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Data center power requirements: measurements from Silicon Valley

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Abstract

Current estimates of data center power requirements are greatly overstated because they are based on criteria that incorporate oversized, redundant systems, and several safety factors. Furthermore, most estimates assume that data centers are filled to capacity. For the most part, these numbers are unsubstantiated. Although there are many estimates of the amount of electricity consumed by data centers, until this study, there were no publicly available measurements of power use. This paper examines some of the reasons why power requirements at data centers are overstated and adds actual measurements and the analysis of real-world data to the public policy debate over how much energy these facilities use.
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1. Introduction

This paper brings the first publicly available measured data to bear on the policy questions surrounding data center power use. There are numerous recent accounts of data centers that consume over 1000 W/m^2 of power—more than 10 times what is required by a typical commercial office space—as well as accounts of facilities that require a large fraction of the power put out by a single power plant [1,2]. For example, prospective builders of a data center in Sacramento, California told the local utility that they would need 50 to 60 MW of power, roughly the equivalent of all other growth in the area in an average year [3]; and a single data center in New Jersey requested an amount of power equal to one-third of that used by the entire city of Newark [4].

Overstated energy demands such as these are problematic. For data center owners, overstated

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demands lead to extra construction expenses and less energy-efficient facilities; for utility planners, these assertions lead to the building of excess generation, transmission, and distribution capacity; and for the public they perpetuate the urban legend that ‘the Internet’ is a huge consumer of electricity. Averting these consequences is important [5], especially from the perspective of avoiding unnecessary costs for electric services.

In spite of the value of obtaining accurate data on power use for these facilities, few credible and publicly available data on this topic existed prior to this analysis (information on power use is a closely guarded proprietary secret for most data centers). This research benefited from unparalleled access to a single Bay Area data center. The owner of that facility granted us access on the condition that confidential data be masked and that full results be made available to them for their own internal use. The results presented here (including the billing data from four other data centers discussed below) accurately portray the energy use in such facilities, and represent a more sound basis for public policy judgments about data center power use than the speculation now commonplace on this topic. Examining the energy needs of these data centers also allows researchers to gain a better understanding of where energy efficiency measures could be most effective in improving their efficiency.

This paper first explores some of the reasons for exaggerated estimates of data center power use, and presents the methodology and results from our analysis. It then summarizes future work and conclusions.

2. Reasons for exaggerated forecasts

This section presents 10 reasons why forecasts of data center power work are often exaggerated, drawing upon the work in [6].

2.1. Lack of common definitions and metrics

Power in data centers is most commonly discussed in terms of power density (in W/m^2, or W/ft^2 in the US). It is often unclear, however, what this watts-per-square-meter number means because the numerator and the denominator vary from use to use. A stated power density of 1000 W/m^2 could refer to the power drawn by an isolated rack, or the average power density of the building. Furthermore, extrapolating the power density of an isolated rack to the entire floor area of a building is misleading because the floor area within a building includes aisle space, office space, restrooms and hallways, all of which require much less power per square meter than computer racks.

2.2. Nameplate power vs. actual power

Power needs are often determined based on the nameplate power consumption, which is the theoretical maximum amount of power that the equipment can draw. For safety reasons most equipment never draws more than 80% of the rated power even during peak demand, and the majority of computer equipment draws much less than 80% of its nameplate rating [6]. As early as 1990, Norford et al. [7] reported that nameplate ratings for personal computers tend to be overstated by factors of two to four. Furthermore, a more recent paper by Kunz [8] reported the electricity consumption of various other pieces of network equipment (i.e. routers, switches, multiplexers, micro repeaters, media converters) and found that the measured power was usually about 30% of the nameplate specifications. Designing for nameplate power consumption rather than actual power draws, therefore, will result in significantly oversizing building circuits and supporting systems.

2.3. Installed vs. utilized circuit capacity

Power estimates are often based on maximum capacity values even when it is unlikely or impossible for the actual power to ever reach this value. For example, one data center facility fact sheet [9] explains that, “To conform to electrical code for peak power use, maximum power usage is limited to 75% of circuit values (e.g. 15 amperes (A) for a 20 ampere circuit).” In this data center, every circuit would always be oversized by at least 33%. Since many data centers are built long before the mix of internal computer equipment is determined, it is difficult to minimize the oversizing of circuits. The capacity of the installed circuits, therefore, will far exceed the actual current capacity needed.

2.4. Dual power supplies

Some computer equipment employs dual power supplies to provide sufficient backup should one circuit fail. In this case, even though the equipment draws a maximum of 6 A, it would have not one but two 6-A power supplies, each connected to its own circuit. Since each power supply must be connected to a separate circuit, three 6 A-rated servers with dual power supplies would require two 20-A circuits—approximately twice the actual power requirements of the equipment even if it were to draw the full nameplate power.

2.5. Reduction in server dimensions

Current facility designs assume that the customer will use the latest most energy-intensive equipment which would mean that a standard rack (approximately 1.8 m) could hold roughly 40 1 U servers (where 1 U = 4.445 cm). Since today’s 1 U servers can have as many processors as older 4 U or 5 U servers, the 1 U server could consume about the same amount of electricity but with a fraction of the physical size. Most data centers, however, still use many pieces of larger, less energy intensive computer equipment.

2.6. Rack and facility utilization

A typical or standard equipment rack has approximately 40 U of space, all of which, in theory, could be occupied by energy-using equipment. However, regardless of how many pieces of equipment can fit in a rack, many racks are under-utilized. At the data center that we studied in most detail, for example, the average rack was only one-third filled, and 47% of the audited racks had no electrical equipment at all. While revenues or payback periods are calculated based on renting only 30–40% of capacity [10], power requirements often assume 100% utilization.

2.7. Anticipation of high future loads

A paper by the Uptime Institute [11], using information from 15 computer manufacturers, shows the trend (from 1992 to 2010) in power use by a full rack of servers. The paper from the Uptime Institute indicates that the amount of power used by a full rack of servers is expected to roughly double between 2000 and 2005. Given the introduction of 1 U servers, and the rapid turnover of computer equipment, data centers have started designing for power-dense equipment. The recent introduction of lower-powered and power-managed servers, however, may mean that these anticipated loads will not materialize [12].

2.8. Oversized heating, ventilation and air conditioning (HVAC) systems

Overestimating the power needs of the computer equipment leads to an overestimate of the heat that will be dissipated from such equipment. The resulting systems will require larger chillers and fans, and more computer room air conditioners (CRAC) than needed. Corresponding electrical systems will have to be sized to accommodate a fully loaded HVAC system even though the full capacity will never be needed. Oversizing HVAC systems reduces system efficiencies and wastes energy.

2.9. Compounded safety factors

In an industry where reliability is highly valued, several systems will be oversized so that each provides redundancy. The oversizing of each system is further compounded by the fact that the engineers that design the mechanical systems are not the same engineers that design the electrical systems or the computer equipment. Each discipline adds its own safety factors. The electrical system, therefore, will be oversized for an already oversized computer and mechanical load.

2.10. Overly optimistic forecasts of the number of data centers

As a result of the slowing market, it is likely that forecasts of the number of data centers and the total floor area in these facilities are significantly overstated. Companies may not end up completing data centers or building all of the data centers that they planned. It is also possible that some of the speculative data centers are being double counted. When new data centers are sited, owners may 'shop' their power needs to more than one utility to secure favorable rates. Speculative power requests can lead to overestimates of the aggregate amount of power required for this industry.

2.11. Summary of reasons

All of the reasons above cause total data center power requirements to be portrayed as higher than actual. While the current estimates are too high, security and confidentiality concerns make it difficult to gather the data required to determine more accurate estimates of power densities or total power loads for these facilities. Companies that own data centers are often unwilling to share information about their operation because they feel it may compromise proprietary information.

For example, reporting the presence of empty racks or cabinets may make the company seem unpopular or unprofitable to observers. For this reason, until this study, there were no publicly available measurements of power requirements at data centers.

3. Measurements from a Silicon Valley data center

The estimates in this section are based on measured data, electrical and mechanical drawings, equipment counts, manufacturer's specifications for the equipment at this data center, electricity billing data, and, where specified, previous relevant studies. While still rough, these estimates provide a benchmark for a variety of electricity uses within data centers and offer a sense of the complexities involved with estimating the power needs of these facilities.

3.1. General description of the facility

The data below were collected from a 11 645 m^2 facility located in Silicon Valley, California (USA). Like many data centers throughout the country, this facility was built within an existing building shell to minimize construction time. At the time these measurements were taken, there were 2555 m^2 of active computer rooms that occupied 22% of the total building floor area (see Fig. 1.) The facility also contained office space, equipment rooms, and areas still under construction. All space under construction is included in the 'Other Area' category in Fig. 1. Bathrooms, hallways, and lobbies are also included in 'Other Area.' In addition to the renovated space, there was approximately 1170 m^2 of floor area that remained in its prior use. All equipment in this area, therefore, was in this facility prior to the recent renovation. Thus, the power loads from this part of the building do not represent new power requirements due to growth of the Internet, or

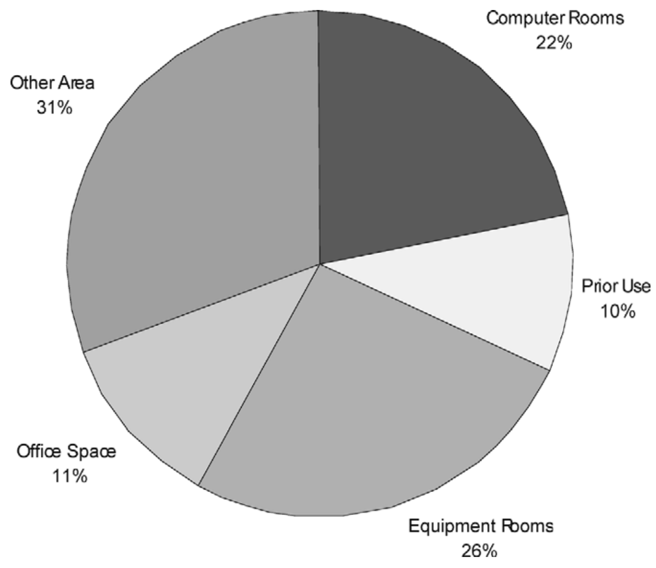

Fig. 1. Facility floor space (11 645 m^2 total).

the addition of a data center. This ‘Prior-Use Area’ is approximately 10% of the total facility’s floor space.

All of the space in the active computer rooms was leased; however, on average, only one-third of the rack capacity was used. This space contained both cages that could hold from five to several dozen racks and free standing cabinets (racks with doors). The equipment in an easily accessible portion of one computer room was inventoried to determine the different types of computer equipment currently in this data center. The area was part of a co-location facility where the computer equipment was enclosed in cabinets. These cabinets were located in an area that covered approximately 240 m^2. This area was selected because the equipment could be easily viewed and counted. Racks within cages were not selected because access to the cages was restricted and it was impossible to accurately inventory the computer equipment from outside the cages. The data, therefore, may over-represent smaller customers because they tend to rent cabinets rather than larger cages. The inventory for this area is reported in Table 1.

Approximately 47% of the racks in this space were empty. (A few had cable connections, but no energy-using equipment.) The remaining racks had varying amounts of equipment. Servers, ranging in size from 1 U to 8 U accounted for 61% of the utilized rack space. One third of these servers were 2 U servers. While the data in Table 1 give a sense of the types of equipment in this space, it is difficult to estimate power consumption based on this information because the energy demands vary depending on the internal configuration of the equipment. Although servers generally use less power per unit area than routers, one 4 U server may require significantly more power than another 4 U server depending on its vintage, design, function, etc. As a result, it is difficult to determine the power requirements from the external appearance of the computer equipment.

3.2. Determining power demands from computer equipment

All of the computer equipment was connected to power distribution units (PDUs) that displayed the voltage and current for each of the three phases. Power readings from these PDUs were taken in January 2001. The apparent power requirement for the computer equipment was approximately

Table 1
Inventory of equipment found in cabinets in a co-location hosting facility

Type of equipment	Number	Space in Us (where 1 U = 4.445 cm)	Percent of utilized rack space devoted to equipment
Servers	229	596	61%
Switches	101	177	18%
Disks	18	88	9%
Routers	13	81	8%
Firewalls	8	15	2%
Other	12	19	2%
Total	381	976	100%

The above equipment was located in approximately 240 m^2 of a computer room in Silicon Valley, California. Data collected by Bruce Nordman and Jennifer Mitchell-Jackson, November 2000.

445 kW. A power factor of 0.97 was used to convert from apparent to real power. Newer computer equipment usually corrects the incoming power to eliminate harmonic distortions that might cause disruptions. For example, new switching power supplies for Sun computers have active power factor correction to at least 0.99 in most cases.[1] Measurements from a both a New York City data center and an Oakland data center, however, indicated that the aggregate power factor for computer equipment (including routers, switches and hubs) is closer to 0.97. The real power requirement for the computer equipment was approximately 432 kW, resulting in a computer power density slightly less than 170 W/m^2.

3.3. Power used in the prior-use area

An approximate average power density for the 'Prior-Use' area, which represented 10% of the total building area, was determined from historic billing data. The power density was approximately 215 W/m^2 over this 1170 m^2 area. This value includes all of the equipment, lights, fans and plug loads in this area but does not include the power needed to provide chilled water to the air conditioning units (i.e. the central plant requirements—see Section 3.8 below) because the HVAC central plant power was on a separate meter.

3.4. Power used by computer equipment in office space

The number of computers was much less than would be expected in an equally large commercial office space since the main employees of the building were mechanical and electrical personnel. The average heat gain for a typical office computer is approximately 55 watts [13]. A medium-sized monitor would add an additional 90 watts [14]. This estimate is for an active computer and does not take into account that the computer and monitor would draw less if it is in a power saving mode, nor the fact that these computers are probably not on 24 h a day. Furthermore, a laptop would require less power and generate less heat than a desktop computer. We assumed that the 12 computers found in the office space consumed 145 watts at all times. This is approximately 1740 watts, or 1.3 W/m^2 over the 1330 m^2 office space.

3.5. Lighting

The electrical drawings indicated that the power density of the lighting in the computer rooms was approximately 12 W/m^2. Mechanical and equipment rooms tend to have a slightly lower lighting power density; therefore, a value of 8 W/m^2—a typical value for this type of room determined from an earlier study on lighting [15]—was used for these areas. In the office space of a typical commercial building, lighting requires approximately 19 W/m^2 [15]. Using these values, the total load from lighting was approximately 117 kW. (This does not include lighting in the Prior-Use area.)

[1] Sun Microsystems. 2001. Email from Sun Microsystems technical support desk on active power factor correction on servers. Email text as follows: an active power factor correction to at least 0.99 'has become a regulatory requirement for almost all new switching power supplies, with particularly strict regulations in the European Union. Uncorrected power factor can cause core saturation in the distribution transformers leading to early failure and decreased efficiency in the distribution grid.' February 7.

3.6. Other loads

In addition to lights and computers, other office equipment such as copiers and fax machines contribute small power loads throughout the office space. A recent ASHRAE Journal reported the heat gain to be approximately 1100 watts from an office copier, 30 watts from a facsimile machine, 25 watts from an image scanner, and 550 watts from a large office laser printer [13]. These numbers do not take into account power saving modes or end-of-the-work-day shutdowns but they give a reference point for calculating the additional loads in this space. For our calculations, we assumed that this additional equipment drew just 3 W/m^2 since the power density of the computers in this area was already included in an earlier step, and since this space was not densely occupied. In addition, 1 W/m^2 was added to all 'other' areas to account for small miscellaneous loads. These values carry with them less certainty than the measured data reported above, but they are small in comparison to the larger loads of the computers and HVAC system (discussed below).

3.7. Losses due to auxiliary equipment

As electricity passes through the uninterruptible power supplies (UPSs) and power distribution units (PDUs) some is lost to the internal components in this equipment. With a full load, UPSs are approximately 95% efficient, and PDUs can be close to 98% efficient. As the load drops, however, these efficiencies decrease. Since these systems were under light loads, we assumed that the PDU and UPS efficiencies were on the lower end of these ranges and that the losses were approximately 5 and 7%, respectively. As a result, approximately 22 kW were consumed by the PDUs and 32 kW were used by the UPSs, for a total of 54 kW. In addition, line losses and other auxiliary equipment such as building controls, fire alarms, security systems, telephone systems, and backup diesel generators also use small amounts of power. Overall, approximately 100 kW were consumed by auxiliary equipment and line losses. While these power draws occurred throughout the facility, they were allocated to the active computer rooms since the majority of this auxiliary equipment was in the building for the sole purpose of supporting the computer rooms.

3.8. Power for the HVAC central plant

The active chiller in this facility was an 800 ton York chiller. (An additional 800 ton chiller was also onsite as a backup.) The total heat load in this facility, as indicated by the monitor on the chiller, was approximately 320 tons. Since the chiller required approximately 0.52 kW/ton, demand from the chiller was approximately 166 kW. The active cooling tower had a 30 horsepower, or approximately 22 kW, motor. However, since the cooling tower was running at only 40% of capacity, the motor was using the minimum amount of power: 2.2 kW or 10% of the design (based on manufacturer data). While the chiller and the cooling tower were operating at 40% of capacity, the pump to circulate the chilled water through the facility required a constant horsepower regardless of the load. According to the manufacturer's specification, this pump required full power or approximately 45 kW. In total, the central plant (including the chiller, cooling towers and pump) required approximately 213 kW.

3.9. Power for air distribution

The computer rooms in this facility employed twelve 50-ton CRAC units and six 30-ton CRAC units. In addition, there were four additional air conditioning units that cooled air remotely and then blew the cool air into the computer rooms. Overall, therefore, there were 22 units; for redundancy purposes, however, only 18 ran at one time. Under the current light loads, these units were operating at approximately 30% of capacity. The fans within these units, however, ran constantly. The fans in a typical 50-ton CRAC unit require approximately 10 horsepower or 7.5 kW each. The fans in the smaller 30-ton units used slightly less power. A CRAC with dehumidifiers and reheat systems as well as internal monitors and other components, however, requires closer to 40 HP or approximately 30 kW. Assuming that five of the CRAC units were able to dehumidify and reheat and that the others were just cooling units, the 22 units would use a total of approximately 215 kW. In addition, the office space had its own packaged air-handling unit and additional fans were located throughout the building. As a result, the total air distribution system for this facility was estimated to be 250 kW.

3.10. Total power needs

The computer rooms in this facility were designed so that the computer equipment could draw an average of 646 W/m^2. As shown in Table 2, however, the actual computer power density was 169 W/m^2—just over one-fourth of the design value. Computer power density, however, includes only the power drawn by the computer equipment and does not include power required by the supporting systems. It is not, therefore, indicative of the total power needs of this data center.

Over the building's 11 645 m^2 floor area, the average building power density was 118 W/m^2. (All power density assumptions are listed in Table 3.) The building's total power requirement, approximately 1.4 MW, was determined by multiplying the power density for each area by the appropriate floor area (see Table 4 for total power needs by end use). This monthly average was

Table 2
Data center key terms and findings

Term	Definition	Results
Computer power density	Power drawn by the computer equipment (in watts) divided by the computer room floor area (in square meters or square feet)	169 W/m^2 16 W/ft^2
Building power density	Total power drawn by the building (in watts) divided by the total floor area of the building (in square meters or square feet)	118 W/m^2 11 W/ft^2
Total computer room power density	Power drawn by the computer equipment and all of the supporting equipment such as PDUs, UPSs, HVAC and lights (in watts) divided by the computer room floor area (in square meters or square feet)	355 W/m^2 33 W/ft^2

A conversion factor of 10.76 ft^2/m^2 (0.0929 m^2/ft^2) was used to convert from English to metric units.
Results are from a 11 645 m^2 facility in Silicon Valley, California.

Table 3
Power density by end use from a data center facility in Silicon Valley, California

Area breakdown	Floor area (m^2) [a]	Direct use power densities (W/m^2)			Supporting equipment power densities (W/m^2)			Power density (W/m^2) [c]
		Computers or prior use	Lights	Other	Auxiliary equipment	Central chiller plant[c]	Fans, CRAC units, AHUs [c]	
Computer rooms	2555	169	12	0	39	51	83	355
Prior use	1170	215 [b]	n.a.	n.a.	n.a.	50	n.a	265
Equipment rooms	2990	0	8	0	0	2	3	13
Office space	1330	1	19	3	0	6	9	38
Other floor area	3600	0	11	1	0	3	4	19
Total building	11 645	59	10	1	9	18	21	118

[a] A conversion factor of 10.76 ft^2/m^2 (0.0929 m^2/ft^2) was used to convert from English to metric units.
[b] Lights, other, auxiliary equipment and fans for the 'Prior Use' area are included in the 215 W/m^2. Billing data for this area did not permit a more detailed breakdown.
[c] Note that some values differ slightly from earlier write-up of results [6] because of recent modifications to the calculation methods.

Table 4
Total power demanded by end use as found in a 11 645 m^2 facility in Silicon Valley, California

Area breakdown	Direct use power (kW)			Supporting equipment power (kW)			Total power (kW) [a]
	Computer equipment or prior use	Lights	Other	Auxiliary equipment	Central chiller plant[a]	Fans, CRAC units, AHUs[a]	
Computer rooms	432	30	0	100	131	213	907
Prior use	252	n.a.	n.a.	n.a.	59	n.a.	311
Equipment rooms	0	23	0	0	5	9	36
Office space	2	26	4	0	7	12	51
Other floor area	0	39	4	0	10	16	69
Total	686	117	8	100	213	250	1374

[a] Note that some values differ slightly from earlier write-up of results [6] because of recent modifications to the calculation methods.

independently confirmed by the electricity billing data from the local utility, which showed a load of 1.4 MW for the whole building.

Average building power densities, however, are also not indicative of the power required by data centers because many computer rooms have been added to buildings with previously existing energy needs. In these cases, a significant portion of the power required is not new power or power required by the data center. Furthermore, because the ratio of computer room to other space varies between facilities, it is also impossible to compare these power densities. The average building power density of a skyscraper with one large densely packed computer room, for example, would most likely be much less than the average building power density for a small facility with a sparsely filled computer room despite the fact that the data center in the skyscraper requires much more energy in the aggregate.

Estimates of total computer room power density are most indicative of data center power needs (see Table 2). We define the total computer room power density as the power drawn by the computer equipment and all of the supporting equipment such as PDUs, UPSs, HVAC and lights (in watts) divided by the computer room floor area (in square meters). After including all of the support systems, we estimated that the total computer room power density for this building was approximately 355 W/m^2 (33 W/ft^2). This value was supported by a review of billing data for four additional data centers throughout the country summarized in Table 5 [16]. In each of these four facilities, we found that the upper limit for total computer room power density was less than 430 W/m^2 (40 W/ft^2).

Nearly one half of the power used to support the computer rooms went to the computer equipment (see Fig. 2). The remaining power was used for the HVAC and auxiliary equipment as well as other end uses such as lighting. The HVAC system (including the central plant and the air distribution, or fans) accounted for approximately 38% of the power. Lighting represented only a small percentage—less than 3% of the power needs.

Table 5
Comparison of power densities at five US data centers at the end of 2000

Location	Units	Data center A	Data center B	Data center C	Data center D	Data center E
Building area	m^2	11 643	10 684	14 321	NA	33 292
Computer room area	m^2	2555	3716	4181	4476	3577
Building power density	W/m^2	118	31	106	NA	40
Upper limit for total computer room power density	W/m^2 (W/ft^2)	355 (33)	88 (8)	363 (34)	412 (38)	376 (35)

The upper limit for total computer room power density for data centers B–E was calculated by dividing the average power demand for the entire facility (from billing data) by the computer room area. This number includes all of the power used by the entire building and is therefore an overestimate. The estimate for data center A is based on the results summarized in Tables 3 and 4.

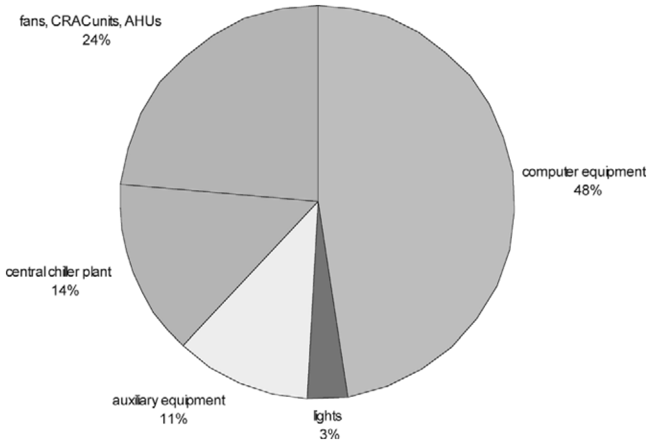

Fig. 2. Total computer room power by end use.

4. Discussion

Confusion about power densities for data centers has led to inaccurate calculations and overestimates of the power requirements of this industry. The commonly cited power density of 1100 W/m^2 sometimes is used to refer to the power drawn by an isolated rack, and sometimes to the average power density of an entire building, with little attention paid to consistency between estimates. Rarely do people reporting these numbers carefully define them, so any claims about power density reported in the media must be viewed with extreme skepticism.

For the data center examined in detail here, the simple calculation of multiplying 1100 W/m^2 by the floor area of the entire facility (11 600 m^2) would give an estimate of 12.5 MW—roughly 14 times what this facility actually uses to support the data center (0.9 MW). Extrapolating a power density in this way overstates power requirements because the floor area within a building includes large areas that require much less power per square meter than do computer racks.

Other estimates of data center power requirements use design power densities to extrapolate total power needs, which are based on the rated power of the equipment, assuming full occupancy, and incorporating various safety factors, as discussed above. If the design power density of computer equipment in this facility (646 W/m^2) were used in the above calculation of total power used by the facility, the result would still be about 7.5 MW, an overestimate of more than a factor of eight.

Finally, because this building (like many other data centers) has other uses, even using the correct building power density (118 W/m^2) times the total floor area can be misleading, if the purpose of the calculation is to estimate the power used by the data center alone. The total building load of 1.4 MW includes 0.5 MW of prior uses. The floor area devoted to other uses can vary wildly by facility, and it is impossible to generalize. The only reliable way to estimate data center power use is to estimate the net floor area for the data center and multiply by the total computer room power density. Any other method will yield erroneous or misleading results.

5. Future work

This research is only the first step in uncovering the true nature of electricity use in data centers. We are now revisiting this same facility to determine what effect (if any) extensive retrofits and operational changes in the past 2 years may have had on electricity use. We are also compiling data on computer power density in dozens of data centers, using a database from the Uptime Institute, an organization of data center designers. Finally, a multi-year LBNL project analyzing potential efficiency improvements funded by the California Energy Commission and the New York State Research and Development Authority has recently begun. Once these activities bear fruit over the next few years, a clearer picture should emerge about current electricity used by these facilities, recent trends in their electricity use, and options for improving their efficiency.

6. Conclusions

Standardized definitions and estimation methodologies can facilitate comparisons of data center energy use. In particular, estimates of total computer room power density allow for comparisons of data center power use between buildings of different sizes, as well as between data centers at different stages of development. The total computer room power density captures all power drawn by the computer equipment, as well as by the supporting equipment such as HVAC, PDUs and UPSs (in watts) divided by the computer room floor area (in square meters).

While not as high as often reported, data center power densities are much higher than those for typical commercial office buildings because of the densely packed computer equipment. In the data center examined in this study, total computer room power density was determined to be approximately 355 W/m^2 (33 W/ft^2), which is much smaller than the numbers often cited by the media. In billing data we examined four other facilities, the upper limit for total computer room power density was always less than 430 W/m^2 (40 W/ft^2).

To support the 2555 m^2 of critical computer room floor area in this facility, the data center drew approximately 900 kW of power. This 900 kW is most indicative of the new power requirements at this data center due to Internet growth. The remaining power (approximately 500 kW) required by this facility was used for ‘Prior Uses’ and existed before the advent of the Internet. When determining power requirements of data centers, care should be taken not to include previously existing loads.

Since many systems within data centers are designed inefficiently, energy efficiency measures can lead to significant energy savings. Targeting computer equipment for energy efficiency gains is an effective measure since computer equipment accounts for nearly one-half of electricity consumption in data centers. Reducing the energy requirements of the computer equipment and getting more accurate estimates of the computer equipment’s electricity use can also have a significant impact because most of the other systems within the facility are sized to the estimated power needs of this equipment.

While this study serves as a benchmark for power densities found at data centers, additional studies and collaborative efforts between utilities, data centers, and local governments are needed. Further studies can help to create a better understanding of the real power needs of data centers and also help to determine appropriate energy efficiency measures for these facilities.

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