REPORT

Energy Efficiency of the San Diego Supercomputer Center and Distributed Data Centers at UCSD

Prepared for:

San Diego Supercomputer Center
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1. INTRODUCTION

Newcomb Anderson McCormick was retained by the San Diego Supercomputer Center (SDSC) to evaluate the energy efficiency of its data center relative to other small data centers on the UCSD campus. The following data centers were evaluated:

- San Diego Supercomputer Center – Main Floor (SDSC Main)
- San Diego Supercomputer Center – New Floor (SDSC New)
- Biomedical Sciences Building (BSB)
- Engineering Building Unit 3A (EBU)
- Urey Hall
- Institute of Geophysics and Planetary Physics (IGPP)

2. PHYSICAL DESCRIPTION

SDSC Main and SDSC New are both located in the Supercomputer Center building on the north end of campus. The other data centers are smaller rooms located in academic buildings. Each of these data centers receives chilled water from the UCSD Central Plant with the exception of IGPP, which is located at the Scripps campus.

2.1 SDSC Main

This facility has traditionally housed supercomputers, but is currently host to a number of server cabinets. This is the largest data center evaluated, covering 13,000 square feet in the main data room. The servers are in cabinets and rows which are generally arranged in a hot and cold aisle arrangement. Some of the cabinets are in the process of being replaced by new cabinets with seismic mounts. The project includes replacing the existing raised floor with a new stronger floor. This reconfiguration of the room should allow full implementation of hot and cold aisles. There is currently no physical separation between the hot and cold aisle air, although initial experimentation with this has begun.

Other SDSC Main areas included in the overall efficiency calculation include the adjacent transformer room, and the basement rooms: Network Access Point (NAP), the UPS room containing an MGE UPS, and another room containing an MGE UPS and a Mitsubishi UPS. These add approximately 1,200 additional square feet to the data center operation. The Network Operation Center adjacent to the main data room is not included in this analysis as it is served by the building HVAC system.

The main data room is conditioned by 12 Liebert CRAH units rated at 30 and 40 tons, which deliver air under the two foot high raised floor. These only condition by using chilled water to cool the air. Although they have the capability to add or remove humidity from the room, these systems are reported to have been overridden off. This significantly improves the energy efficiency of the data center.

Return air is drawn through the ceiling plenum into the CRAH units through ductwork that extend from the CRAHs to the ceiling. This helps reduce room air mixing.

The basement room with the NAP is conditioned by another 30 ton CRAH unit, as well as two 3 ton split package DX units, with condensers mounted outside. This room takes transfer air from an adjacent room with a MGE UPS unit and sends air to one of the 12 kV transformer rooms. The MGE UPS room is cooled by AHU-2 (20 hp) which recirculates room air and also draws air in from the basement. The room housing the other two UPS units is conditioned by AHU-1 (15 hp).

2.2 SDSC New

The new floor in SDSC is not operational yet. It will cover about 5,000 square feet and will house servers in racks with hot and cold aisle alignment. It was conceived as an energy efficient data center, with mechanical design by Rumsey Engineers. Their design included large underfloor and over the ceiling supply and return air plenums, as well as energy efficient air handlers (not CRAHs) and cooling coils tied to the campus chilled water system. No humidification or dehumidification is planned, as the chilled water temperature is boosted through a heat exchanger.

The design did not specifically include physical separation of hot and cold aisles because that equipment was not included in the scope of the building contract. However, the physical separation has been provided in the data center buildout, with cold aisle containment panels in place.

The design includes six air handlers, each rated at 22,000 cfm. These have VFDs and are projected to operate at an average load of 12 hp each at full cooling capacity. They are all controlled by VFDs to the same speed. Two 7.5 hp chilled water pumps will also operate on VFDs.

2.3 Urey Hall

The data center is a room on the 6th floor of Urey Hall with external hallway access. It is cooled by two Data Aire CRAHs rated nominally at 50 tons. These each use 10 hp fan motors to deliver 21,000 cfm. Two chilled water pumps circulate chilled water from the main campus loop. These are dedicated to these CRAH units, and each is sized at 300 gpm with a 20 hp motor. It is designed for one pump to operate at a time. The pumps have VFDs and the CRAHs have two way valves so the chilled water flow varies with the actual equipment load.

The CRAHs have the capacity to remove about 344 kW of electric heat, although the load is significantly lower currently. The data center racks appear to be about one quarter filled with servers. The room is being built with a hot and cold aisle arrangement with partial separation.

The room could probably be made more efficient through the completion of the hot and cold aisle separation and through installation of VFDs on the CRAH fans.

2.4 Engineering Building Unit 3A (EBU)

EBU is a small, highly loaded data center room in the basement of the building. The seven server cabinets are almost fully loaded. They are in rows but are not arranged in hot and cold aisles. The floor area of the data center is 140 square feet.

Cooling is provided by two overhead 10 ton Data Aire fancoils which use chilled water from the main campus loop. The 3 hp fancoils each deliver 4,000 cfm of air though ductwork in the ceiling area. The air distribution from this ductwork has apparently been judged inadequate and new metal flexible ducting has been installed to blow air directly on some of the cabinets. In addition, several floor fans are used to increase circulation in the room.
The room could probably be made more efficient through the use of the hot and cold aisle separation and through installation of VFDs on the CRAH fans. However, the small floor area severely limits the flexibility to reconfigure.

2.5 Biomedical Sciences Building (BSB)

BSB has a room dedicated to servers on the first floor which backs onto the adjacent building mechanical core space. The room has a second level with additional server cabinets supported on an open steel grating floor. Cabinets are not arranged in hot and cold aisle configurations. Air is supplied and returned through the side wall. On the outside of the room sliding glass doors open out to the adjacent office space. The area of the two floors is approximately 406 square feet.

The room is conditioned by two Data Aire CRAH units rated nominally at 30 tons each. The CRAHs have VFDs on the 5 hp motors driving their 11,700 cfm supply fans. These are located in the mechanical core space. It is anticipated that they normally operate at or near full speed because of the open distribution of air in the server room.

The CRAHs receive chilled water from the main campus loop. They also have backup chillers for use if the campus loop is not available. These backup units do not normally operate so they do not enter into the efficiency equation. Normally one 3 hp chilled water pump operates to circulate water through the CRAH units.

2.6 Institute of Geophysics and Planetary Physics (IGPP)

This data center is located in the IGPP building (in IGPP2) at the Scripps campus. The data center houses one row of nine server cabinets and a variety of other computing equipment, as well as a UPS. The cabinets are relatively lightly loaded. The room area is approximately 390 square feet.

The data center is conditioned by two Pomona Air CRAH units in an adjacent room. Supply and return air is through overhead ducting. Nameplate information was not available from the Pomona Air equipment and the manufacturer is no longer in business. Their capacity is estimated by the face area of their filters, 5 square feet, which at 500 feet per minute implies an air flow of 2,500 cfm. This implies a capacity of about 6 tons each, or 12 tons total.
The operation of these two units is said to be inadequate some of the time so a spot cooler was added. This is a SpotCool unit with a cooling capacity of approximately 3 tons. This is located outside the room so it draws in outside air, cools it, and discharges into the room. This pressurizes the room, causing an equal amount of air to leak out. Conventionally, these units are used to cool room air, rather than cooling outside air. The outside air may often need to be dehumidified as it is cooled, causing additional cooling load. At the time of the survey, the unit was blowing air into the room, but its compressor was off. This addition of cool but possibly humid air from the outside was not necessarily contributing to the cooling of the room.

The Pomona Air CRAHs were cooled by chilled water from a chiller dedicated to this building. The chiller is an air cooled Carrier unit with two screw compressors. It is rated at 135 tons. This chiller can cool the entire building through fancoils, but normally building occupants open windows, which disable their fancoils.

The chiller is used to cool several other continuous loads, a smaller data center in IGPP4 and a lab in IGPP2. The lab air handlers are two more Pomona Air units similar to the data center units, installed in the same room, adjacent to the data center. These other loads were not evaluated, but it is estimated that they total a load similar to the data center evaluated.

3. ANALYSIS

The PUE has been calculated for each of these data centers and is shown in Figure 1.

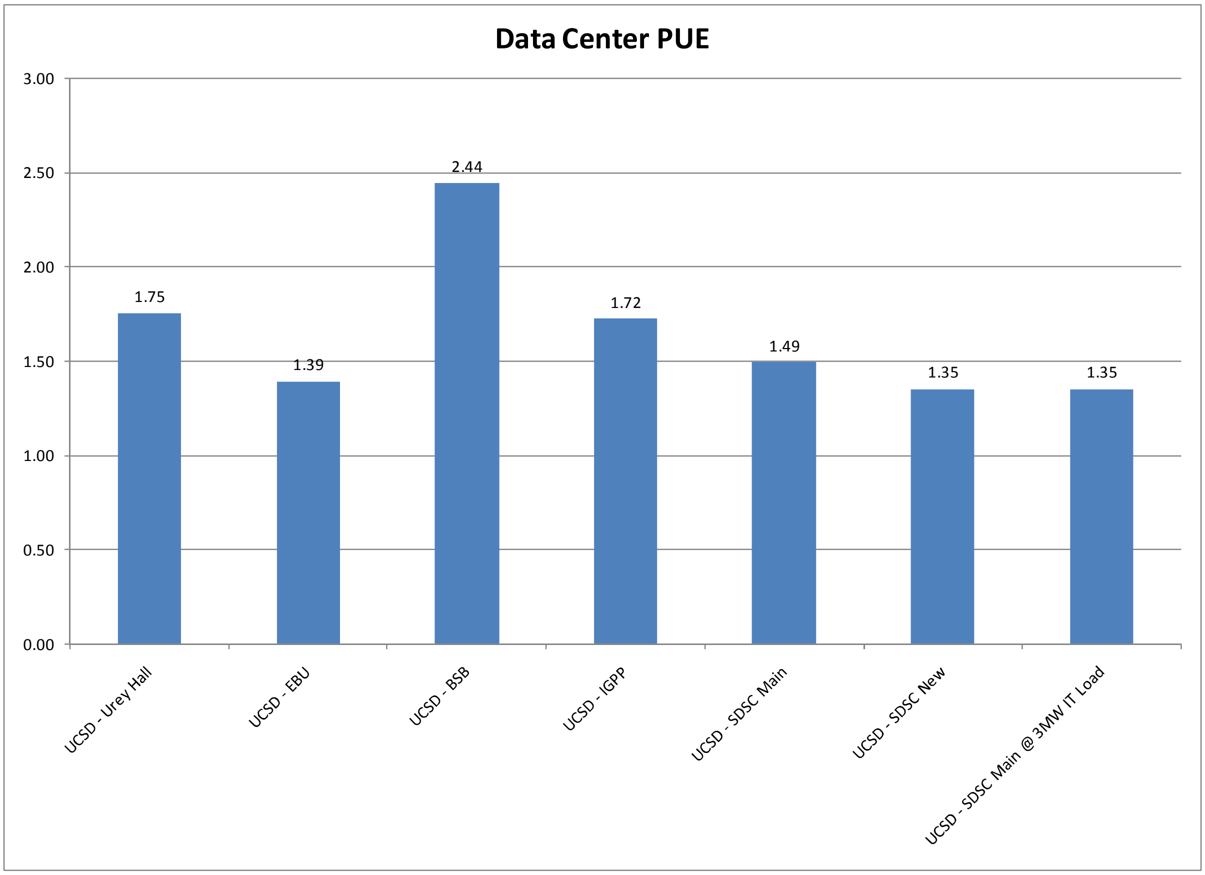

Figure 1. Data Center PUE

3.1 SDSC Main

The PUE of the SDSC Main is the baseline for this analysis. It shows moderate performance at 1.56. One planned modification will significantly improve the PUE of this room. That is the planned addition of hot and cold aisle physical separation. This improved control of cooling airflow through the room should allow the current load to be cooled with a smaller number of CRAH units instead of the current operation of 12 units.

Another improvement is recommended for this data center. The basement air handlers, AHU-1 at 15 hp, AHU-2 at 20 hp, and the CRAH in the NAP are all oversized for the loads they are serving. Installation of VFDs on these fan motors would improve the performance of the data center. The cooling load on these units is relatively low. For example, the 30 ton CRAH is cooling the NAP, which according to the UPS serving it is loaded to 17 kW, or 5 tons of cooling load. The other air handlers are similarly lightly loaded. The combination of these two improvements would result in a data center with a PUE of 1.47.

Note that the data center equipment found in the basement includes the NAP as well as three UPS systems. These are housed in rooms adjacent to preexisting electrical transformer rooms. These transformer rooms are partially cooled through air transfer fans that draw air through the wall from the UPS and NAP rooms. This continuously introduces basement air to the UPS and NAP rooms. This air could significantly increase the cooling load on these air handlers. This potential penalty has not been included in this analysis because it is not clear where the transfer air comes from or how it is conditioned originally.
A better operation approach might be to set the thermostats of the air handlers and CRAH to a high temperature that is still acceptable to the UPS. The MGE UPS website, for example, indicates that the MGE EPS 6000 needs an operating environment between 32 and 104^{0}F. If the room were cooled only by transfer air and the air handler were left off until the room temperature exceeds 104^{0}F, then the fan load and cooling load would be greatly reduced. As long as chilled water is used to cool a room where air is continuously being exhausted, the chilled water coil will be doing unnecessary cooling.

3.2 SDSC New

The projected PUE for this facility is 1.49. It uses the same central chiller plant efficiency as most of the other data centers, so this efficiency is based primarily on the efficient fan and pump system. Note that this calculation assumes a 91% efficient UPS serving the entire server load. The actual planned UPS installation is unknown. If a UPS is not used, this PUE improves to 1.38. If a UPS of high efficiency is used, or if only part of the load is on the UPS, the performance will be between these two.

This calculation assumes the data center is fully loaded with approximately 840 kW of servers and computer equipment. Until this peak is reached the fan load will be slightly lower, improving performance.

3.3 BSB

The calculated PUE for this facility is 2.44. The high PUE is due to several reasons. The load of the data center is less than 10% relative to the cooling capacity of the HVAC system. The HVAC system was designed with VFDs to account for potentially lower loads, but the fan motors appear to be fully loaded. Adjusting the airflow is one approach to improving the PUE for this data center.

3.4 EBU

The calculated PUE for this facility is 1.39. This is the lowest, or best, PUE observed in these data centers. There are several reasons for this. This is the highest loaded data center, relative to its cooling capacity, so most of the fan power is being put to use. The air distribution in the data center is not good, but it is adequate.

In addition, the data center does not use a UPS. This factor improves the PUE by roughly 10%, although there are certainly operational tradeoffs as a result.

3.5 Urey

This data center has a calculated PUE of 1.75, the second highest of the group. The data center is only loaded to about 10% of its cooling capacity and there are no VFDs on the fans. As a result, the fan power is out of line with the actual cooling being done.

There appears to be cabinet space to significantly increase the number of servers in the future. This will result in a better PUE. There is construction in process to partially isolate the hot and cold aisles. Full isolation of the hot and cold aisles, along with the addition of the VFDs on the CRAH units would further improve the efficiency of this data center.

3.6 IGPP

The calculated PUE for this facility is 1.72. This number was computed by extending what is known about the data center to the other small loads served by the building's 135 ton chiller. The large chiller operates much of the year at low load (about 17 tons) to serve these loads. The use of the chiller for this data center, as well as for a smaller data center and a lab in the same building, must be addressed as one issue.

4. CONCLUSIONS

This analysis has shown that the SDSC existing data center has a good PUE, which will be improved further as modifications are made to the facility. The PUE of the new addition to the SDSC will be somewhat better than the current data center, dependent upon its use of UPS equipment.

The other data centers reviewed have a wide variety of PUEs. Most have a good basis for efficiency because they use the same campus chilled water as SDSC. Many, however, have oversized fans, resulting in a significantly higher PUE. The IGPP has a significantly less efficient chilled water system, which operates most of the year at a low load.

When the different applications of UPS are adjusted for, the SDSC data center is the most efficient of the data centers evaluated.

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APPENDICIES

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Appendix A
Spreadsheet Calculations

UC Data Centers

		Campus	UCSD	UCSD	UCSD	UCSD	UCSD	UCSD	UCSD
		Data Center	Urey Hall	EBU	BSB	IGPP	SDSC Main	SDSC New	SDSC Main @ 3MW IT Load
Building	Location		6th Floor		1st Floor				
Building	Above		5th Floor						
Building	Below		7th Floor						
Building	Exterior Walls		Yes	No	No	Yes	Yes	No	Yes
Data Center	Mainframe								
Data Center	Administrative Functions								
Data Center	Academic Functions								
Data Center	Telcom								
Data Center	Research Clusters								
Data Center	Medical Support								
Data Center	Printers								
Data Center	Data Center Floor Area	sf	1,150	140	406	1,170	14,980	5,000	14,980
Data Center	UPS Floor Area	sf	-	-	-	-	-	-	-
Data Center	Total Floor Area	sf	1,150	140	406	1,170	14,980	5,000	14,980
Data Center	Raised Floor		No	No	No	No	Yes	Yes	Yes
Cooling	Chilled Water - Campus		100%	100%	100%		99%	100%	99%
Cooling	Chilled Water - Local, Air Cooled		0%	0%	0%		0%	0%	0%
Cooling	DX - Air Cooled		0%	0%	0%		1%	0%	1%
Cooling	DX - Dry Cooler		0%	0%	0%		0%	0%	0%
Cooling	DX - Cooling Tower		0%	0%	0%		0%	0%	0%
UPS-1	In Data Center				No	Yes	No	No	No
UPS-1	Output Capacity	kVA			15	30	2000	1399	2232
UPS-1	Output Capacity	kW			14.9	27	1980	1385	2210
UPS-1	Output Display Reading	kW			9.1	23.2	323	1385	2210
UPS-1	Output Display Reading	kVA			9.6	24.4	336.5	1442.7	2232
UPS-1	Input Display Reading	kW					351	1399	2232
UPS-1	Percent Load				64.0%	81.3%	16.8%	103.1%	100.0%
UPS-1	Curve Fit Efficiency				90.2%	90.8%	86.1%	90.9%	91.0%
UPS-1	Metered UPS Losses	kW			0	0	28	13.98989899	22.3
UPS-1	Calculated Average UPS Losses	kW			0.9	2.1	44.9	126	198.9
UPS-1	Implied Efficiency						92%	99%	99%
UPS-1	Projected Annual Output	kWh/yr			79,716	203,232	2,829,480	12,132,600	19,359,600
UPS-1	Projected Annual Input	kWh/yr			87,600	221,628	3,468,084	13,358,912	21,297,516
UPS-2	In Data Center						No		
UPS-2	Output Capacity	kVA							
UPS-2	Output Capacity	kW							
UPS-2	Output Display Reading	kW					240		
UPS-2	Output Display Reading	kVA					252.6		0
UPS-2	Input Display Reading	kW					261		
UPS-2	Percent Load								
UPS-2	Curve Fit Efficiency						0.838		0.838
UPS-2	Metered UPS Losses	kW					21		0
UPS-2	Estimated UPS Losses	kW					38.9		0
UPS-2	Implied Efficiency						92%		
UPS-2	Projected Annual Output	kWh/yr					2,102,400		-
UPS-2	Projected Annual Input	kWh/yr					2,627,124		-
Lighting	Installed Lighting Load	kW	1.00	0.28	0.75	1.75	16.60	5.00	16.60
Lighting	Lighting Density	W/sf	0.9	2.0	1.8	1.5	1.1	1.0	1.1
Lighting	Control		Manual	Manual	Manual	Manual	Manual	Manual	Manual
Lighting	Estimated On Time		5%	5%	5%	10%	75%	75%	75%
Lighting	Average Lighting Load	kW	0.1	-	-	0.2	12.5	3.8	12.5
Lighting	Annual Energy Use	kWh/yr	876	-	-	1,752	109,500	33,288	109,500
Process Load	UPS-1 Output	kW	0.0	0.0	9.1	23.2	323.0	1385.0	2210.0
Process Load	UPS-2 Output	kW	0.0	0.0	0.0	0.0	240.0	0.0	0.0
Process Load	Computer load not on UPS	kW	34.0	46.0	8.0	24.4	200.0	0.0	790.0
Process Load	UPS Losses	kW	0.0	0.0	0.9	2.1	49.0	14.0	22.3
Process Load	Distribution Losses	kW	1.7	2.3	0.9	2.4	38.2	69.3	150.0
Process Load	Lighting Load (Average)	kW	0.1	0.0	0.0	0.2	12.5	3.8	12.5
Process Load	Total Data Center Load	kW	35.8	48.3	18.9	52.3	862.7	1472.1	3184.8
Process Load	Load Density	W/sf	31.1	345	46.6	44.7	57.6	294.4	212.6
Total Load	Computing Load	kW	34.0	46.0	17.1	47.6	763.0	1385.0	3000.0
Total Load	UPS + PDU + Dist. Losses	kW	1.7	2.3	1.8	4.5	87.2	83.3	172.3
Total Load	Lighting (average)	kW	0.1	0.0	0.0	0.2	12.5	3.8	12.5
Total Load	**Fans**	kW	12.8	3.9	15.0	6.6	69.8	56.1	127.1
Total Cooling	Total Electric Load to Cool	kW	48.6	52.2	33.9	58.9	932.5	1528.189899	3311.9
Total Load	Air Conditioning (average)	kW	11.4	11.8	7.7	23.3	214.6	351.0	754.4
Total Load	Total Load	kW	60.0	64.0	41.6	82.2	1147.1	1879.2	4066.3
	Computing (IT) Load	W/sf	29.6	328.6	42.1	40.7	50.9	277	200.3
	Total Electric Load	W/sf	52.2	457.1	102.5	70.3	76.6	375.8	271.5
Electric Balance	Check								
	DCiE Energy (Computing/Total)		0.57	0.72	0.41	0.58	0.67	0.74	0.74
	PUE (Total/Computing)		1.75	1.39	2.44	1.72	1.49	1.35	1.35

Total Load	Computing Load	%	56.7%	71.9%	41.1%	57.9%	66.5%	73.7%	73.8%
Total Load	UPS + PDU + Dist. Losses	%	2.8%	3.6%	4.3%	5.5%	7.6%	4.4%	4.2%
Total Load	Lighting (average)	%	0.2%	0.0%	0.0%	0.2%	1.1%	0.2%	0.3%
Total Load	Fans	%	21.3%	6.1%	36.1%	8.0%	6.1%	3.0%	3.1%
Total Load	Air Conditioning (average)	%	19.0%	18.4%	18.5%	28.3%	18.7%	18.7%	18.6%
Total Load	Total Load	%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Energy Use	Computing Load	kWh/yr	297,840	402,960	149,796	416,976	6,683,880	12,132,600	26,280,000
Energy Use	Electric Losses	kWh/yr	14,892	20,148	15,768	39,420	763,872	729,620	1,509,552
Energy Use	Lighting (average)	kWh/yr	876	-	-	1,752	109,500	33,288	109,500
Energy Use	Fans	kWh/yr	112,128	34,164	131,400	57,816	611,448	491,436	1,113,396
Energy Use	Air Conditioning (average)	kWh/yr	99,864	103,368	67,452	204,108	1,879,896	3,074,760	6,608,544
Energy Use	Total	kWh/yr	525,600	560,640	364,416	720,072	10,048,596	16,461,704	35,620,992
Energy Cost	Computing Load		$ 23,232	$ 31,431	$ 11,684	$ 32,524	$ 521,343	$ 946,343	$ 2,049,840
Energy Cost	Electric Losses		$ 1,162	$ 1,572	$ 1,230	$ 3,075	$ 59,582	$ 56,910	$ 117,745
Energy Cost	Lighting (average)		$ 68	$ -	$ -	$ 137	$ 8,541	$ 2,596	$ 8,541
Energy Cost	Fans		$ 8,746	$ 2,665	$ 10,249	$ 4,510	$ 47,693	$ 38,332	$ 86,845
Energy Cost	Air Conditioning (average)		$ 7,789	$ 8,063	$ 5,261	$ 15,920	$ 146,632	$ 239,831	$ 515,466
Energy Cost	Total		$ 40,997	$ 43,730	$ 28,424	$ 56,166	$ 783,790	$ 1,284,013	$ 2,778,437
Energy Cost	Electric Rate per kWh	SEP	$0.078	$0.078	$0.078	$0.078	$0.078	$0.078	$0.078
DC AC-1	Air Conditioning Unit		CRAH	CRAH	CRAH	CRAH	CRAH	CRAH	CRAH
DC AC-1	Manufacturer		Data Aire	Data Aire	Data Aire	Pomona Air	Liebert	Liebert	Liebert
DC AC-1	Model			DALC-1034-P	DACO-3034 ??		FH740C-ASEI	FH740C-ASEI	FH740C-ASEI
DC AC-1	Cooling Source		Chilled Water - Campus	Chilled Water - Campus	Chilled Water - Campus	Chilled Water - Local, Air Cooled	Chilled Water - Local, Air Cooled	Chilled Water - Local, Air Cooled	Chilled Water - Local, Air Cooled
DC AC-1	Cooling Capacity	ton	50	10	30	32	40	60.80	60.8
DC AC-1	Nominal Airflow	cfm	21,000	4,000	11,700	2,636	16,500	16,500	16,500
DC AC-1	Fan	hp	10.0	3.0	15.0	2.1	10.0	10.0	10.0
DC AC-1	Quantity		2	2	2	5	3	3	6
DC AC-2	Air Conditioning Unit						CRAH	CRAH	CRAH
DC AC-2	Manufacturer						Liebert	Liebert	Liebert
DC AC-2	Model								
DC AC-2	Cooling Source						Chilled Water - Local, Air Cooled	Chilled Water - Local, Air Cooled	Chilled Water - Local, Air Cooled
DC AC-2	Cooling Capacity	ton					40	60.80	60.8
DC AC-2	Nominal Airflow	cfm					16,500	16,500	16,500
DC AC-2	Fan	hp					10.0	10.0	10.0
DC AC-2	Quantity						6	6	6
DC AC-3	Air Conditioning Unit						CRAH	CRAH	CRAH
DC AC-3	Manufacturer						Liebert	Liebert	Liebert
DC AC-3	Model						FH529CVAAEI	FH529CVAAEI	FH529CVAAEI
DC AC-3	Cooling Source						Chilled Water - Local, Air Cooled	Chilled Water - Local, Air Cooled	Chilled Water - Local, Air Cooled
DC AC-3	Cooling Capacity	ton					29	44.08	44.08
DC AC-3	Nominal Airflow	cfm					12,400	12,400	12,400
DC AC-3	Fan	hp					7.5	7.5	7.5
DC AC-3	Quantity						4	4	4
DC AC-4	Air Conditioning Unit						AHU-1/2	AHU-1/2	AHU-1/2
DC AC-4	Manufacturer								
DC AC-4	Model								
DC AC-4	Cooling Source								
DC AC-4	Cooling Capacity	ton							
DC AC-4	Nominal Airflow	cfm					3,500	3,500	3,500
DC AC-4	Fan	hp					35.0	35.0	7.0
DC AC-4	Quantity						1	1	1
DC AC-5	Air Conditioning Unit						(2) Dx units & (1) RTU	(2) Dx units & (1) RTU	(1) RTU
DC AC-5	Manufacturer								
DC AC-5	Model								
DC AC-5	Cooling Source								
DC AC-5	Cooling Capacity	ton					6	6	
DC AC-5	Nominal Airflow	cfm					1,500	1,500	1,500
DC AC-5	Fan	hp					1.5	1.5	1.5
DC AC-5	Quantity						1	1	1
								1.52	1.52
Building AC	OSA from Building Air Handler	cfm	173	21	61	176	2,247	750	2,247
Building AC	Cooling from Building Air	ton	-	-	-	-	4	1	4
Cooling	Total Air Handler Nominal Cooling Capacity	ton	100	20	60	160	486	731	910
Cooling	Total Nominal Airflow	cfm	42,173	8,021	23,461	13,356	205,347	203,850	254,847
Cooling	Total Fan Power	hp	20	6	30	10.25	156.5	156.5	158.5
Cooling	Heat Removal Capacity	kW	352	70	211	563	1,709	2,570	3,200
Cooling	Data Center Load Minus Fans	ton	10	14	5	15	245	419	906
Cooling	Data Center Load Minus Fans	kW	**35.8**	**48.3**	**18.9**	**52.3**	**862.7**	**1472.089899**	**3184.8**
Cooling	Total Load (-Fans) / Heat Removal Capacity		10%	69%	9%	9%	50%	57%	100%
Cooling	Space Capacity kW, Based on 200 W/sf	200	230	28	81	234	2,996	1,000	2,996
Cooling	Nominal Unit Airflow	cfm/sf	36.7	57.3	57.8	11.4	13.7	40.8	17
Cooling	Delta T for Just Data Center Load	F	2.7	18.9	2.5	12.3	13.2	22.7	39.3

Total Cooling	Total Cooling Load Inc. Fans	ton	13.8	14.8	9.6	16.8	265.2	434.6	942
DX Cooling	Cooling Source						DX - Air Cooled	DX - Air Cooled	
DX Cooling	Percent this Source						1%	1%	
DX Cooling	Source Efficiency	kW/ton					1.4	1.4	
DX Cooling	Average Load on this Source	ton	0	0	0	0	2.7	4.3	0
DX Cooling	Average Electric Load of Source	kW	0	0	0	0	3.8	6	0
DX Cooling	Annual Electricity Use	kWh/yr	-	-	-	-	33,288	52,560	-
CHW Cooling	Cooling Source		Chilled Water - Campus	Chilled Water - Campus	Chilled Water - Campus	Chilled Water - Local, Air Cooled	Chilled Water - Campus	Chilled Water - Campus	Chilled Water - Campus
CHW Cooling	Percent this Source		100%	100%	100%	100%	99%	99%	100%
CHW Cooling	Source Efficiency	kW/ton	0.82	0.80	0.80	1.39	0.80	0.80	0.80
CHW Cooling	Average Load on this Source	ton	13.8	14.8	9.6	16.8	262.5	430.3	942
CHW Cooling	Average Electric Load of Source	kW	11.4	11.8	7.7	23.3	210.8	345	754.4
CHW Cooling	Annual Electricity Use	kWh/yr	99,864	103,368	67,452	204,108	1,846,608	3,022,200	6,608,544
Total Cooling	Total Cooling Energy Use	kW	11.4	11.8	7.7	23.3	214.6	351	754.4
Controls	Humidify?		No	No	No	No	No	No	No
Controls	Dehumidify?		No	No	No	No	No	No	No
	Ceiling		No	No	No	No	T Bar, Planum	T Bar, Planum	T Bar, Planum
Generator	Generator Capacity	kW							
	Fire Control								
	Fire Control								

Energy Use	Fans	kWh/yr	112,128	34,164	131,400	57,816	611,448	491,436	1,113,396
Energy Use	Air Conditioning (average)	kWh/yr	99,864	103,368	67,452	204,108	1,879,896	3,074,760	6,608,544
Energy Cost	Fans	$ -	$ 8,746	$ 2,665	$ 10,249	$ 4,510	$ 47,693	$ 38,332	$ 86,845
Energy Cost	Air Conditioning (average)	$ -	$ 7,789	$ 8,063	$ 5,261	$ 15,920	$ 146,632	$ 239,831	$ 515,466
			$ 16,535	$ 10,728	$ 15,510	$ 20,430	$ 194,325	$ 278,163	$ 602,311

Project Savings

Proposed Delta T

Potential Projects

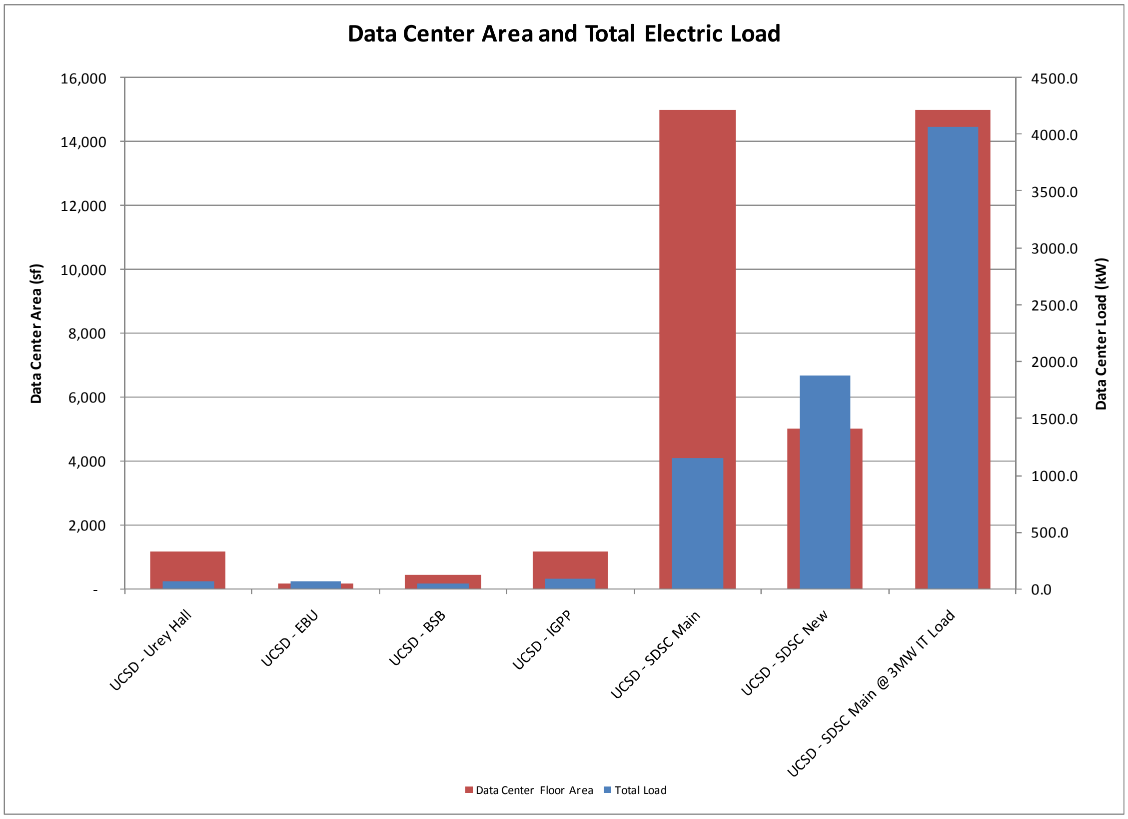
Hot aisle cold aisle physical separation							
Airside Economizer							
Waterside Economizer							
Centralize controls							
VFDs on supply fans							
Convert to central plant cooling							
More Efficient Chillers							
Make condenser water dry cooler water cooled							
Limit Humidification and Dehumidification							

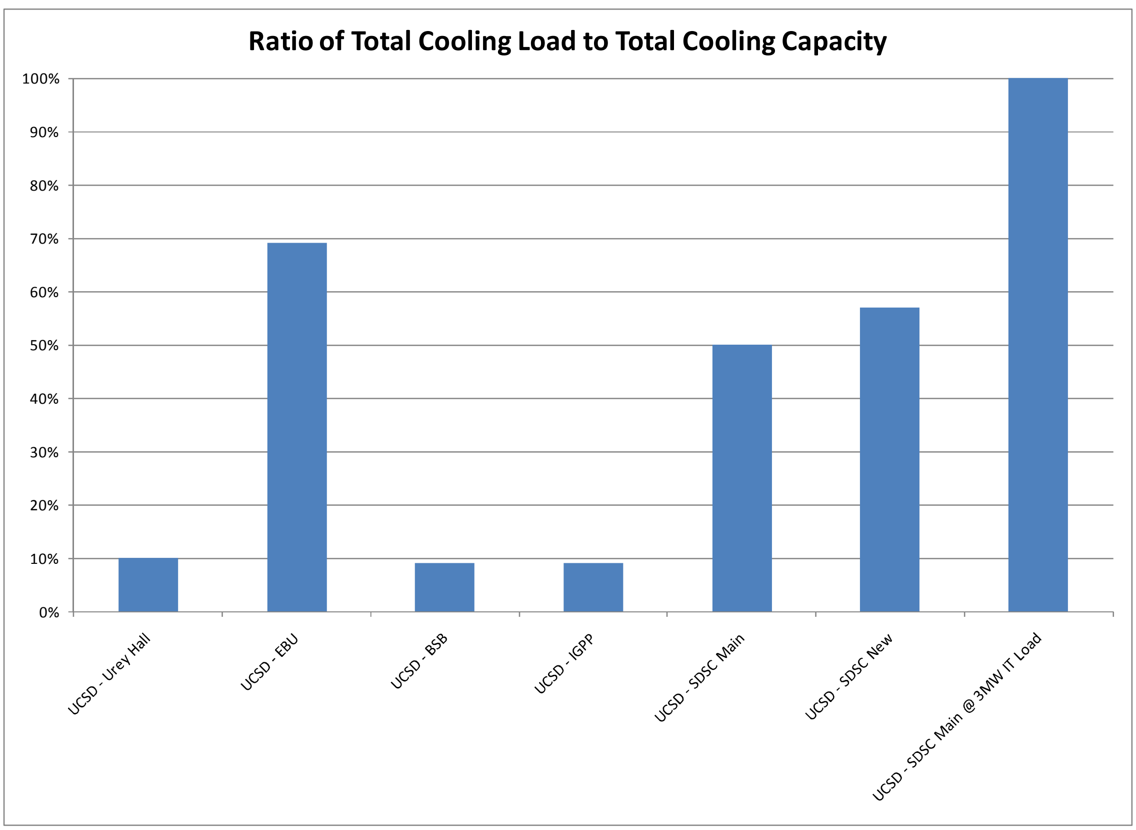
	PDU Loss (% of UPS Output)	5%
Building AC	Default cfm/sf	0.15
Building AC	Cooling (ton) from Delta T (F)	20
	Fan Loading Estimate	80%
	Fan Motor Efficiency Estimate	93%

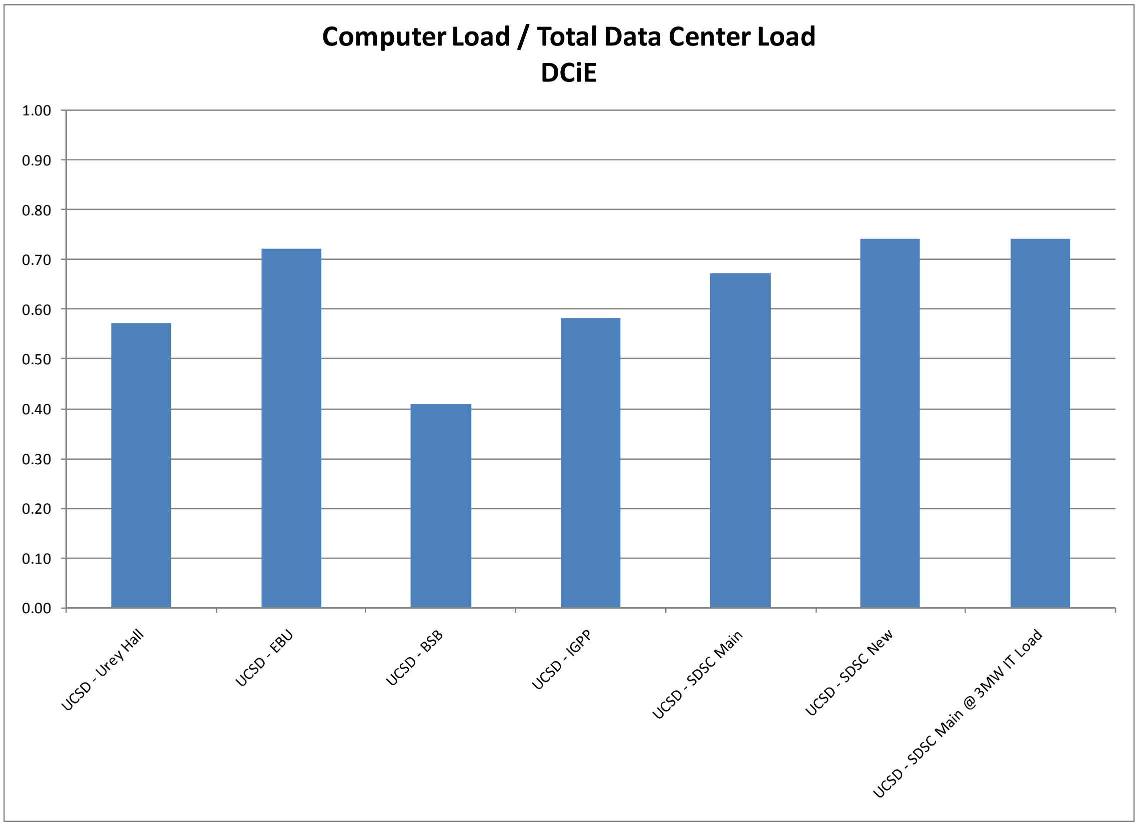
CHW Source Eficiency modified for dedicated pumps (kw/ton)	0.82	0.00	0.82	1.39	0.80	0.80	0.80
Nominal CHW Source Efficiency (kW/ton)	0.80		0.80	1.28	0.80	0.80	0.80
Total Cooling Load, incl. Fans (kW)	48.6	52.1	33.8	59.1	933.5	1529.8	3315.8
Total Dedicated Pump Power (kW)	1.5		0.9	4.9	3.5	3.5	3.5

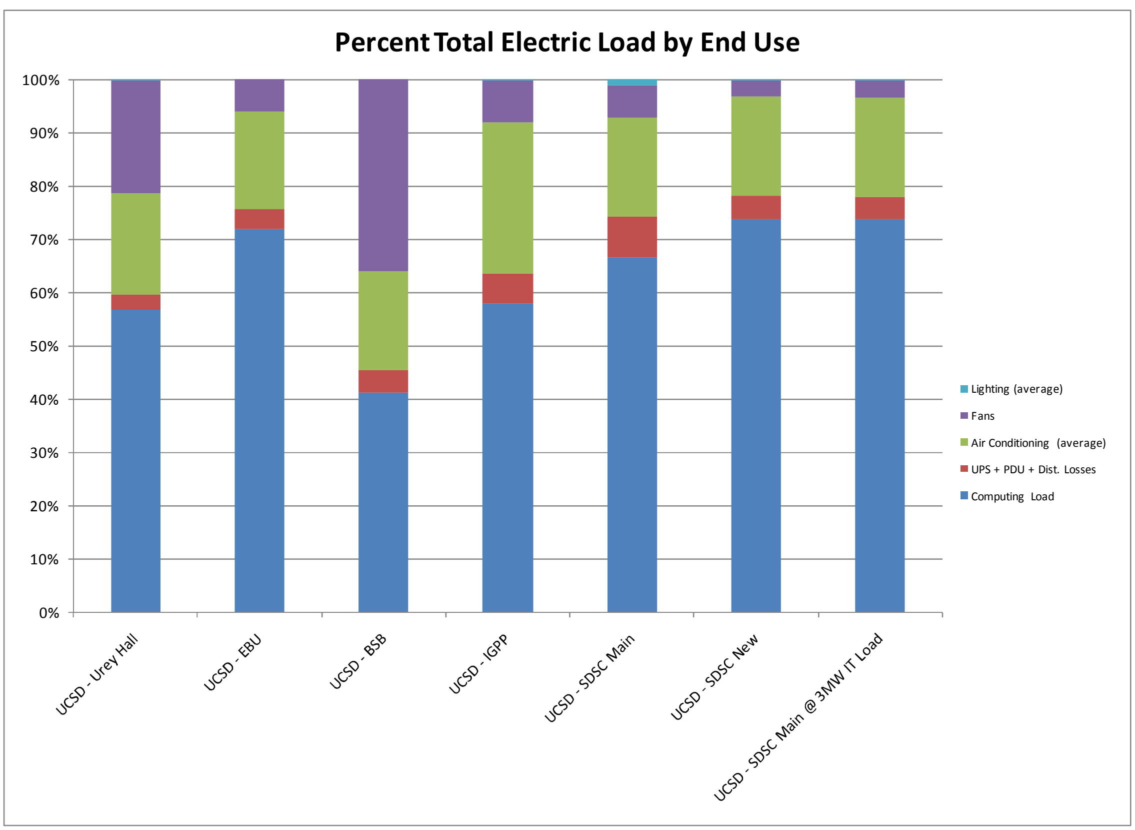
Newcomb | Anderson | McCormick
ENERGY ENGINEERING AND CONSULTING

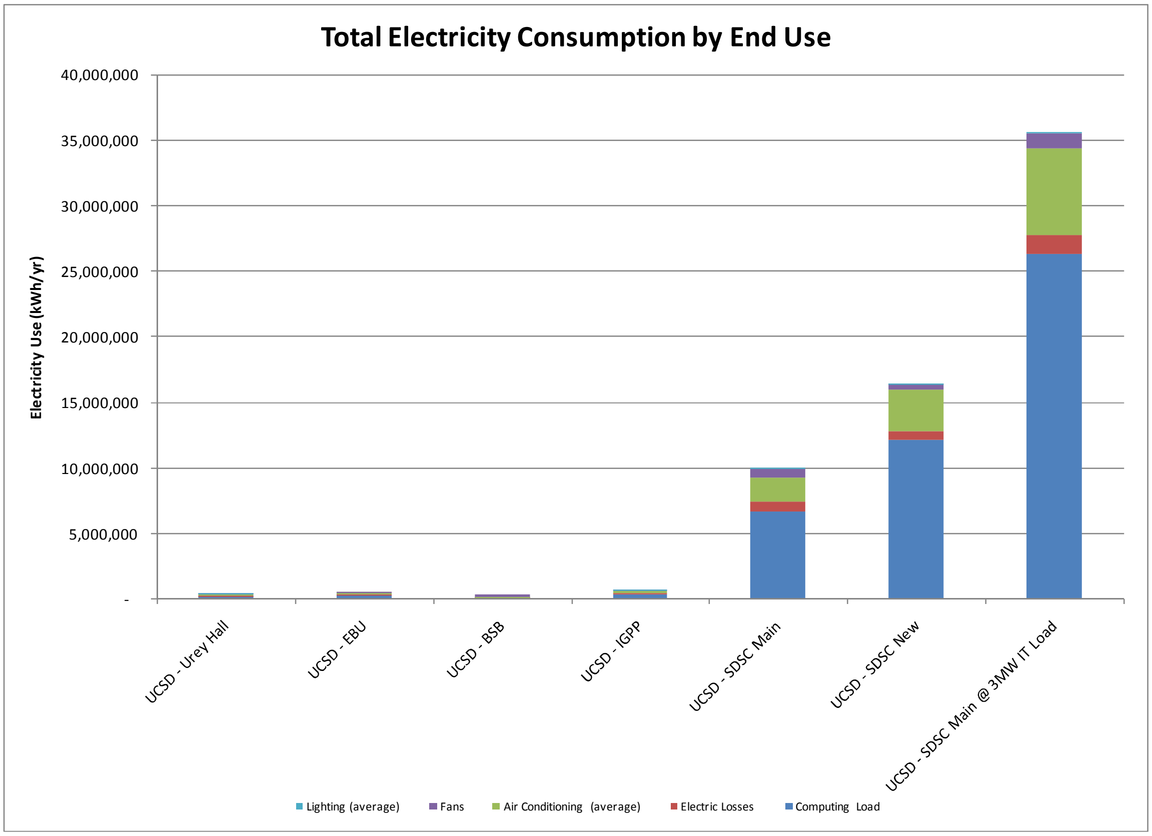
Appendix B
Graphs

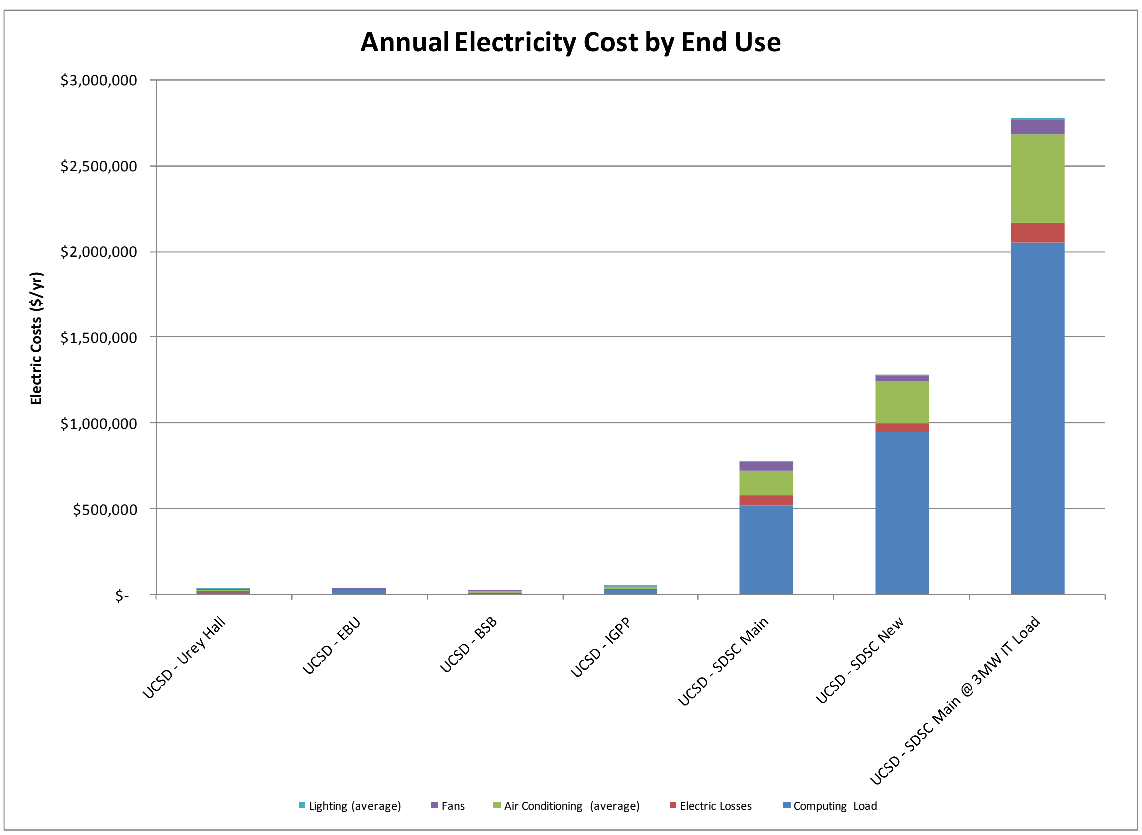

Data Center Area and Total Electric Load
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Data Center Area (sf)
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
Data Center Load (kW)
UCSD - Urey Hall
UCSD - EBU
UCSD - BSB
UCSD - IGPP
UCSD - SDSC Main
UCSD - SDSC New
UCSD - SDSC Main @ 3MW IT Load
Data Center Floor Area
Total Load


Ratio of Total Cooling Load to Total Cooling Capacity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
UCSD - Urey Hall
UCSD - EBU
UCSD - BSB
UCSD - IGPP
UCSD - SDSC Main
UCSD - SDSC New
UCSD - SDSC Main @ 3MW IT Load


Computer Load / Total Data Center Load
DCiE
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
UCSD - Urey Hall
UCSD - EBU
UCSD - BSB
UCSD - IGPP
UCSD - SDSC Main
UCSD - SDSC New
UCSD - SDSC Main @ 3MW IT Load


Percent Total Electric Load by End Use
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
UCSD - Urey Hall
UCSD - EBU
UCSD - BSB
UCSD - IGPP
UCSD - SDSC Main
UCSD - SDSC New
UCSD - SDSC Main @ 3MW IT Load
Lighting (average)
Fans
Air Conditioning (average)
UPS + PDU + Dist. Losses
Computing Load


Total Electricity Consumption by End Use
Electricity Use (kWh/yr)
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
UCSD - Urey Hall
UCSD - EBU
UCSD - BSB
UCSD - IGPP
UCSD - SDSC Main
UCSD - SDSC New
UCSD - SDSC Main @ 3MW IT Load
Lighting (average)
Fans
Air Conditioning (average)
Electric Losses
Computing Load


Annual Electricity Cost by End Use
Electric Costs ($/yr)
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$-
UCSD - Urey Hall
UCSD - EBU
UCSD - BSB
UCSD - IGPP
UCSD - SDSC Main
UCSD - SDSC New
UCSD - SDSC Main @ 3MW IT Load
Lighting (average)
Fans
Air Conditioning (average)
Electric Losses
Computing Load