

Standards 90.1 and 90.4

Meeting Data Center Energy Compliance

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Data centers are unique among commercial buildings because a specific energy standard is dedicated to this classification of building. In response to industry requests, ASHRAE developed and published ANSI/ASHRAE Standard 90.4, *Energy Standard for Data Centers*, in 2016 to create new methods and metrics for demonstrating energy efficiency compliance for data center system designs. This column examines some of the compliance complexities associated with Standard 90.4 and Standard 90.1.

Prior to 2016, ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, was the only means of demonstrating compliance since inclusion of data centers in the 2010 edition. (For details on compliance to the 2010 edition of ASHRAE Standard 90.1, refer to Reference 1.) Standard 90.1-2010 used the power utilization effectiveness (PUE) metric to demonstrate compliance; however, that metric was developed as an operational method of measurement, not design, prior to the data center's being operational. As of the 2019 edition of Standard 90.1, Standard 90.4 is directly referenced as an alternative compliance path, allowing both standards to be adopted by code (International Code Council [ICC]) and referenced within the International Energy Conservation Code (IECC).

Because the 2016 (or earlier) versions of the standards are still in use in most U.S. jurisdictions, both the 2016 and 2019 versions are discussed and compared here.²

Compliance Paths with Standard 90.1

Standard 90.1-2016 lists several compliance paths. Per paragraph 6.2.1, Compliance, all projects must show compliance with Sections 6.2, General; 6.7, Submittals; 6.8, Minimum Equipment Efficiency Tables; and one of the following:

- Section 6.3, Simplified Approach Option of HVAC Systems;
- Section 6.4, Mandatory Provisions and 6.5, Prescriptive Paths;
- Section 6.4, Mandatory Provisions and 6.6, Alternative Compliance Path.

Among the above options, Section 6.5, Prescriptive Path, Paragraph 6.5.1 Economizers, is a prescriptive path that has introduced new challenges to many designers and has often been avoided to minimize operational risk experienced from economizers.³ This topic has been discussed by experts in the data center industry

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at various conferences and data center-specific forums. Certain exceptions exist within the standard for computer rooms (see paragraph 6.5.1, #11 and #12).

Section 6.6, Alternate Compliance Path, paragraph 6.6.1 Computer Room Systems, indicates that HVAC systems serving the heating, cooling or ventilating needs of a computer room shall comply with Sections 6.1, 6.4, 6.6.1.1 or 6.6.1.2, 6.7 and 6.8.

Section 6.6.1.1 states that the PUE1 (an energy *consumption* metric defined in the standard) shall be less than or equal to the values listed in Table 6.6.1.

In turn, Section 6.6.1.2 states that the PUE0 (an energy *demand* metric defined in the standard) shall be less than or equal to the values listed in Table 6.6.1, at both 100% and 50% of the design IT equipment load.

For reference, Standard 90.1-2016 Table 6.6.1 is listed here as *Table 1*. A definition for PUE1 appears in the standard.

Standard 90.1-2019

For Standard 90.1-2019, Table 6.6.1 has been eliminated, and the compliance path under Section 6.6, Alternative Compliance Path, is simply a reference to Standard 90.4.⁴

Standard 90.4-2016

The mechanical system compliance path for Standard 90.4-2016 consisted of achieving both design and energy targets for a calculated entity called the mechanical load component (MLC). There was both a design MLC, which needed to be satisfied at 100% and 50% of information technology equipment (ITE) load (per Table 6.2.1.1) and an annualized MLC, which also had

to be met at 100% and 50% of ITE load (per Table 6.2.1.2). In addition, a limitation existed on electrical infrastructure losses, as defined by a metric called the design electrical loss component (ELC). Section 11 of the standard allows for trade-offs between the MLC and the ELC to achieve overall compliance with the standard.

Standard 90.4-2019

The design MLC is removed from the 2019 version of the standard, and there is only an annualized energy MLC. In recognition that data centers operate with a range of ITE loads, which also vary over time (typically but not always increasing), the MLC annual energy calculation is performed at 25%, 50%, 75% and 100% of the ITE design loads to make sure the system is designed to be efficient over a range of possible ITE operation. Requirements pertaining to the calculation are listed in the new standard, with both binned and TMY3 weather data modeling approaches acceptable.

It is difficult to make a direct comparison between the 2016 and 2019 MLC, partly because the 2016 standard had one set of values for all sizes of data centers, while the 2019 standard differentiates between small and large data centers, with a threshold of 300 kW. For small data centers, the 2019 MLC values are between 14% and 31% lower than the 2016 values, while for large data centers the 2019 values are between 28% and 60% lower, depending on climate zone (*Table 2*).

The ELC looks at electrical losses, but instead of looking at annual energy consumption, it is more of a design loss calculation, with

TABLE 1 ASHRAE Standard 90.1-2016. Maximum PUE (Table 6.6.1 from Standard 90.1-2016).

TOPIC	MAXIMUM POWER USAGE EFFECTIVENESS (PUE1)
	90.1-2016
ASHRAE CLIMATE ZONE	
0A	1.64
0B	1.62
1A	1.61
1B	1.53
2A	1.49
3A	1.41
4A	1.36
5A	1.36
6A	1.34
2B	1.45
3B	1.42
4B	1.38
5B	1.33
6B	1.33
3C	1.39
4C	1.38
5C	1.36
7	1.32
8	1.30

part-load energy efficiency taken into consideration by calculating the ELC at both 100% and 50% of ITE load. The electrical losses are divided into three segments: incoming electrical service, uninterruptible power supply (UPS) and ITE distribution. For the purposes of calculating the ELC, the threshold between a small data center and a large one is 100 kW, rather than 300 kW for the MLC calculations.

For small data centers, the 2019 ELC is between 11% and 19% lower than the 2016 ELC. For large data centers, the ELC is between 8% and 18% lower than in 2016. The adjustment primarily reflects continued improvements in UPS efficiency (*Table 3*).

TABLE 2 ASHRAE Standard 90.4. Comparison of maximum annualized mechanical load component (MLC) values from 2016 to 2019.

TOPIC	SMALL DATA CENTERS (<300 KW)				LARGE DATA CENTERS (>300 KW)			
	90.4-2016	90.4-2019	DIFFERENCE (2016 TO 2019)	PERCENTAGE REDUCTION (2016 TO 2019)	90.4-2016 (SAME AS SMALL)	90.4-2019	DIFFERENCE (2016 TO 2019)	PERCENTAGE REDUCTION (2016 TO 2019)
ASHRAE CLIMATE ZONE								
0A	0.37	0.31	-0.06	16%	0.37	0.25	-0.12	32%
0B	0.40	0.34	-0.06	15%	0.40	0.28	-0.12	30%
1A	0.36	0.31	-0.05	14%	0.36	0.26	-0.10	28%
1B	0.38	0.32	-0.06	16%	0.38	0.27	-0.11	29%
2A	0.35	0.29	-0.06	17%	0.35	0.23	-0.12	34%
3A	0.33	0.27	-0.06	18%	0.33	0.21	-0.12	36%
4A	0.33	0.26	-0.07	21%	0.33	0.18	-0.15	45%
5A	0.33	0.25	-0.08	24%	0.33	0.16	-0.17	52%
6A	0.32	0.24	-0.08	25%	0.32	0.16	-0.16	50%
2B	0.36	0.27	-0.09	25%	0.36	0.17	-0.19	53%
3B	0.35	0.26	-0.09	26%	0.35	0.17	-0.18	51%
4B	0.35	0.24	-0.11	31%	0.35	0.14	-0.21	60%
5B	0.33	0.23	-0.10	30%	0.33	0.14	-0.19	58%
6B	0.34	0.24	-0.10	29%	0.34	0.14	-0.20	59%
3C	0.32	0.23	-0.09	28%	0.32	0.14	-0.18	56%
4C	0.32	0.23	-0.09	28%	0.32	0.14	-0.18	56%
5C	0.32	0.23	-0.09	28%	0.32	0.14	-0.18	56%
7	0.32	0.23	-0.09	28%	0.32	0.14	-0.18	56%
8	0.32	0.22	-0.10	31%	0.32	0.13	-0.19	59%

TABLE 3 ASHRAE Standard 90.4. Comparison of maximum electrical load component (ELC) values from 2016 to 2019.

TOPIC	SMALL DATA CENTERS (<100 KW)				LARGE DATA CENTERS (>100 KW)			
	90.4-2016	90.4-2019	DIFFERENCE (2016 TO 2019)	PERCENTAGE REDUCTION (2016 TO 2019)	90.4-2016	90.4-2019	DIFFERENCE (2016 TO 2019)	PERCENTAGE REDUCTION (2016 TO 2019)
Single Feed UPS (N, N + 1, etc.) or No UPS								
ELC at 100% of IT load	0.297	0.265	-0.032	11%	0.265	0.245	-0.020	8%
ELC at 50% of IT Load	0.265	0.231	-0.034	13%	0.231	0.189	-0.042	18%
Active Dual Feed UPS (2N, 2N + 1, etc.)								
ELC at 100% of IT load	0.265	0.231	-0.034	13%	0.231	0.189	-0.042	18%
ELC at 50% of IT Load	0.302	0.245	-0.057	19%	0.258	0.233	-0.025	10%

Energy Modeling to Achieve Compliance with Standard 90.1 Appendix G and Standard 90.4

For energy models used with Standard 90.1 Appendix G, the specific requirement is that the modeling software comply with ASHRAE Standard 140-2017, *Method of Test for Evaluating Building Performance Simulation Software*.

For Standard 90.4, the 2019 version of the standard does not require specific software but indicates that bin data be used with a maximum of 2°F (1°C)

increments, or that TMY3 data be used. If the data center uses mechanical cooling, the calculated data center conditions (temperature and humidity) must fall within ASHRAE's *Thermal Guidelines for Data Processing Environments*, 4th Edition for at least 8,460 hours per year.

Whether using bin data or a full 8,760-hour energy model, it is vital to use proper equipment performance curves applicable to a wide variety of ambient conditions. Unlike typical cooling comfort applications, the

overall data center cooling load does not fluctuate significantly throughout the year based on envelope gains. It is, therefore, important to obtain part-load performance data for heat rejection equipment assuming fairly constant IT loads but varying outside air temperatures. This information is generally not readily available and often requires several custom selections from equipment vendors.

The U.S. Department of Energy has 16 commercial prototype building models across all U.S. climate zones with the most recent update following Standard 90.1-2019. However, the prototypes do not include data centers. To remedy this deficiency, LBNL recently developed two prototype energy models for data centers.⁵

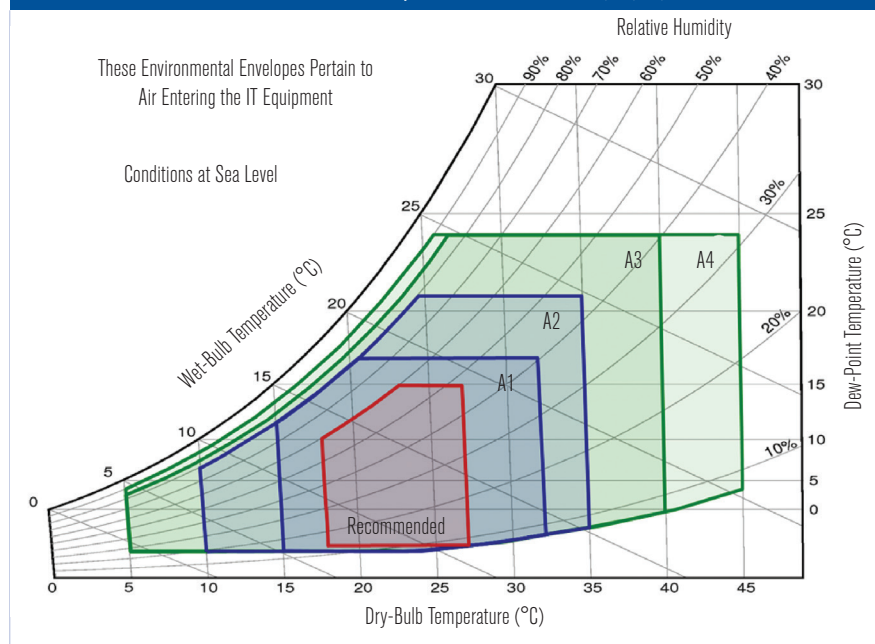
The first model represents a small-size data center with computer room air conditioner (CRAC) units and two levels of ITE load density of 40 W/ft² (431 W/m²) and 100 W/ft² (1076 W/m²). The second model represents a stand-alone large-size data center model with computer room air handler (CRAH) units and two levels of ITE load density of 100 W/ft² (1076 W/m²) and 500 W/ft² (5382 W/m²). All other assumptions (e.g., construction, lighting, schedules and equipment efficiencies) for both models reference corresponding versions of ASHRAE Standard 90.1.

The data center prototype models are a great reference to compare energy codes and standards, but they are limited to their underlying assumptions. For example, the models do not represent all air distribution scenarios, are only applicable to raised flow air distribution case studies, and users can only provide constant inputs of supply/return temperature controls.

Closing Comments

The latest version of Standard 90.1 includes various data center energy compliance paths, one of which is Standard 90.4. The requirements for data center energy efficiency have become more stringent in the 2019 editions for both standards. Data center-specific baseline building models for demonstrating compliance using an annualized energy calculation are now available.

FIGURE 1 2015 recommended and allowable envelopes for ASHRAE Classes A1, A2, A3, and A4.



With this integration of both standards, authorities having jurisdiction (AHJs) can now adopt a holistic solution for data center energy efficiency intended for the design. The age-old challenges of demonstrating compliance with economizers have continued to increase with significantly more stringent compliance target values. However, the added baseline models have created the framework necessary to use wider operating environmental controls (floating point control of the cooling system across a wider psychrometric range (Figure 1, which is Figure 2.3 from *Thermal Guidelines for Data Processing Environments*), which can permit designs without economizers and even designs without chillers, while still demonstrating compliance to the newer standards.

References

1. Quirk, D., 2011. "Navigating ASHRAE Standard 90.1-2010 requirements for economizers in datacom." *ASHRAE Transactions* 117(2).
2. DOE. 2021. "Status of State Energy Code Adoption—Commercial." U.S. Department of Energy." <https://tinyurl.com/eccjr57b>
3. Quirk, D., V. Sorell. 2010. "Economizers in datacom—risk mission vs. reward environment?" *ASHRAE Transactions* 116(2).
4. ANSI/ASHRAE/IES Standard 90.1-2019, *Energy Efficiency Standard for Buildings Except Low-Rise Residential Buildings*.
5. Sun, K., N. Luo, X. Luo, T. Hong. 2021. "Prototype energy models for data centers." *Energy and Buildings* 231:110603. ■