Better Buildings
U.S. DEPARTMENT OF ENERGY

Plug and Process Loads in Commercial Buildings

BETTER BUILDINGS ALLIANCE

Capacity and Power Requirement Analysis

This brochure addresses gaps in actionable knowledge that can help reduce the plug load capacities designed into buildings. Prospective building occupants and real estate brokers lack accurate references for plug and process load (PPL) capacity requirements, so they often request 5–10 W/ft^2 in their lease agreements. This brochure should be used to make these decisions so systems can operate more energy efficiently; upfront capital costs will also decrease. This information can also be used to drive changes in negotiations about PPL energy demands. It should enable brokers and tenants to agree about lower PPL capacities. Owner-occupied buildings will also benefit. Overestimating PPL capacity leads designers to oversize electrical infrastructure and cooling systems (see Figure 1).

KEY TAKEAWAYS

- Prospective building occupants and real estate brokers lack accurate references for PPL capacity requirements.
- Prospective tenants typically request 5–10 W/ft^2; in some cases they request up to 16 W/ft^2 (CBEA 2012).
- Overestimating PPL capacity leads designers to oversize electrical infrastructure and cooling systems, increasing upfront capital costs and energy usage.
- This project found the following:
  - The *peak* PPL energy use intensity for offices with data centers is 0.88 W/ft^2.
  - On *average*, the typical PPL energy use intensity for offices (without laboratories or data centers) is around 0.28 W/ft^2, and 0.27 W/ft^2 for higher education buildings.
  - Right-sizing HVAC system components led to an average 14% reduction in upfront capital costs and a 3–4% reduction in energy costs.
  - Offices with data centers or laboratories do exhibit higher PPL energy use intensities (up to 2.27 W/ft^2).

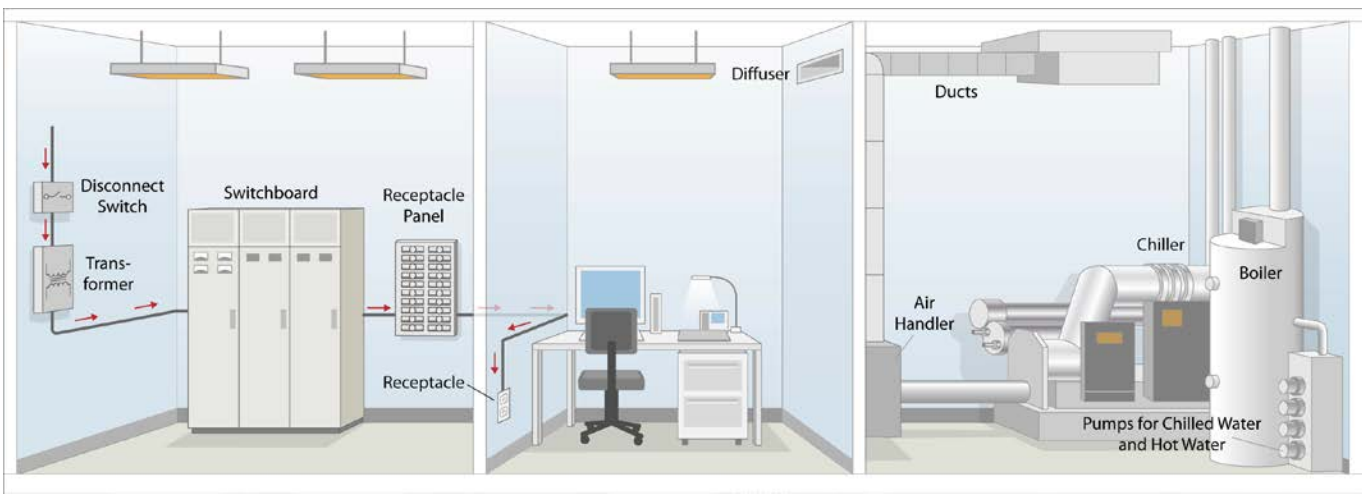

Figure 1 Building systems that are affected by plug and process load densities specified in lease agreements. Illustration by Al Hicks

Better Buildings Alliance collaborators and industry partners have stated that the primary target building type for this brochure is office buildings, which included about 824,000 buildings (12 billion ft^2) in 2003 (CBECS 2003, Table A2). A secondary target is higher education buildings. These buildings have spaces that reflect typical office setups and equipment.

PPL densities in commercial buildings are typically much lower than those currently specified. Brokers sometimes suggest PPL density needs of up to 16 W/ft^2 as part of the lease structure (CBEA 2012). In 2012, the U.S. General Services Administration (GSA) changed its standard lease PPL requirements from a 7 W/ft^2 to a 4 W/ft^2 minimum (Pentland 2011; GSA Public Buildings Service 2011; GSA 2013) as part of its government-wide efforts to create green, sustainable buildings.

However, this is still high. Table 1 summarizes the varied PPL densities reported in select literature.

Table 1 PPL Power Densities Reported in Select Literature

Reference	Building Type	PPL Power Density (W/ft^2)
Wilkins and Hosni (2011)	Office	0.25–2.0 (minimum capacity)
ASHRAE (2009)	Office	1 (minimum capacity)
Srinivasan et al. (2011)	K-12 Education	0.33–1.06 (average density)
Metzger et al. (2011)	Office	0.9 (average density cubicle only)
NRDC (2011)	Office	7.5 (requested minumum capacity)
GSA (2011); Haun (2013); GSA (2013)	Office	4 (requested minimum capacity)

Building Selection for Inclusion in This Study

Twenty-one buildings were selected, including large office, small office, higher education (office and classroom), municipal office, and single-tenant and multitenant office spaces. For buildings that didn't already have metering, current transducers were installed in the electrical panels to submeter all PPL branch circuits (see Figure 2). Table 2 shows the measured average and peak PPL energy use intensity.

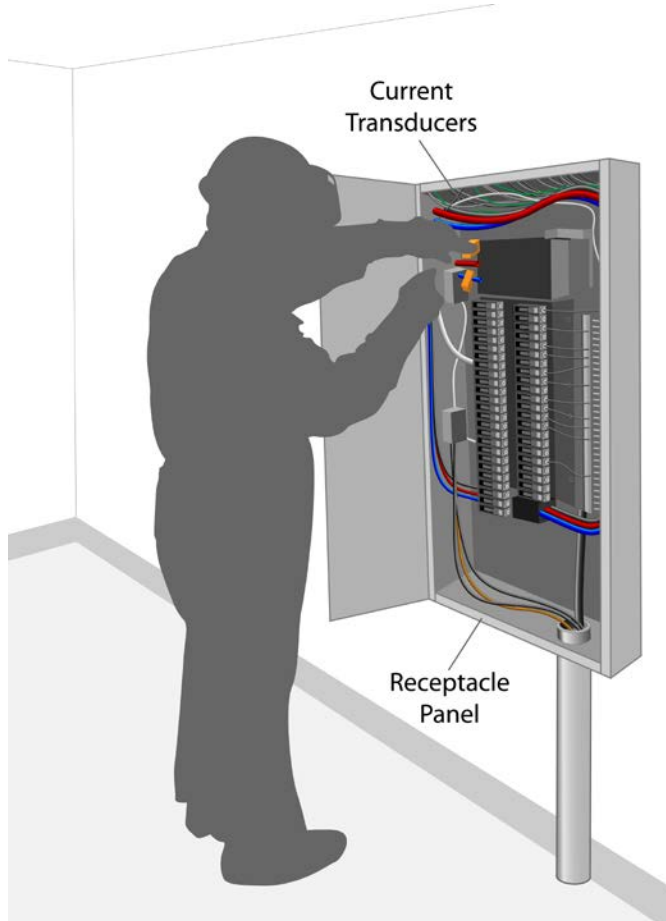

Figure 2 This study required that metering be installed to capture PPL energy use intensity. Illustration by Al Hicks

Table 2 Measured Average and Measured Peak PPL Energy Use Intensity

Building Type		Average (W/ft^2)	Peak (W/ft^2)	Total Area (ft^2)
Office – Single Government Tenant		0.24	0.52	18,818
Office – Single Government Tenant		0.16	0.55	138,000
Office – Single Government Tenant w/Data Center		0.34	0.51	18,755
Office – Single Government Tenant w/Data Center		0.77	1.25	220,000
– Data center only		0.57	0.82	
Higher Education – Classrooms, Meeting Areas, and Faculty Offices	Bldg. 1	0.23	0.41	115,110
	Bldg. 2	0.30	0.64	49,360
	Bldg. 3	0.16	0.42	83,130
	Bldg. 4	0.40	1.08	26,326
	Bldgs. 5–7	0.28	0.63	113,584

Table 3 Measured Average PPL Energy Use Intensity

Building Type	Average (W/ft^2)	Total Area (ft^2)
Office – Multi-Tenant w/Data Center	1.17	50,725
Office – Multi-Tenant w/Data Center	0.19	365,000
Office – Multi-Tenant w/Data Center	0.37	191,799
Office – Multi-Tenant	0.49	173,302
Office – Municipal	0.40	172,000
Office – Single Tenant w/Warehouse	0.19	94,621
Office – Single Corporate Tenant w/Data Center	0.58	97,500
Office – Single Corporate Tenant w/Data Center	0.36	195,721
Office – Single Corporate Tenant w/Kitchen	0.64	91,980
Office – Single Corporate Tenant w/Laboratories	2.27	222,616

Findings

Findings from this project strongly suggest that actual PPL densities in office and higher education buildings are substantially lower than are usually requested. Table 3 summarizes the measured average annual PPL energy use intensity of 14 office buildings and seven higher education buildings, totaling 2.5 million square feet.

Unlike other building systems such as HVAC, PPLs typically do not vary dramatically with the seasons. For example, the PPL energy use intensity of seven higher education buildings did not fluctuate by more than 0.06 W/ft^2 over the course of 15 months. In general, similar "flat" PPL energy use intensity profiles were observed in the other buildings included in this study.

Through our measurement and analysis of actual PPL densities over a range of commercial building types, we have documented significantly lower (by a factor of 5 to 10) peak PPL densities than what is typically requested, negotiated, or required in leases. On average, the peak PPL energy use intensities for offices (without laboratories or data centers) are 0.50 W/ft^2, and 0.64 W/ft^2 for higher education buildings. The peak PPL energy use intensity for offices with data centers is 0.88 W/ft^2. On average, the average PPL energy use intensities for offices (without laboratories or data centers) are 0.28 W/ft^2, and 0.27 W/ft^2 for higher education buildings. Offices with data centers or laboratories do exhibit higher average PPL energy use intensities. However, these buildings still do not require a PPL capacity of 5 W/ft^2 – 10 W/ft^2.

Conclusions

Based on the large amount of square footage represented in Table 2, it is reasonable to conclude that the standard industry practice (mentioned in the previous sections) is causing buildings to have oversized PPL capacities (by a factor of 5–10).

With this evidence in hand, building owners, leasing brokers, and energy managers can set realistic PPL power densities that are commensurate with actual use. This should lead to the right sizing of HVAC and electrical systems. Case studies of two buildings have shown that right sizing HVAC system components led to an average 14% reduction in upfront capital costs and a 3%–4% reduction in energy usage (Thomas and Moller 2007).

During construction or in deep retrofits, it is advisable to design flexibility into HVAC and electrical systems, allowing for future tenants. For example, rather than oversizing the entire system, HVAC distribution pipework and main ductwork can be generously sized to allow for larger capacity needs in the future. For more strategies on how to avoid oversizing systems, please refer to the case study by Thomas and Moller (2007).

For more details on this study, please read the full technical report *http://www.nrel.gov/docs/fy14osti/60266.pdf* Plug and Process Loads Capacity and Power Requirements Analysis.

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