.3.1.

c. Each block shall have a single definition of *floor* to *floor* or *floor* to ceiling heights. Where *floor* heights differ by more than two ft, unique blocks shall be created for the floors with varying heights.

d. Each block can include either above-*grade* or below-*grade* exterior *floors*. For *buildings* with both above-*grade* and below-*grade floors*, separate blocks shall be created for each. For *buildings* with *floors* partially above-*grade* and partially below-*grade*, if the total *wall* area of the floor(s) in consideration is greater than or equal to 50% above-*grade*, then it shall be simulated as a completely above-*grade* block, otherwise it shall be simulated as a below-*grade* block.

e. In order to combine multiple *floors* into a single block, each *wall* on a façade of a block shall have similar *vertical fenestration area*. The product of the *proposed design U-factor* times the area of vertical *fenestration* (UA_{VerFen}) on each façade of a given floor cannot differ by more than 15% of the average UA_{VerFen} for that façade in each block. The product of the *proposed design SHGC* times the area of vertical *fenestration* ($SHGCA_{VerFen}$) on each façade of a given floor cannot differ by more than 15% of the average $SHGCA_{VerFen}$ for that façade in each block. If these conditions are not met, additional blocks shall be created consisting of *floors* with similar *fenestration*.

f. For a *building* model with multiple blocks, each block façade input shall provide adequate information to identify the outside boundary condition (outside, inside to adjacent block, ground contact, or adiabatic) of each façade or portion of each façade that match the actual *proposed design*.

Informative Note:

The *simulation program* may automatically identify the adjacent block façade outside boundary conditions through a graphic input process.

J2.2.2 Building Envelope Components

Building envelope thermal properties used in the *proposed design* shall be based on the actual *proposed design* using documented user-defined values and shall comply with all of the following:

a. Where different *roof* thermal properties are present in a single block, an area-weighted *U-factor* shall be used.
b. Where different *wall* constructions exist on the façade of a block an area-weighted *U-factor* shall be used.
c. Where different *below-grade wall* constructions exist in a block, an area-weighted *C- factor* shall be used.
d. Where different *floor* constructions exist in the block an area-weighted *U-factor* shall be used.
e. Where different *slab-on-grade floor* constructions exist in a block, an area-weighted *F-factor* shall be used.
f. Where different vertical *fenestration* types or sill heights exist, area-weighted sill heights, *U-factor* and *SHGC* values shall be used.
g. Where different *skylight* types exist, area-weighted *U-factor* and *SHGC* values shall be used.
h. Permanent shading devices such as overhangs shall be modeled only if >50% of the area of vertical *fenestration* on a façade is shaded by the same.

J2.2.3 HVAC System Components

The *HVAC system* parameters shall be provided for the *proposed design* with clarifications and simplifications as described in Table J2.2.3 and as follows:

a. All *HVAC zones* within a block shall be served by the same *HVAC system* type as listed in Table J1.1.1.
b. Where multiple *system* components serve a block, average values weighed by the appropriate metric as described in Section J2.2.3.1 shall be used.

Informative Note:

Table J2.2.3 includes both user-defined parameters and parameters that are fixed in the *simulation program* and may not be changed by the user. They are maintained in one table here so related items are together.

Table J2.2.3: Proposed Building HVAC System Parameters

Category	Parameter	Fixed or User Defined	Required
HVAC System Type	*System* Type	User-defined	Selected from Table J1.1.1
System Sizing	Design Day Information	Fixed	99.6% heating design and 1% dry-bulb and 1% wet-bulb cooling design
	Zone Coil Capacity	Fixed	Sizing factors used are 1.25 for heating *equipment* and 1.15 for cooling *equipment*
	Supply Airflow	Fixed	Based on the greater of a supply-air-to-room-air temperature *set point* difference of 20°F (11°C) or required *outdoor air ventilation*
Outdoor *Ventilation* Air and Filtration	Portion of supply air with proposed Filter ≥MERV 13	User-defined	Percentage of supply air flow subject to higher filtration (Adjusts Reference Fan Power higher. prorated)
	Outdoor *Ventilation* Supply Air Flow Rate Adjustments	Fixed	Basis is 1.0 Zone Air Distribution Effectiveness

Category	Parameter	Fixed or User Defined	Required
	Outdoor *Ventilation* Supply Air Flow Rate	Fixed	As specified in ASHRAE Standard 90.1 Normative Appendix C, adjusted for proposed *DCV control* (see separate item below)
System Operation	*Space* Temperature *Set Points*	Fixed	As specified in ASHRAE Standard 90.1 Normative Appendix C with the exception of hotel/motel that shall be 70°F (21°C) heating 72°F (22°C) cooling
	Fan Operation – Occupied (where DOAS meets *ventilation* requirements)	User-defined	Fan either 1) runs continuously during occupied hours or 2) is cycled to meet thermal load
	Fan Operation – Occupied (where heating and cooling units provide *ventilation* – No DOAS)	Fixed	Fan runs continuously during occupied hours; *VAV* or multi-speed fans reduce airflow related to thermal load
	Fan Operation -Night Cycle	Fixed	Fan cycles on to meet *setback* temperatures
Packaged *Equipment Efficiency*	DX Cooling *Efficiency*	User-defined	Cooling *COP* without fan *energy* calculated in accordance with Section J4.2.3(d).
	DX Coil Number of Stages	User-defined	Single Stage or Multistage
	Heat Pump *Efficiency*	User-defined	Heating *COP* without fan *energy* calculated in accordance with Section J4.2.3(d).
	Furnace *Efficiency*	User-defined	Furnace thermal *efficiency*
Heat Pump Supplemental Heat	Control	Fixed	Supplemental electric heat locked out above 40°F (4°C) OAT. Runs In conjunction with compressor between 40°F (4°C) and 0°F (-17.8°C).
System Fan Power and control	Design Fan Power (W/cfm) (W·s/L)	User-defined	Input electric power for all fans required to operate at *fan system design conditions* divided by the supply airflow rate. Include any VSD losses at design condition. This is a “wire to air” value including all drive, motor *efficiency* and other losses.
	Part-load Fan Controls: -Constant volume -Two Speed, then input: W/cfm (W·s/L) at low speed % cfm (% L/s) at low speed -*VAV*	User-defined	Static pressure reset included for *VAV*.
Variable-air-volume system Systems	Supply Air Temperature Controls (select): -None -OAT SAT reset -Warmest zone SAT reset	User-defined	If not SAT reset then constant at 55°F (12.8°C). Options for reset based on OAT or warmest Zone. If OAT reset, SAT is reset higher to 60°F (15.6°C) at outdoor low of 50°F (10°C). SAT is 55°F (12.8°C) at outdoor high of 70°F (21.1°C). If warmest zone, then the user can specify the minimum and maximum temperatures.
	Zone minimum damper & Evs 62.1 simple method except for Schools	Fixed	Schools: Zone minimum = 1.2 * Voz minimum design *ventilation* rate; Evs = 0.65 Other *buildings*: Simple 62.1 method is 1.5 * Voz cfm zone minimum design *ventilation* rate; Evs = 0.75
	Dual *set point* minimum *VAV* damper position	User-defined	Heating minimum and maximum airflow fraction
	Terminal Unit Heating Source	User-defined	Electric or hydronic
	Fan Powered Terminal Unit Type	User-defined	Series or parallel FPTU
	Parallel FPTU Fan		Sized for 50% peak primary air at 0.35 W/cfm (0.74 W·s/L)
	Series FPTU Fan	Fixed	Sized for 50% peak primary air at 0.35 W/cfm (0.74 W·s/L)

Category	Parameter	Fixed or User Defined	Required
Economizer	OSA Economizer Presence	User-defined	Yes or No
	Economizer High Limit	Fixed	Lockout on Differential dry-bulb temperature (OAT > RAT) in 6A, 5A, All B & C climate zones; fixed enthalpy >28 Btu/lb (47 kJ/kg) or fixed drybulb OAT > 75°F (24°C) in 0A to 4A climate zones
Energy Recovery	Sensible Effectiveness	User-defined	Heat exchanger sensible effectiveness at design heating and cooling conditions
	Latent Effectiveness	User-defined	Heat exchanger latent effectiveness at design heating and cooling conditions
	Bypass SAT *Set point*	User-defined	If bypass, target supply air temperature
	Fan Power Reduction when in Bypass	User-defined	If bypass, specify fan power reduction (W/CFM)
Demand Controlled *Ventilation*	*DCV* Application on/off	User-defined	Percentage of block floor area under occupied standby controls, ON/OFF only (See Section 6.5.3.8) with no variable control
	DCV Application CO_2	User-defined	Percentage of block floor area under variable *DCV* control (CO^2); may include both variable and ON/OFF control
DOAS	DOAS Fan Power W/cfm	User-defined	Fan electrical input power in W/cfm of supply airflow
	DOAS Supplemental Heating and Cooling	User-defined	Heating source, cooling source
	Maximum SAT *Set point* (Cooling)	User-defined	SAT *set point* if DOAS includes supplemental cooling
	Minimum SAT *Set point* (Heating)	User-defined	SAT *set point* if DOAS includes supplemental heating
Heating Plant	*Boiler Efficiency*	User-defined	*Boiler* thermal *efficiency*
	Heating Water loop Configuration	User-defined	Variable flow primary only; Variable flow primary & secondary; Constant flow primary – variable flow secondary
	Heating Water Primary *Pump* Power (W/gpm) (W·s/L)	User-defined	Heating water constant primary *pump* input W/gpm (W·s/L) heating water flow
	Heating Water Secondary *Pump* Power (W/gpm) (W·s/L)	User-defined	Heating water variable secondary *pump* input W/gpm (W·s/L) heating water flow (if primary/secondary)
	Heating Water Loop Temperature	User-defined	Heating water supply and return temperatures, °F (°C)
	Heating Water Temperature Reset Included	User-defined	Yes/No
	Heating Water Loop Supply Temperature Reset	Fixed	Reset HWS by 27.3% of design delta-T (HWS – 70°F (21.1°C) *Space* Heating temperature *set point*) between 20°F (-6.7°C) and 50°F (10°C) OAT
	Boiler Type	Fixed	Regular where input thermal *efficiency* is less than 86%; Condensing *boiler* otherwise
Chilled Water Plant	Chiller Condenser Type	User-defined	Air-cooled or water-cooled; For water-cooled: positive displacement or centrifugal
	Chiller Full Load *Efficiency*	User-defined	Chiller *COP*
	Number of chillers	User-defined	In simulation, chillers will be sized equally with 1 – 3 chillers
	Chilled water coil design delta-T	User-defined	Chilled water supply temperature and chilled water return temperature at design conditions
	Chilled Water loop Configuration	User-defined	Variable flow primary only, constant flow primary – variable flow secondary
	Chilled Water Primary *Pump* Power (W/gpm) (W·s/L)	User-defined	Primary *pump* input W/gpm (W·s/L); chilled water flow

Category	Parameter	Fixed or User Defined	Required
	Chilled Water Secondary *Pump* Power (W/gpm) (W·s/L)	User-defined	Secondary *Pump* input W/gpm (W·s/L); chilled water flow (if primary/secondary)
	Chilled Water Temperature Reset Included	User-defined	Yes/No
	Chilled Water Temperature Reset Schedule	Fixed	*Outdoor air* reset: Use input chilled water supply temperature at 80°F *outdoor air* dry bulb and above, chilled water supply temperature add 10°F (-12.2°C) at 60°F (15.6°C) *outdoor air* dry bulb temperature and below, ramped linearly between
Condenser Loop	Condenser Water *Pump* Power (W/gpm) (W·s/L)	User-defined	*Pump* input W/gpm (W·s/L) condenser water flow
	Condenser Water *Pump* Control	Fixed	Constant speed, one *pump* per chiller
Cooling Tower	Cooling Tower *Efficiency*	User-defined	gpm/hp (1000L/s·*kW*) tower fan, as defined in Table 6.8.1-7
	Cooling Tower Flow Turndown	Fixed	Turn down to 50% flow
	Cooling Tower Fan Control	User-defined	Constant or variable speed
	Cooling Tower Approach and Range	User-defined	Design cooling tower approach and range temperature
Heat Pump Loop	Loop flow and Heat Pump Control Valve	Fixed	Two position valve with VSD on *Pump*.
	Heat Pump Loop Flow Control	Fixed	Loop flow at 3 gpm/ton (0.054 L/s·*kW*)
	Heat Pump Loop Temperature Control	User-defined	User input based on fluid cooler and *boiler* size; restrict to minimum 20°F (11°C) temperature difference, with maximum temperature difference at 40°F (22°C)
GLHP Bore Field		Fixed	Bore depth = 250 ft (76.2 m).; Bore length 200 ft/ton (17.3 m/*kW*) for greater of cooling or heating load Bore spacing = 15 ft (4.6 m). Bore diameter = 5 in (127 mm) with ¾ in (25 mm) nominal diameter polyethylene pipe Ground and grout conductivity = 4.8 Btu·in/h·ft^2·°F (0.69 W/m·°C)

J2.2.3.1 Proposed Building HVAC System Aggregation

Projects using the Mechanical *System* Performance Method shall comply with all the following requirements.

a. Where multiple fan *systems* serve a single block, fan power shall be based on weighted average using the design supply air cfm (L/s).

b. Where multiple cooling *systems* serve a single block, COP shall be based on a weighted average using cooling capacity. DX coils shall be entered as multi-stage if more than 50% of coil capacity serving the block is multi-stage with staged controls.

c. Where multiple heating *systems* serve a single block, thermal *efficiency* or heating COP shall be based on a weighted average using heating capacity.

d. Where multiple *boiler*s or chillers serve a heating water or chilled water loop, *efficiency* shall be based on a weighted average for using heating or cooling capacity.

e. When multiple cooling towers serving a condenser water loop are combined, the cooling tower *efficiency*, cooling tower design approach and design range are based on a weighted average of the design water flow rate through each cooling tower.

f. Where multiple *pump*s serve a heating water, chilled water or condenser water loop, *pump* power shall be based on a weighted average for using design water flow rate.

g. When multiple *system* types with and without economizers are combined, the economizer maximum outside air fraction of the combined *system* shall be based on weighted average of 100% supply air for *systems* with economizers and design *outdoor air* for *systems* without economizers.

h. Multiple *systems* with and without ERVs cannot be combined.

i. *Systems* with and without supply air temperature reset cannot be combined.

j. *Systems* with different fan control (constant volume, multi-speed or *VAV*) for supply fans cannot be combined.

J3 SIMULATION PROGRAM

The *simulation program* shall have the following capabilities:

J3.1 Calculation of the TSPR

The *simulation program* shall calculate both the $TSPR_p$ and $TSPR_r$ based only on the input for the *proposed design* and the requirements of this Appendix. The calculation procedure shall not allow the user to directly modify the *building* component characteristics of the *TSPR reference building design* nor the HVAC parameters identified as fixed input in Table J2.2.3.

J3.2 TSPR Simulation Program

All components of the *proposed design* for blocks served by *HVAC systems* using this method shall be explicitly modeled by the *simulation program*. The *code official* shall be permitted to approve a *simulation program* for a specified application or limited scope.

J3.2.1 Minimum Capability

The *simulation program* shall be approved by the *code official* and shall, at a minimum, have the ability to explicitly model all of the following:

a. 8760 hours per year.

b. Hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat set points*, and *HVAC system* operation, defined separately for each day of the week and holidays.

c. Thermal mass effects.

d. Ten or more *thermal blocks*.

e. Part-load performance curves for mechanical *equipment*.

f. Capacity and *efficiency* correction curves for *mechanical heating* and *mechanical cooling equipment*.

g. Air economizers with integrated control.

h. The *energy* use of all *HVAC system* types included in the analysis and *energy* impact from all related fixed and user inputs in Table J2.2.3.

i. Ability to automatically generate the *TSPR reference building design* as specified in Section J4.3

Informative Note

The *simulation program* shall include clear prompts or accessible help topic references defining specific parameters and units for all required *building* and *system* characteristic inputs.

J3.2.2 TSPR Determination

The *simulation program* shall have the ability to either directly determine the $TSPR_p$ and $TSPR_r$ or produce hourly and annual reports of *energy* use by each *energy* source suitable for determining the $TSPR_p$ and $TSPR_r$ using a separate calculation.

J3.2.3 Load Calculations

The *simulation program* shall be capable of performing design load calculations to determine required HVAC *equipment* capacities and air and water flow rates in accordance with Section 6.4.2.1 for both the *proposed design* and *TSPR reference building design*.

J3.2.4 Testing

The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the *simulation program* alongside the results of the other *simulation programs* included in ASHRAE Standard 140 Annexes B8 and B16. The modeler report in Standard 140 Annex A2 Attachment A2.7 shall be completed for results exceeding the maximum or falling below the minimum of the reference values or for missing results.

Informative Note

There are no pass/fail criteria established by this requirement.

J3.3 Climatic Data

Climatic Data shall meet the requirements of Section G2.3.

J3.4 Compliance Report

The *simulation program* shall generate a report that includes the following:

a. Address of the *building*.
b. Name of individual completing the compliance report.
c. Name and version of the compliance *simulation program* and the edition of Standard 90.1 the *simulation program* method complies with.
d. The dimensions, floor heights and number of *floors* for each block.
e. By block, the *U-factor*, *C-factor*, or *F-factor* for each simulated *opaque building envelope* component and the *U-factor* and *SHGC* for each *fenestration* component.
f. By block or by surface for each block, the *fenestration* area and total area of each *opaque building envelope* component
g. By block, a list of the HVAC *equipment* simulated in the *proposed design* including the *equipment* type, fuel type, rated *equipment efficiencies*, rated capacities and *system* control parameters.
h. Annual site HVAC *energy* use by end use for the *proposed design* and *TSPR reference building design.*
i. Annual sum of hourly heating and cooling loads for the *TSPR reference building design.*
j. The HVAC *total system performance ratio* for both the *TSPR reference building design* and the *proposed design* and compliance result in accordance with Section 6.6.2.2.

J4 CALCULATION PROCEDURE

Except as specified by this appendix, the *TSPR reference building design* and *proposed design* shall be configured and analyzed using identical methods and techniques.

J4.1 Simulation of the Proposed Design (Non-HVAC)

The *proposed design* non-HVAC *systems* shall be configured and analyzed as specified in this section. At a minimum, the *simulation program* shall support the *building* use types included in the analysis. The allowed *building* use types are listed in Section J1.1.1.1.

J4.1.1 Simplified Block Approach

The *simulation program* shall model the *building* using one or more simplified geometric simulation *building* blocks, described in Section J2.1. Each block contains one or multiple *thermal blocks*. The *simulation program* shall provide for simplified input described in Section J2.2 and allow for multiple block simulation.

J4.1.2 Thermal Zoning

Each *floor* in a block shall be modeled as a single *thermal block* or as five *thermal blocks* consisting of four perimeter zones and a core zone. Below-*grade floors* shall always be modeled as a single block. If any façade in the block is less than 45 ft (13.7 m) in length, there shall only be a single *thermal block* per *floor*. Otherwise each *floor* shall be modeled with five *thermal blocks*. A perimeter zone shall be created extending from each façade to a default depth of 15 ft (4.6 m) with a user input range of 8 to 20 ft (2.4 to 6.1 m). Where facades intersect, the zone boundary shall be formed by a 45° angle with the two facades. The remaining area or each *floor* shall be modeled as a core zone with no exterior *walls*.

J4.1.3 Building Use Type

The *building* use type for each block shall be consistent with the *proposed design* and allowed *building* use types in Section J1.1.1.1. The occupant density, heat gain, and schedule shall be as specified by Normative Appendix C.

J4.1.6 Building Envelope Components

Building envelope thermal properties used in the *proposed design* shall be modeled based on the actual *proposed design* using inputs described in Section J2.2.2 and shall comply with all of the following:

a. *Roofs* shall be modeled with insulation above a steel *roof* deck. *Roof* solar absorbtance shall be modeled at 0.70 and thermal *emittance* at 0.90.

b. *Above-grade walls* shall be modeled as steel frame construction.

c. Above-*grade* exterior floors shall be modeled as steel frame construction.

d. The area, *U-factor* and *SHGC* of vertical *fenestration* shall be modeled for each façade based on the actual *proposed design*. The *simulation program* shall model a combined single window centered on each façade based on the area and sill height input by the user.

e. The *skylight* area shall be modeled for each *roof* based the actual *proposed design*. *Skylights* shall be combined into a single *skylight* centered on the *roof* of each zone based on the area input by the user.

J4.1.7 Lighting

For each block the interior *lighting power density* shall be equal to the applicable allowance in Table 9.5.1 based on the assigned *building* use type. The Lighting profile schedule shall be for the applicable *building* use type as specified by Normative Appendix C. The impact of lighting controls is assumed to be captured by the lighting schedule and no explicit controls (including daylighting controls) shall be modeled. Exterior lighting shall not be modeled.

J4.1.8 Miscellaneous Equipment

The miscellaneous *equipment* schedule and power shall be based on the assigned *building* use type as specified by Normative Appendix C. The impact of miscellaneous *equipment* controls is assumed to be captured by the *equipment* schedule and no explicit controls shall be modeled.

J4.1.9 Elevators

Elevators shall not be modeled.

J4.1.10 Service Water Heating Equipment

Service water heating shall not be modeled.

J4.1.11 On-site Renewable Energy Systems

On-site renewable energy systems shall not be modeled.

J4.2 Simulation of the Proposed Design (HVAC)

The *proposed design HVAC systems* shall be configured and analyzed as specified in this section.

J4.2.1 HVAC Equipment

The *simulation program* shall analyze the *control* parameters that meet the mandatory requirements of Section 6.4 and the parameters provided by the user or specified as fixed in Section J2.2.3 as applicable for each *HVAC system* included in the *proposed design*.

J4.2.2 Supported HVAC Systems

The *HVAC systems* included in the *proposed design* and the *TSPR reference building design* shall be supported by the *simulation program. HVAC systems* permitted are limited to those shown in Table J1.1.1. The *simulation program* shall support multiple blocks being served by one central *system*.

J4.2.3 Proposed Building HVAC System Simulation.

The *HVAC systems* shall be modeled as in the *proposed design* with clarifications and simplifications as described in Table J2.2.3 and the following rules:

a. *System* parameters not described in Table J2.2.3 and the following sections shall be simulated to meet the minimum requirements of Section 6.4.

b. Where multiple *system* components serve a block, average values weighed by the appropriate metric as described in Section J2.2.3.1 shall be used.

c. Heat loss from ducts and pipes shall not be modeled.

d. Where a full- and part-load *efficiency* rating is provided in Tables 6.8.1-1 through 6.8.1-4, the full-load equation below shall be used:

1. For packaged single-zone air conditioners (cooling only), water-loop heat pumps, ground-source heat pumps and packaged rooftop heat pumps:

$$COP_{nfheating} = 1.48E\text{-}7 \times COP_{47} \times Q + 1.062 \times COP_{47}$$

$$(COP_{nfheating} = 5.05E\text{-}4 \times COP_{H8.3} \times Q + 1.062 \times COP_{H8.3})$$

$$COP_{nfheating} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF$$

$$(COP_{nfheating} = -0.3446 \times SCOP_H^2 + 2.434 \times SCOP_H)$$

$$COP_{nfcooling} = 7.84E\text{-}8 \times EER \times Q + 0.338 \times EER$$

$$(COP_{nfcooling} = 9.13E\text{-}4 \times COP_C \times Q + 1.15 \times COP_C)$$

$$COP_{nfcooling} = -0.0076 \times SEER^2 + 0.3796 \times SEER$$

$$(COP_{nfcooling} = -0.0885 \times SCOP_C^2 + 1.295 \times SCOP_C)$$

2. *Packaged terminal heat pumps*

$COP_{nfcooling} = 0.3322 \times EER - 0.2145$

$(COP_{nfcooling} = 9.13E\text{-}4 \times COP_C \times Q + 1.15 \times COP_C)$

$COP_{nfheating} = 1.1329 \times COP - 0.214$

$(COP_{nfheating} = 1.1329 \times COP - 0.214)$

3. *Packaged terminal air conditioners*

$COP_{nfcooling} = 0.3322 \times EER - 0.2145$

e. Part-load fan and *pump* power shall be calculated using a cubic function with coefficients as shown in Table J4.2.3-1. The independent variable shall be the fraction of design water flow rate for *pump*s and the fraction of design air flow rate for fans as shown in Figure J4.2.3-1.

f. *Demand Controlled Ventilation (DCV*) shall be modeled using a simplified approach that adjusts the design outdoor supply air flow rate based on the area of the *building* that is covered by *DCV* with coefficients as shown in Table J4.2.3-2. The input shall accommodate two types of *DCV*:
   1. Variable control based on people sensor response (CO_2 sensor or other)
   2. On/Off occupied standby *control* that closes the *VAV* box primary air damper or shuts off *outdoor air* when the zone is completely unoccupied based on an occupancy sensor (See: Section 6.5.3.8).

Informative Note:

Due to lower probability occurrence, the On/Off controls are given 1/3 the reduction of the CO_2 sensor *DCV*. The OSA reduction factor shall be based on a smaller area of *control* being applied to higher density *spaces* first—adjusted for *building* type, with OSA reduction factors and an application formula as shown.

For Office, School, and Retail:

DCV effective controlled Floor Area =

$$Area_{VarDCV} + 1/3 * Area_{ON\text{-}OFF} \text{ AND } Area_{ON\text{-}OFF} < 1 - Area_{VarDCV}$$

For Hotel, Motel, Dormitory, and Multi-family:

DCV effective controlled Floor Area =

$$Area_{VarDCV} + Area_{ON\text{-}OFF}$$

Where:

$Area_{VarDCV}$ = Fraction of block floor area with variable sensor-based *DCV control*

$Area_{ON\text{-}OFF}$ = Fraction of block floor area with only occupied standby *control* as defined in Section 6.5.3.8 that does not also have variable sensor-based *demand controlled ventilation.*

Table J4.2.3-1 Fan and Pump Power Curve Coefficients

Fan Power Coefficients	*Pump* Power Coefficients

Equation Term	VSD + SP reset	Ride *Pump* Curve	VSD + DP/valve reset
b	0.0408	0	0
x	0.088	3.2485	0.0205
x^2	-0.0729	-4.7443	0.4101
x^3	0.9437	2.5295	0.5753

Figure J4.2.3-1 Fan and Pump Power Performance as a Function of Design Water or Air Flow

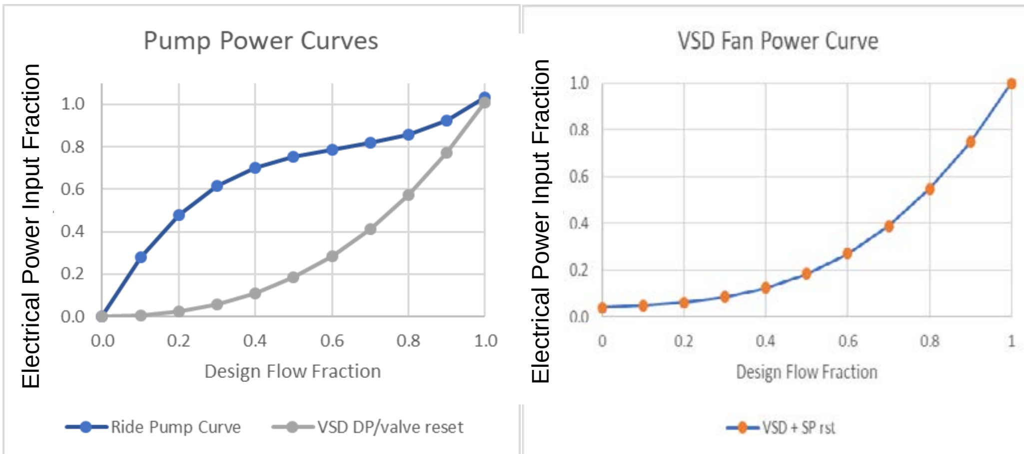
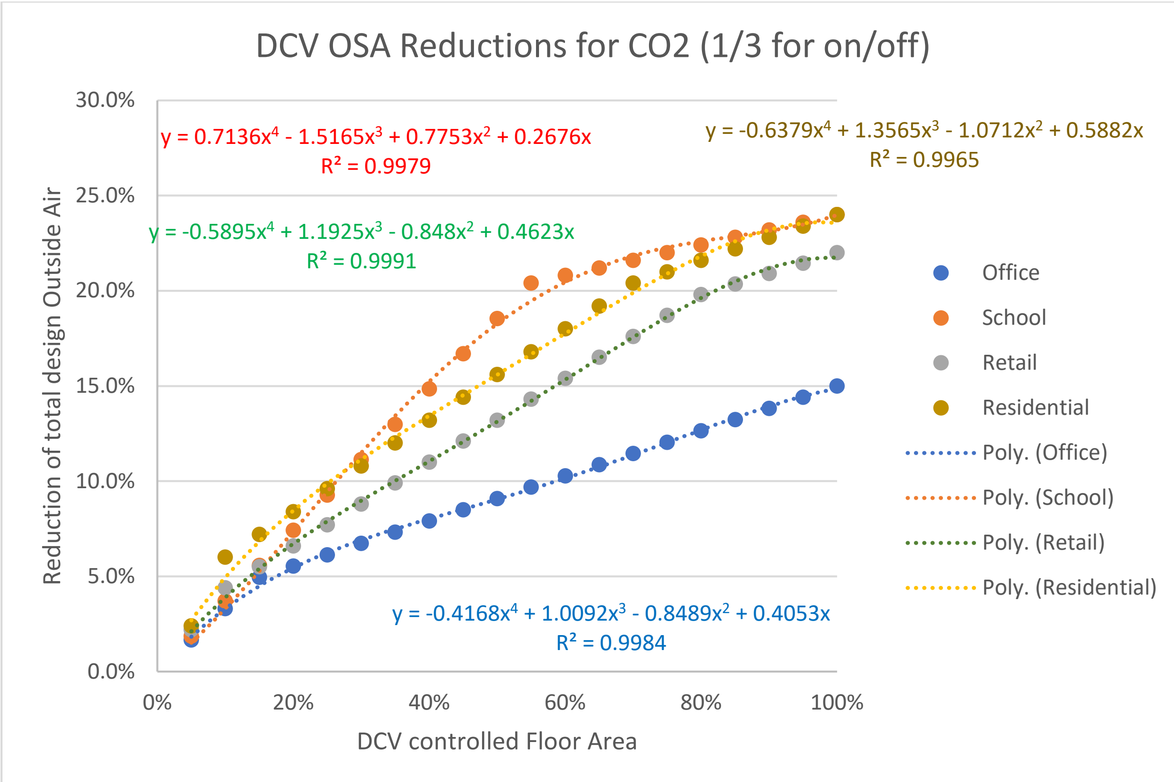


Table J4.2.3-2 DCV Outdoor Air Reduction Curve Coefficients

Equation Term	*DCV* OSA reduction (y) as a function of effective *DCV* control area (x)			
	Office	School	Hotel; Motel; Multi-Family; Dormitory	Retail
b	0	0	0	0
x	0.4053	0.2676	0.5882	0.4623
x^2	-0.8489	0.7753	-1.0712	-0.848
x^3	1.0092	-1.5165	1.3565	1.1925
x^4	-0.4168	0.7136	-0.6379	-0.5895

Figure J4.2.3-2 DCV OSA Reduction as a Function of Controlled Floor Area



J4.3 Simulation of the TSPR Reference Building Design.

The *TSPR reference building design* shall be configured and analyzed as specified in this section.

J4.3.1 Non-HVAC Inputs

Utility rates, blocks, *HVAC zones*, *building* use types, schedules, occupant density, heat gains, *building envelope* components, lighting power, and miscellaneous *equipment loads* shall be modeled the same as in the *proposed design.*

Elevators, *service water-heating equipment*, and *on-site renewable energy systems* shall not be modeled; same as in the *proposed design*.

J4.3.2 HVAC Equipment.

The *TSPR reference building design* HVAC *equipment* consists of separate *space* conditioning *systems* and dedicated *outdoor air systems* as described in Table J4.3.2-1 through Table J4.3.2-3 for the appropriate *building* use types. In these tables, 'Warm' refers to climate zones 0 to 2 and 3A and 'Cold' refers to climate zones 3B, 3C, and 4 to 8.

Table J4.3.2-1 - TSPR Reference Building Design HVAC Complex Systems

Building Type Parameter	Large Office (warm)	Large Office (cold)	School (warm)	School (cold)
System Type	*VAV*/ RH Water-cooled Chiller/ Electric Reheat (PIU)	*VAV*/ RH Water-cooled Chiller/ *Gas Boiler*	*VAV*/ RH Water-cooled Chiller/ Electric Reheat (PIU)	*VAV*/ RH Water-cooled Chiller/ *Gas Boiler*
Fan control	VSD	VSD	VSD	VSD
Main fan power (W/CFM (W·s/L) Proposed ≥ MERV13	1.165 (2.485)	1.165 (2.485)	1.165 (2.485)	1.165 (2.485)

Building Type Parameter	Large Office (warm)	Large Office (cold)	School (warm)	School (cold)
Main fan power (W/CFM (W·s/L) proposed < MERV13	1.066 (2.274)	1.066 (2.274)	1.066 (2.274)	1.066 (2.274)
Zonal fan power (W/CFM (W·s/L))	0.35 (0.75)	NA	0.35 (0.75)	NA
Minimum zone airflow fraction	1.5* Voz	1.5* Voz	1.2* Voz	1.2 * Voz
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Outdoor air economizer	No	Yes except 4A	No	Yes except 4A
Occupied OSA (= proposed)	Sum(Voz)/0.75	Sum(Voz)/0.75	Sum(Voz)/0.65	Sum(Voz)/0.65
Energy recovery ventilator *efficiency* ERR (Enthalpy Recovery Ratio) ERV bypass SAT *set point*	NA	NA	50% No Bypass	50% 60°F except 4A
DCV	No	No	No	No
Cooling Source	(2) Water-cooled Centrif Chillers	(2) Water-cooled Centrif Chillers	(2) Water-Cooled Screw Chillers	(2) Water-Cooled Screw Chillers
Cooling *COP* (net of fan)	Path B for profile	Path B for profile	Path B for profile	Path B for profile
Heating source (reheat)	*Electric resistance*	Gas *Boiler*	*Electric resistance*	Gas *Boiler*
Furnace or *boiler efficiency*	1.0	75% Et	1.0	80% Et
Condenser heat rejection	Cooling Tower	Cooling Tower	Cooling Tower	Cooling Tower
Cooling tower *efficiency* (gpm/hp (L/s·*kW*))—See G3.1.3.11	38.2 (3.23)	38.2 (3.23)	38.2 (3.23)	38.2 (3.23)
Tower turndown (> 300 ton (1060 *kW*))	50%	50%	50%	50%
Pump (constant flow/variable flow)	Constant Flow; 10°F (5.6°C) range	Constant Flow; 10°F (5.6°C) range	Constant Flow; 10°F (5.6°C) range	Constant Flow; 10°F (5.6°C) range
Tower approach	G3.1.3.11	G3.1.3.11	G3.1.3.11	G3.1.3.11
Cooling condenser *pump* power (W/gpm (W·s/L))	19 (300)	19 (300)	19 (300)	19 (300)
Cooling primary *pump* power (W/gpm (W·s/L))	9 (142)	9 (142)	9 (142)	9 (142)
Cooling secondary *pump* power (W/gpm (W·s/L))	13 (205)	13 (205)	13 (205)	13 (205)
Cooling coil chilled water delta-T, °F (°C)	12 (6.7)	12 (6.7)	12 (6.7)	12 (6.7)
Design chilled water supply temperature, °F (°C)	44 (6.7)	44 (6.7)	44 (6.7)	44 (6.7)
Chilled water supply temperature (CHWST) reset *set point* vs OAT, °F (°C)	CHWST/OAT: 44-54/ 80-60 (6.7-12.2/ 26.7-15.6) (see Apx G)	CHWST/OAT: 44-54/ 80-60 (6.7-12.2/ 26.7-15.6) (see Apx G)	CHWST/OAT: 44-54/ 80-60 (6.7-12.2/ 26.7-15.6) (see Apx G)	CHWST/OAT: 44-54/ 80-60 (6.7-12.2/ 26.7-15.6) (see Apx G)
CHW cooling loop *pump*ing control	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD
Heating *pump* power (W/gpm (W·s/L))	16.1 (254)	16.1 (254)	19 (254)	19 (254)
Heating oil HW dT. °F (°C)	50 (10)	50 (10)	50 (10)	50 (10)
Design HWST. °F (°C)	180 (82)	180 (82)	180 (82)	180 (82)
HWST reset *set point* vs OAT, °F (°C)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)
Heat loop *pumping* control	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD

Table J4.3.2-2 - TSPR Reference Building Design HVAC Simple Systems 1

Building Type Parameter	Medium Office (warm)	Medium Office (cold)	Small Office (warm)	Small Office (cold)	Retail (warm)	Retail (cold)
System type	Package *VAV* - Electric Reheat	Package *VAV* - Hydronic Reheat	PSZ-HP	PSZ-AC	PSZ-HP	PSZ-AC
Fan control	VSD	VSD	Constant Volume	Constant Volume	Constant Volume	Constant Volume
Main fan power (W/CFM (W·s/L)) proposed ≥ MERV13	1.285 (20.29)	1.285 (20.29)	0.916 (14.46)	0.916 (14.46)	0.899 (14.19)	0.899 (14.19)
Main fan power (W/CFM (W·s/L)) proposed < MERV13	1.176 (18.59)	1.176 (18.59)	0.850 (13.42)	0.850 (13.42)	0.835 (13.42)	0.835 (13.42)
Zonal fan power (W/CFM (W·s/L))	0.35 (5.53)	NA				
Minimum zone airflow fraction	30%	30%	NA	NA	NA	NA
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental heating availability	NNAA	NANA	<40°F (<4.4°C) OAT	NANA	<40°F (<4.4°C) OAT	NNAA
Outdoor air economizer	No	Yes except 4A	No	Yes except 4A	No	Yes except 4A
Occupied OSA source	Packaged unit, occupied damper, all *building* use types					
Energy recovery ventilator	No	No	No	No	No	No
DCV	No	No	No	No	No	No
Cooling source	DX, multi-stage	DX, multi-stage	DX, 1 stage (heat pump)	DX, single stage	DX, 1 stage (heat pump)	DX, single stage
Cooling *COP* (net of fan)	3.40	3.40	3.00	3.00	3.40	3.50
Heating source	*Electric resistance*	Gas *Boiler*	Heat Pump	Furnace	Heat Pump	Furnace
Heating *COP* (net of fan) / furnace or *boiler efficiency*	1.0	75% E_t	3.40	80% E_t	3.40	80% E_t

Table J4.3.2-3 - TSPR Reference Building Design HVAC Simple Systems 2

Building Type Parameter	Hotel (warm)	Hotel (cold)	Multifamily (warm)	Multifamily (cold)
System type	*PTHP*	*PTAC*	*PTHP*	*PTAC*
Fan control	Constant Volume	Constant Volume	Constant Volume	Constant Volume
Main fan power (W/CFM (W·s/L))	0.300 (4.74)	0.300 (4.74)	0.300 (4.74)	0.300 (4.74)
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental heating availability	<40°F (<4.4°C)		<40°F (<4.4°C)	
Outdoor air economizer	No	No	No	No
Occupied OSA source	Packaged unit, occupied damper	Packaged unit, occupied damper	Packaged unit, occupied damper	Packaged unit, occupied damper
Energy recovery ventilator	No	No	No	No
DCV	No	No	No	No
Cooling source	DX, 1stage (heat pump)	DX, 1 stage	DX, 1 stage (heat pump)	DX, 1 stage
Cooling *COP* (net of fan)	3.10	3.20	3.10	3.20

Building Type Parameter	Hotel (warm)	Hotel (cold)	Multifamily (warm)	Multifamily (cold)
Heating source	*PTHP*	(2) Hydronic *Boiler*	*PTHP*	(2) Hydronic *Boiler*
Heating *COP* (net of fan) / furnace or *boiler efficiency*	3.10	75% E_t	3.10	75% E_t
Heating *pump* power (W/gpm (W·s/L))	NA	19 (300)	NA	19 (300)
Heating coil heating water delta-T, °F (°C)		50 (27.8)		50 (27.8)
Design HWST, °F (°C)	NA	180 (82.2)	NA	180 (82.2)
HWST reset *set point* vs OAT, °F (°C)		HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)		HWST/OAT: 180/150 20/50 (82-65.6/ -6.7-10)
Heat loop *pump*ing control	NA	2-way Valves & ride *pump* curve	NA	2-way Valves & ride *pump* curve

J5 TSPR METRIC FOR SITE HVAC ENERGY INPUT

For purposes of calculating *TSPR* for the *proposed design* and the *TSPR reference building design*, the calculated HVAC *energy* input of each *building* project *energy* source shall be converted to cost using the *energy* cost prices from Table J5-1.

Table J5-1 Energy Conversion Factors for HVAC Energy Input[a]

Building Project *Energy* Source	Units	*Energy* Cost $/Unit	*Energy* Cost $/ site MMBtu(GJ)	Site *energy* Btu/unit (W·h/unit)
Electricity	kWh	$0.1099	$32.21	3,412
Natural gas	therm *(GJ)*	$0.983 ($9.32)	$9.83 ($9.32)	100,000 (277,778)
Propane	therm (*GJ*)	$0.983 ($9.32)	$9.83 ($9.32)	100,000 (277,778)
Distillate fuel oil	gallon (L)	$1.353 ($0.357)	$9.83 ($9.32)	137,600 (10,651)

a. *Energy* input conversion factors are based on U.S. averages. Non-electric heating prices are based on blended heating prices adjusted for the US average mix of heating fuels. These prices are applied to fuel output per unit.

Informative Note:
The blended heating prices in Table J5-1 that are used for fossil fuels are not intended to represent actual average prices, but to represent a consistent blended price per MMBtu (GJ) used. This will avoid requiring the simulation program to run the reference systems with a fossil fuel type that matches the proposed building. The common price per site fuel Btu (GJ) allows proposed *system efficiency* to be properly compared with the reference *system*.

Informative note:

Tables J5-2 through J5-5 include values for alternate energy input metrics that may be adopted by a jurisdiction. If so, the jurisdiction should replace the *TSPR* "*energy* input" of *energy* **cost** in Section J5 with the alternate metric and should include appropriate metric values from Table J5-2 into Table J5-1. The Jurisdiction should replace the MPF values in Table 6.6.2 with one of the following:

- For carbon emissions, replace Table 6.6.2 MPF values with those in Table J5-3
- For source *energy*, replace Table 6.6.2 MPF values with those in Table J5-4
- For site *energy*, replace Table 6.6.2 MPF values with those in Table J5-5

Table J5-2 Informative Energy Conversion Factors for HVAC Energy Input[a]

Building Project *Energy* Source	Units	Carbon Emissions CO_2e, lb/unit (kg/unit)	Source *Energy* Btu/unit (W·h/unit)
Electricity	kWh	1.418 (0.643)	9,008
Natural gas	therm *(GJ)*	19.960 (85.833)	109,000 (302,778)
Propane	therm (*GJ*)	19.080 (76.367)	115,000 (319,445)
Distillate fuel oil	gallon (L)	28.830 (13.077)	163,744 (12,674)

a. *Energy* input conversion factors are based on ASHRAE Standard 189.1-2020. They represent average United States values and may be replaced with local values.

Table J5-3 Mechanical Performance Factors (MPF), Carbon Emission Basis (Informative)

Climate Zone: *Building* type	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium)[a]	0.75	0.75	0.74	0.74	0.72	0.69	0.75	0.70	0.70	0.76	0.71	0.75	0.80	0.75	0.76	0.82	0.79	0.83	0.85
Office (large)[a]	0.91	0.93	0.94	0.93	0.88	0.94	0.80	0.88	0.94	0.75	0.93	0.78	0.79	0.86	0.78	0.79	0.81	0.77	0.75
Retail	0.61	0.59	0.52	0.56	0.48	0.47	0.43	0.46	0.63	0.52	0.62	0.75	0.55	0.70	0.76	0.57	0.58	0.53	0.48
Hotel/ Motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.69	0.73	0.55	0.64	0.61	0.49	0.55	0.63	0.45	0.48	0.41	0.34
Apartment/ Dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.60	0.55	0.57	0.55	0.49	0.57	0.51	0.44	0.56	0.52	0.53	0.50
School/ Education	0.89	0.89	0.89	0.87	0.83	0.82	0.79	0.79	0.8	0.77	0.85	0.77	0.86	0.84	0.72	0.90	0.84	0.85	0.79

[a] Office sizes defined in Section J1.1.1.1.

Table J5-4 MECHANICAL Performance Factors (MPF), Site Energy Basis (Informative)

Climate Zone: *Building* type	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium)[a]	0.75	0.75	0.74	0.74	0.72	0.69	0.75	0.70	0.72	0.83	0.75	0.82	0.87	0.80	0.84	0.88	0.86	0.89	0.91
Office (large)[a]	0.91	0.93	0.94	0.93	0.88	0.94	0.80	0.88	0.92	0.71	0.88	0.71	0.74	0.79	0.70	0.76	0.75	0.74	0.72
Retail	0.61	0.59	0.52	0.56	0.48	0.47	0.43	0.46	0.64	0.50	0.66	0.80	0.51	0.76	0.79	0.54	0.53	0.48	0.42
Hotel/ Motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.69	0.73	0.45	0.59	0.52	0.38	0.47	0.51	0.35	0.38	0.31	0.26
Apartment/ Dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.60	0.55	0.53	0.50	0.44	0.54	0.47	0.38	0.55	0.50	0.51	0.47
School/ Education	0.89	0.89	0.89	0.87	0.83	0.82	0.79	0.79	0.78	0.80	0.85	0.78	0.91	0.85	0.71	0.96	0.89	0.89	0.82

[a] Office sizes defined in Section J1.1.1.1.

Table J5-5 MECHANICAL Performance Factors (MPF), Source Energy Basis (Informative)

Climate Zone: *Building* type	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium)[a]	0.75	0.75	0.74	0.74	0.72	0.69	0.75	0.70	0.69	0.75	0.71	0.74	0.79	0.74	0.75	0.80	0.78	0.81	0.84
Office (large)[a]	0.91	0.93	0.94	0.93	0.88	0.94	0.80	0.88	0.94	0.76	0.94	0.80	0.80	0.87	0.79	0.80	0.82	0.77	0.75
Retail	0.61	0.59	0.52	0.56	0.48	0.47	0.43	0.46	0.63	0.52	0.61	0.74	0.56	0.69	0.76	0.58	0.58	0.55	0.50
Hotel/ Motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.69	0.73	0.56	0.65	0.63	0.51	0.57	0.65	0.47	0.50	0.43	0.36
Apartment/ Dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.60	0.54	0.58	0.56	0.50	0.57	0.51	0.46	0.56	0.52	0.54	0.51
School/ Education	0.89	0.89	0.89	0.87	0.83	0.82	0.79	0.79	0.80	0.76	0.85	0.77	0.85	0.83	0.73	0.88	0.84	0.84	0.79

[a] Office sizes defined in Section J1.1.1.1.