REPORT

Strategic Energy Plan for University of California Data Centers

Final

Prepared for

University of California
Office of the President

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PREFACE

This report was produced by Newcomb Anderson McCormick for the University of California Office of the President.

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1. EXECUTIVE SUMMARY

The Regents of the University of California adopted the Policy on Sustainable Practices in March 2007. This policy states that the University will develop a Strategic Energy Plan (SEP) for implementing energy efficiency projects in existing buildings. The initial goal for the retrofit projects is to reduce systemwide, growth-adjusted energy consumption by 10% or more by 2014 from the year 2000 base consumption level.

As an extension of the UC Strategic Energy Plan, UC Office of the President has sponsored a study of campus data centers. Data centers are typically the most energy intensive areas on a campus. This study evaluates the potential for retrofit energy efficiency retrofit projects in the mechanical and electrical systems of campus data centers.

The campuses are already pursuing efficiency projects related directly to the computing loads, such as server virtualization and centralized PC power management software. There are many other opportunities to pursue energy efficiency in the procurement of IT equipment by selecting the right power supplies, UPS systems, efficient displays and thin clients.

Fifteen data centers at nine University of California campuses and medical centers were surveyed for this report. The data centers range in size from 1,000 to 10,000 square feet and total about 56,000 square feet.

In these fifteen data centers, the total electric load from computing equipment is approximately 2,000 kW. With distribution losses, UPS losses, lighting and fan loads, this load increases to approximately 2,600 kW. The electricity required to remove this heat with air conditioning totals roughly 700 kW, giving a total data center load of roughly 3,300 kW, or 3.3 MW. Data center loads operate continuously year-round, resulting in a total electricity use of about 29 million kWh/yr, at a total cost of over $2.7 million per year.

This report identifies the potential for energy efficient retrofits in the mechanical and electrical systems at these data centers, as summarized in Table 1.1. Recommended measures include physical separation of hot and cold aisles (Measure 1), installing airside (Measure 2) or waterside (Measure 3) economizers, and improving the efficiency of existing air conditioning equipment (Measure 4). At each data center, the savings and cost reflect the implementation of one or more of these measures, as deemed appropriate for that data center. These are preliminary cost and savings estimates, in line with the Strategic Energy Plan project evaluation.

The savings and costs presented in Table 1.1 are based on a specific combination of the potential measures at each data center that appears most attractive, although a data center may pursue a different combination to meet its particular needs. Based on these preliminary assessments, it is estimated that there is potential to save 6.0 million kWh and $570,000 per year, at an implementation cost of $4.3 million. Excluding any incentive funding available from the UC/CSU/IOU Partnership Program, the resulting simple payback is 7.6 years.

The anticipated 2009-11 Partnership incentive for these projects is a payment of $0.24 for every kWh saved in a year of operation. This is applicable to the campuses served electricity by IOU/UC/CSU Partnership utilities PG&E, SCE and SDG&E. Incentives from the publically owned utilities (SMUD, LADWP and City of Riverside) are assumed for simplicity to be at the same levels, as was assumed for other Strategic Energy Plan projects, although this is yet to be determined. The economics of the projects with the incentives factored in are shown in Table 1.2. The potential utility funding of $1.4 million reduces the campus net simple payback to 5.1 years.

Note that there are significant opportunities to reduce electricity use in other aspects of the data center operations in addition to the retrofit projects addressed in this report. These include the purchase of energy efficient equipment on a replacement basis (power supplies, power distribution units, uninterruptible power supplies, monitors, backup systems), the implementation of software solutions (server virtualization and power management software), and campus-wide approaches such as reducing distributed data closets (particularly when they cause large air handlers to operate continuously) and encouraging new computing capacity to be installed in the data centers.

There are also no cost measures which the campuses can implement, such as relaxing or eliminating humidity control, as some campuses have done already, and relaxing temperature setpoints. Finally, since the data centers are dynamic facilities, planned growth should be taken into account when implementing these projects. It is anticipated that these projects will both improve the efficiency and increase the capacity of the campus data centers.

Table 1.1: Recommended Project Cost and Savings by Data Center

Campus	Savings kWh/yr	Savings $/yr	Cost ($)	Simple Payback (yrs)
Berkeley Campus				
Measure 1 + 3 + 4 Savings	1,925,389	$ 159,807	$ 953,865	6.0
Davis Campus				
Measure 1 + 3 Savings	588,458	$ 52,373	$ 374,653	7.2
Davis Medical Center - ASB				
Measure 1 + 3 Savings	582,834	$ 51,872	$ 428,436	8.3
Davis Medical Center - Davis Tower				
Total Measure 1 Savings	43,800	$ 3,898	$ 11,012	2.8
Irvine - Berkeley Place				
Measure 1 + 2 Savings	211,214	$ 27,880	$ 207,383	7.4
Irvine - NACS				
Measure 1 + 3 Savings	398,796	$ 52,641	$ 492,012	9.3
Irvine MC - Data Center				
Measure 1 + 3 + 4 Savings	284,317	37,530	328,013	9
Los Angeles - Math Science				
Total Measure 1 Savings	395,952	$ 34,844	$ 231,211	6.6
Los Angeles MC - Oppenheimer				
Measure 1 + 3 Savings	778,925	$ 68,545	$ 669,946	9.8
Los Angeles MC - CHS Westwood				
Total Measure 1 Savings	22,776	$ 2,004	$ 11,931	6.0
Los Angeles MC - Reagan B				
Total Measure 1 Savings	43,450	$ 3,824	$ 17,632	4.6
Los Angeles MC - Reagan 3				
Total Measure 1 Savings	36,967	$ 3,253	$ 17,632	5.4
Los Angeles MC - Santa Monica				
Total Measure 1 Savings	28,382	$ 2,498	$ 9,636	3.9
Riverside				
Total Measure 1 Savings	150,847	$ 9,805	$ 147,809	15.1
Santa Cruz				
Measure 1 + 3 Savings	554,992	59,384	432,979	7
Totals	**6,047,099**	**$ 570,158**	**$ 4,334,149**	**7.6**

Measure 1. Hot and Cold Aisle Physical Separation
Measure 2. Utilize Airside Economizers for Free Cooling
Measure 3. Utilize Waterside Economizers for Free Cooling
Measure 4. Utilize Energy Efficient Air Conditioning Equipment

Table 1.2 Recommended Project Cost and Savings By Data Center with Incentives

Campus	Savings		Cost ($)	Incentive ($)	Net Cost ($)	Simple Payback (yrs)
	kWh/yr	$/yr				
Berkeley Campus						
Measure 1 + 3 + 4 Savings	1,925,389	$ 159,807	$ 953,865	$ 462,093	$ 491,772	3.1
Davis Campus						
Measure 1 + 3 Savings	588,458	$ 52,373	$ 374,653	$ 141,230	$ 233,423	4.5
Davis Medical Center - ASB						
Measure 1 + 3 Savings	582,834	$ 51,872	$ 428,436	$ 139,880	$ 288,556	5.6
Davis Medical Center - Davis Tower						
Total Measure 1 Savings	43,800	$ 3,898	$ 11,012	$ 2,202	$ 8,810	2.3
Irvine - Berkeley Place						
Measure 1 + 2 Savings	211,214	$ 27,880	$ 207,383	$ 50,691	$ 156,692	5.6
Irvine - NACS						
Measure 1 + 3 Savings	398,796	$ 52,641	$ 492,012	$ 95,711	$ 396,301	7.5
Irvine MC - Data Center						
Measure 1 + 3 + 4 Savings	284,317	$ 37,530	$ 328,013	$ 68,236	$ 259,777	6.9
Los Angeles - Math Science						
Total Measure 1 Savings	395,952	$ 34,844	$ 231,211	$ 95,028	$ 136,183	3.9
Los Angeles MC - Oppenheimer						
Measure 1 + 3 Savings	778,925	$ 68,545	$ 669,946	$ 186,942	$ 483,004	7.0
Los Angeles MC - CHS Westwood						
Total Measure 1 Savings	22,776	$ 2,004	$ 11,931	$ 5,466	$ 6,465	3.2
Los Angeles MC - Reagan B						
Total Measure 1 Savings	36,967	$ 3,253	$ 17,632	$ 8,872	$ 8,760	2.7
Los Angeles MC - Reagan 3						
Total Measure 1 Savings	28,382	$ 2,498	$ 9,636	$ 6,812	$ 2,824	1.1
Los Angeles MC - Santa Monica						
Total Measure 1 Savings	28,382	$ 2,498	$ 9,636	$ 6,812	$ 2,824	1.1
Riverside						
Total Measure 1 Savings	150,847	$ 9,805	$ 147,809	$ 36,203	$ 111,606	11.4
Santa Cruz						
Measure 1 + 3 Savings	554,992	$ 59,384	$ 432,979	$ 133,198	$ 299,781	5.0
Totals	**6,047,099**	**$ 570,158**	**$ 4,334,149**	**$ 1,451,304**	**$ 2,882,845**	**5.1**

Measure 1. Hot and Cold Aisle Physical Separation
Measure 2. Utilize Airside Economizers for Free Cooling
Measure 3. Utilize Waterside Economizers for Free Cooling
Measure 4. Utilize Energy Efficient Air Conditioning Equipment

2. INTRODUCTION

A number of energy efficiency projects are already underway at the University of California (UC) data centers, particularly on the computing load side. Primary among these is server virtualization, which is being pursued at most campuses. Server virtualization allows fewer computers to perform the same processing work, so that partially loaded and inefficiently cooled computers can be shut down.

Other campus retrofit initiatives for computer equipment include centralized PC power management for computers distributed around the campus, replacement of CRT monitors with LCDs, and migration of servers from inefficient distributed closets to the data centers. New data storage technologies can also improve energy efficiency while providing higher levels of protection.

Campuses can also prioritize energy efficiency at the time of purchase of new equipment. This can include the purchase of new servers which are more energy efficient per processing unit than existing servers, the purchase of servers with more efficient power supplies, and the purchase of more efficient UPS (uninterruptible power supply) systems. For example, line interactive UPS systems offer an efficiency which is typically 5% higher than the double conversion mode UPS systems most campuses use. The purchase of new energy efficient computer equipment usually cannot be justified on the basis of energy savings alone, but the marginal cost of energy efficient equipment is almost always justified in computer equipment, which tends to run heavily loaded and continuously.

In an academic computing work redundancy may not be worth the energy cost. Some UC data centers operate their research servers with no UPS. The NERSC supercomputing facility, for example, uses no backup power supply. If the power goes out, as it does a few times a year, the calculation is just restarted. Servers can be purchased without redundant power supplies in this application as well.

UC should consider a process to create energy efficiency purchasing standards that can be used by each campus for procurement of the best IT and support equipment. The dynamic changes in the field warrant a continuously moving set of guidelines, updated at least annually. The purchasing power of the UC data centers, research strength of the campuses and sustainability targets of the Regents could be combined to drive the market.

Retrofit Projects

This report concentrates on another part of data center energy efficiency, the data center mechanical and electrical infrastructure. The intention of this study is to identify the potential for retrofit projects that can be constructed in the existing data centers to improve energy efficiency and reduce utility costs. These concentrate on efficiently cooling the computer equipment, while meeting its environmental needs. It is anticipated that there will be ancillary benefits to these energy efficiency projects, such as improved control of data center environmental conditions and increased capacity of the data center facilities. In some cases data center electric loads could increase, but the amount of power per computational unit will significantly decrease.

The 2009-11 IOU/UC/CSU Partnership will include utility incentives to reduce the initial cost of these projects at campuses served by PG&E, SCE and SDG&E. The UC Office of the

President will offer loans to the campuses for the remainder of the cost of these energy efficiency projects. The payback on the loans will allow the data centers to implement aggressive energy efficiency programs while maintaining positive cash flow. This will contribute significantly to the UC Regents sustainability targets.

3. UNIVERSITY OF CALIFORNIA DATA CENTER OPERATING CHARACTERISTICS

Fifteen data centers have been surveyed for this portion of the University of California Systemwide Strategic Energy Plan. All of the data centers addressed in this report are Class 1 data centers with mission critical equipment. Most fall in the mid-tier range between 1,000 and 5,000 square feet, with a few of the larger sites considered enterprise-class data centers.

The nameplate and operational information for each of these sites is included in a spreadsheet in Appendix A. Key data is summarized in Table 3.1, including the size of the data centers, their electrical loads, cooling capacity and cooling source.

This section presents the analysis and comparison of the data centers in graphical form. Note that there are significant differences between the data centers, in terms of size, age, computing density, utility cost, and other characteristics. These results are reported together for the sake of convenience in viewing the data, rather than for comparison of one data center to another.

Table 3.1 shows the magnitude of the computing loads at each data center, and how much of that load is backed up by a UPS. The purpose of a UPS is to maintain a continuous supply of power to critical equipment in case the main power supply is interrupted. In some data centers all of the computing loads are served by a UPS, while in others specific servers may not be. For example, a cluster of servers used for research, where a batch process can be rerun in the case of a power interruption, may not justify the cost and complexity of a UPS.

In some data centers a given server may take power from a UPS source and a non UPS source, drawing from both when both are available and switching to either non-UPS power or UPS power if the other is interrupted. The UPS power is typically metered, while the non-UPS power may be metered if it is delivered through a Power Distribution Unit (PDU).

Almost all of the cooling at all data centers is delivered through floor-standing computer room air conditioning (CRAC) units with integral compressors or computer room air handler (CRAH) units with chilled water from an external source. Only a small portion of the cooling load is met by conventional air handlers. Several server clusters use refrigerant cooling delivered by small fan coils mounted over the server cabinets.

The source of the data center cooling is also listed in Table 3.1. Where the cooling load comes from multiple sources, the percent contribution is shown. The types of cooling used in the data centers are described in Section 4.

Table 3.1 also indicates the total air handler cooling capacity for each data center. This represents the nominal capacity of the CRAC/H units, based on their nameplate model units. The cooling capacity of a CRAC/H unit is dependent on the temperature of the air returned to the unit. This nominal capacity can only be achieved in the field when the temperature of the air returned to the units is high, typically above 90ºF. This is discussed more in Section 4.

Table 3.1: Recommended Project Summary

		Berkeley	Davis	Davis Medical Center	Davis Medical Center	Irvine	Irvine	Irvine Medical Center	Los Angeles	Los Angeles Medical Center
		Campus	Campus	ASB	Davis Tower	Berkeley Place	NACS	Data Center	Math Science	Oppenheimer
Location		Top Floor	First Floor	First Floor	Middle Floor	First Floor	First Floor	Fifth Floor	Fourth Floor	First Floor
Exterior Walls		Yes	Yes	Yes	No	Yes	Yes	Yes	No	No
Printers		No	No	Yes	No	Yes	No	Yes	No	No
Total Floor Area	**sf**	10,573	3,241	4,600	960	2,185	2,517	3,274	6,443	10,480
Raised Floor		Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Total UPS Output	**kW**	371.8	131.1	197.4	60.0	43.0	142.4	81.4	120.0	183.0
Computer load not on UPS	**kW**	0.0	72.0	0.0	4.6	0.0	5.0	22.0	162.6	0.0
Ceiling		T Bar, No Room Above	Very High, Sloped	T Bar Plenum Rated	No Ceiling	T Bar	T Bar, Plenum	T Bar, Plenum	T Bar, Plenum	T Bar, Very High
Generator Capacity	**kW**	2000	750			125	350	400	2000	
Fire Control		FM 200	Sprinklers	Sprinklers	Sprinklers	Sprinklers	Dry Preaction Sprinklers	Halon	FM 200	Halon
Fire Control				Adding FM 200					Dry Preaction Sprinklers	Sprinklers
Chilled Water - Campus			8%	12%	100%		100%		100%	
Chilled Water - Local, Air Cooled										100%
DX - Air Cooled			92%	88%						
DX - Dry Cooler		100%				100%				
DX - Cooling Tower								100%		
Total Air Handler Nominal Cooling Capacity	**ton**	307	92	110	31	41	140	54	402	178
Total Nominal Airflow	**cfm**	146,439	44,000	43,290	17,094	16,328	50,000	26,050	137,766	66,672
Total Fan Power	**hp**	90	17.2	25	15	15	30	12	60	35
Humidify?		Yes	No	No	No	Yes	No	Yes	Yes	Yes
Dehumidify?		Yes	No	No	No	Yes	No	Yes	Yes	Yes

Table 3.1: Recommended Project Summary (continued)

		Los Angeles Medical Center	Los Angeles Medical Center	Los Angeles Medical Center	Los Angeles Medical Center	Riverside	Santa Cruz	15 Data Centers
		CHS Westwood	Reagan B	Reagan 3	Santa Monica	Statistics	Communications	Total or Average
Location		First Floor	Basement	Third Floor	Basement	First Floor	Basement	
Exterior Walls		No	No	Yes	No	No	No	
Printers		No	No	No	No	Yes	No	
Total Floor Area	**sf**	1,040	1,537	1,537	840	4,190	3,220	**56,637**
Raised Floor		Yes	Yes	Yes	No	Yes	Yes	
Total UPS Output	**kW**	22.8	8.6	15.2	17.9	109.0	161.4	**1,665**
Computer load not on UPS	**kW**	16.0	6.0	11.2	0.0	5.0	0.0	**304**
Ceiling		T Bar	T Bar	T Bar	T Bar	T Bar, Not Plenum Rated	T Bar	
Generator Capacity	**kW**							
Fire Control		Halon	Sprinklers	Sprinklers	Sprinklers	Sprinklers	FM 200	
Fire Control		Sprinklers					Sprinkler	
Chilled Water - Campus		100%	100%	100%	100%	100%	35%	
Chilled Water - Local, Air Cooled								
DX - Air Cooled							65%	
DX - Dry Cooler								
DX - Cooling Tower								
Total Air Handler Nominal Cooling Capacity	**ton**	24	32	32	18	106	85	**1,652**
Total Nominal Airflow	**cfm**	10,656	12,331	12,331	8,126	40,989	46,508	**678,580**
Total Fan Power	**hp**	4	6	6	5	31	26.87	**378**
Humidify?		Yes	Yes	Yes	Yes	Yes	No	
Dehumidify?		Yes	Yes	Yes	Yes	Yes	No	

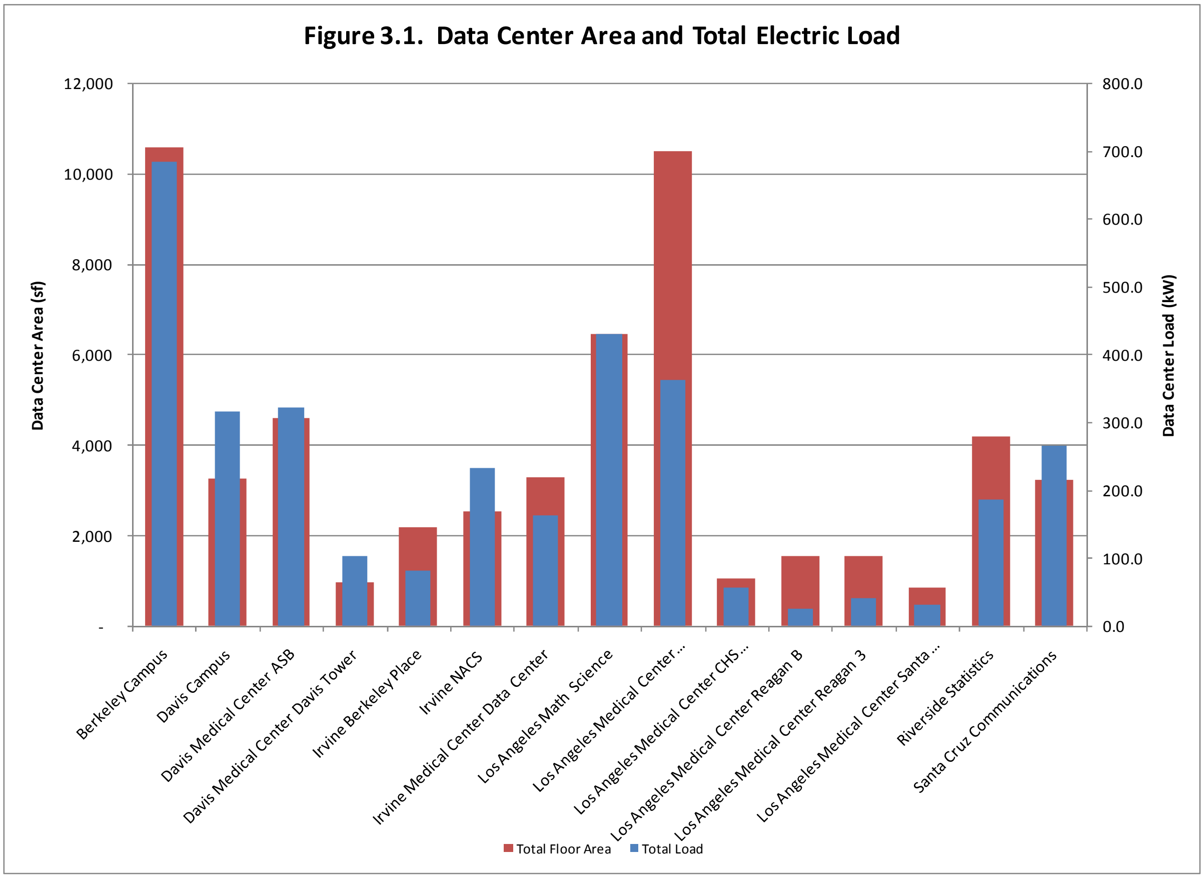
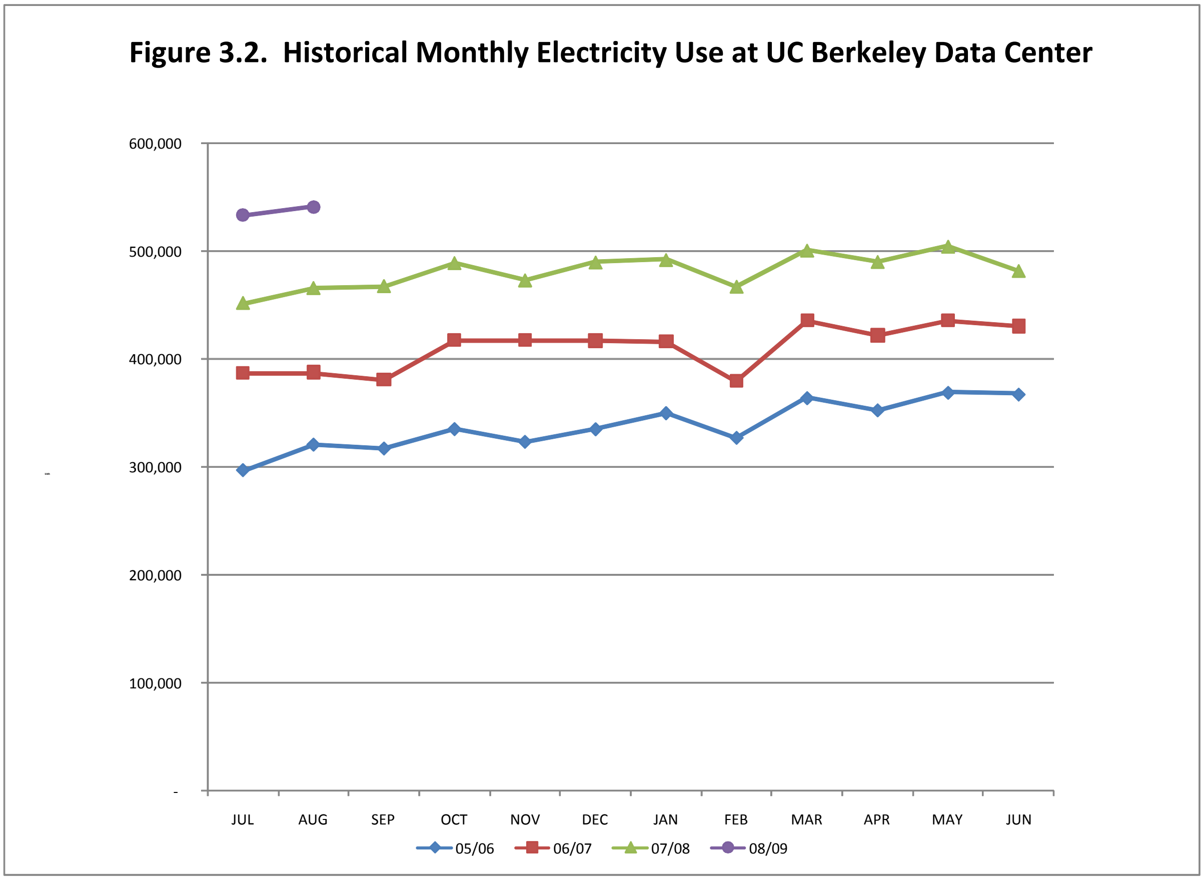


Figure 3.1 indicates the floor area of the data centers. In this report the floor area presented typically includes the area of the room the servers are located in, most of which has a raised floor. The floor area typically does not include the adjacent Network Operations Center where staff is located, unless this area is conditioned by the data center CRAC/Hs. The reported floor area also includes the area of rooms with uninterruptible power supplies when they are separate from the data center. The floor area does not refer just to the area covered by racks or to the area of the whole building.

Figure 3.1 also shows the total electric load of each data center, including the computing loads and losses in the UPS, PDU (power distribution unit) and distribution wiring. These loads include the fans in the servers and fans in the cabinets, as well as the fans in the air handlers and the air conditioning loads.

These loads were determined through instantaneous readings of the UPS outputs (which were observed to be quite unvarying), monitoring loads over several weeks, utilizing past load studies performed by the data centers, assigning part load efficiencies to the UPS according to their loading, and other engineering calculations described in the Appendices and field data sheets. The air conditioning loads were determined through a calculation of the total cooling load and the air conditioning plant efficiency.



Note that while the loads in the data center do not vary much from hour to hour, they are observed to increase over periods of months. An example is the data center at UC Berkeley, where total monthly electricity use is available for the past several years, as shown in Figure 3.2. The electricity use is seen to increase by roughly 20% per year. This data center is only three years old, so it is possible that some of the growth is related to a transition of equipment from the old data center to this facility.

This pace of growth makes much of the past data regarding energy use out of date for analyzing current operation. Further, the loads shown here may be inaccurate in a matter of months. This growth must be accounted for in evaluating data center performance and designing for the future.

Figure 3.3. Data Center Load Density (W/sf)

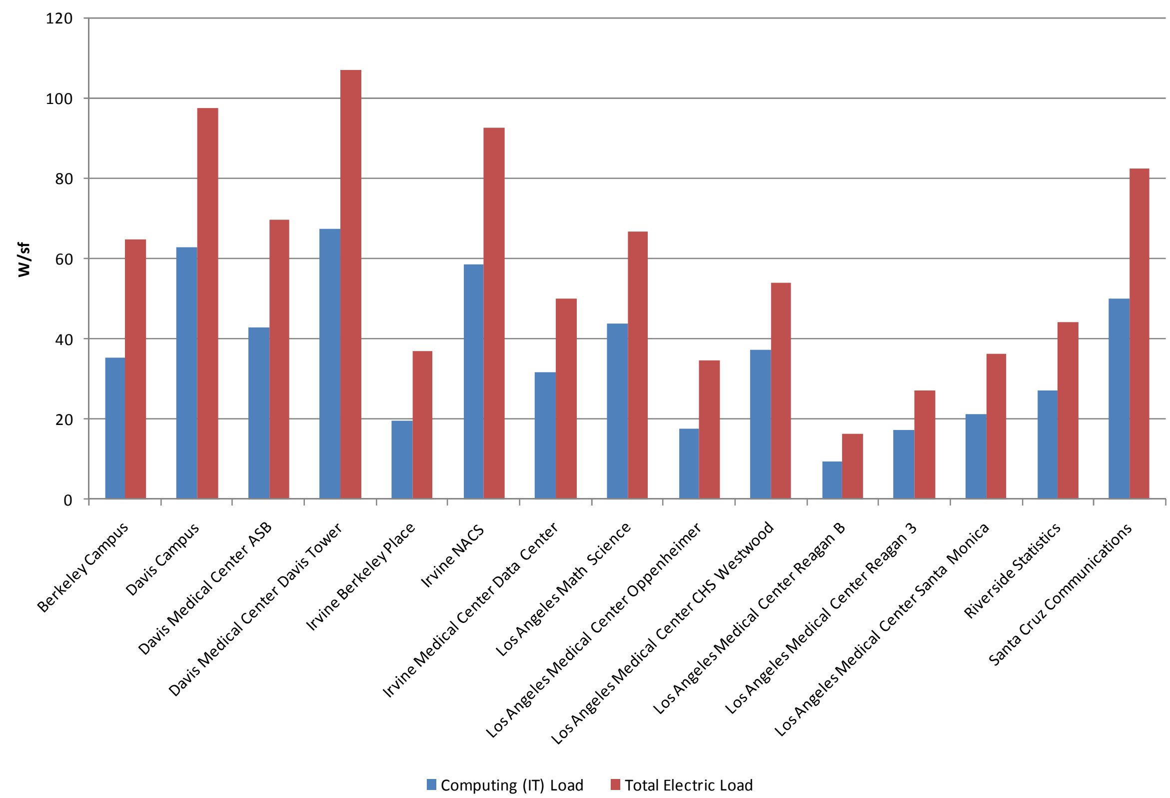


Figure 3.3 compares the power density of different data centers in terms of watts per square foot. It shows the computing (or IT) load separately, as well as the total data center load. The IT load excludes UPS inefficiencies, power distribution losses, and so on, focusing on what is used within the equipment cabinets. The total load numbers include these losses, as well as CRAC/H fans and air conditioning loads. Where the data center is cooled by a large central plant, a portion of the plant is calculated in as part of the electrical load, based on data center load and central plant efficiency.

There is a wide range in IT power density, from 10 to almost 70 W/sf (Watt per square foot). The lower density in some of these (such as the two in Reagan Medical Center) is a function of their recent occupancy and incomplete buildout.

These numbers represent a relatively low density of computer loads relative to some new data centers. There is potential, in terms of floor space and cooling capacity, to add significant new computer loads to most of these data centers, but this must be accompanied by proper airflow management.

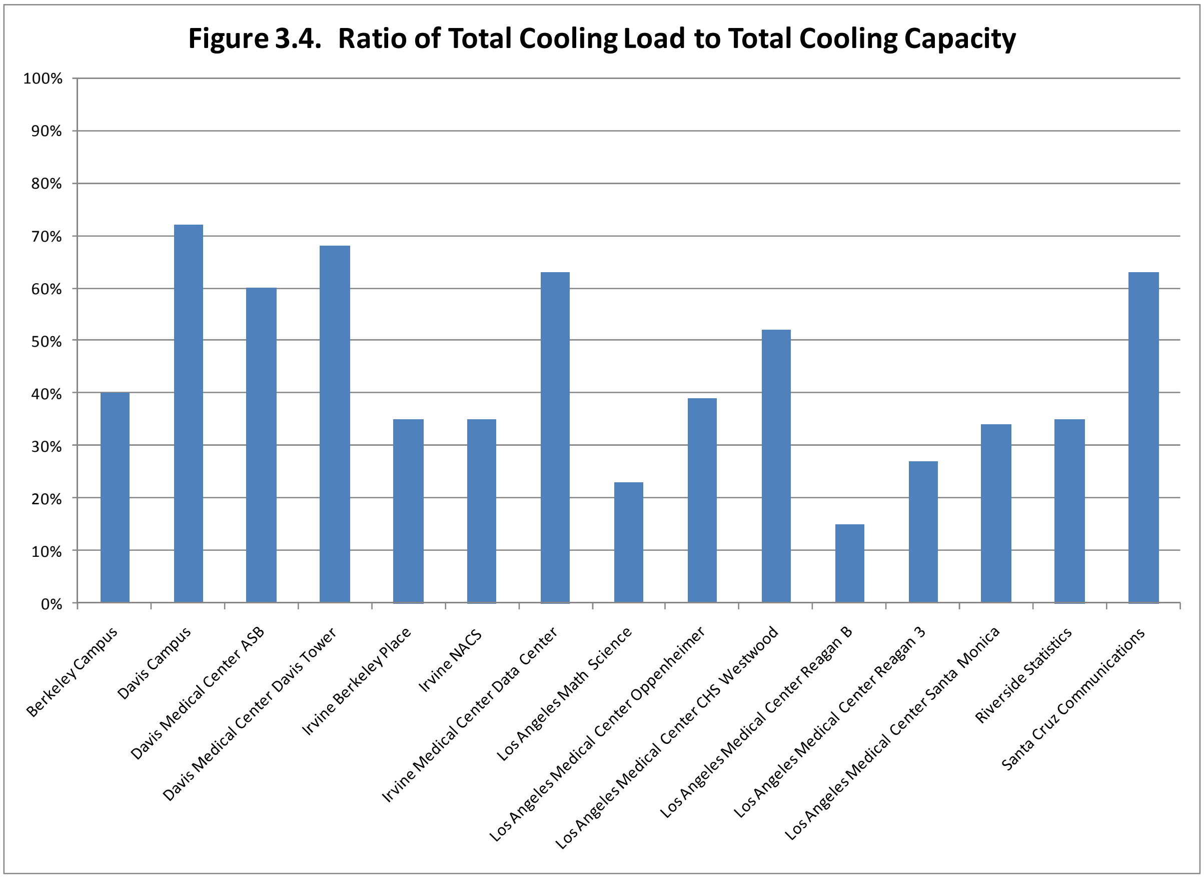
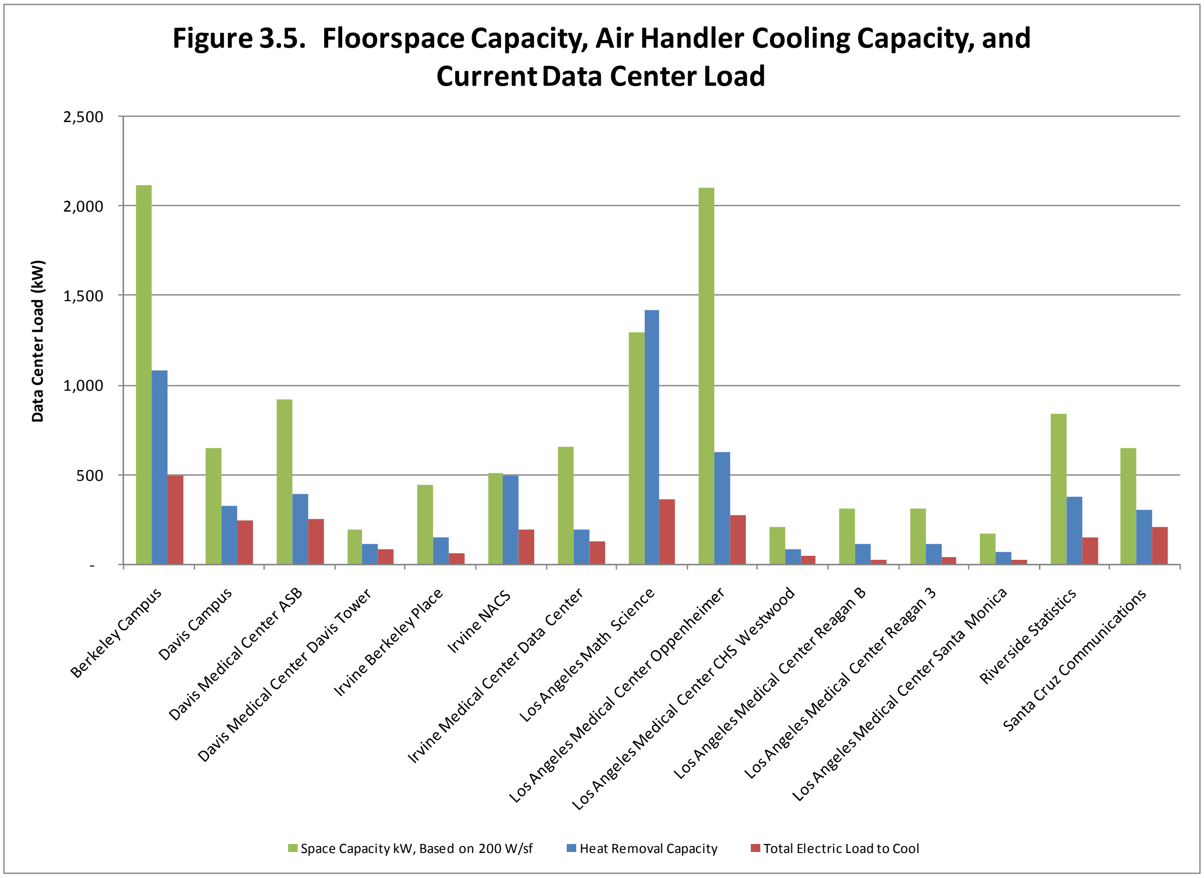


Figure 3.4 shows the percentage of the data center cooling capacity currently being used by the computer equipment. The total cooling load represents the tons of cooling that the installed IT equipment is using.

The cooling equipment capacity is the sum of the nominal cooling tons capacity of all of the computer room air handlers and air conditioners, including split systems serving isolated UPS equipment. The data centers are loaded to between 15% and 70% of their nominal cooling capacity. The total electric load that must be removed by the air conditioning in all 15 data centers is 2,551 kW, which is a cooling load of 726 tons. The total nominal cooling capacity of all of the air conditioning equipment in the data centers is 1,652 tons.

Note that the nominal cooling output of these air conditioning units cannot typically be achieved unless air is returned to the unit at a warm temperature, which cannot be done without the improved airflow control. If proper airflow control is provided, significant additional IT loads can be installed in the data centers without adding more air conditioning equipment.

No determination was made of the electrical system percent loading but a number of data centers are in the process of increasing electrical infrastructure to support future increased loads.



A maximum density of 200 W/sf was chosen as a somewhat arbitrary target for data centers in this report. This is described in Section 4.2 Computer Load Density as the density resulting from 42 servers per cabinet and 25 cabinets per 1,000 square feet. This is a typical density used for design purposes where 40 square feet are assigned to one cabinet. This includes the area needed by the cabinet plus its share of other room area including hot and cold aisles, and other support areas.

Figure 3.5 shows a comparison of the current electric loads in the data center that need to be removed by the air conditioning (including CRAC/H fans) and the magnitude of loads that could be supported by the cooling capacity presently available in the data center, as well as the potential buildout of the site to 200 W/sf.

Figure 3.5 also indicates that the installed load is typically significantly lower than the nominal cooling available and significantly lower than the potential build out based on floor area. In several cases the cooling capacity has already been installed to match the potential floorspace buildout.

These numbers do not necessarily imply that more computing load could be added to any data center without effort. Several factors interact so that it is difficult for the nominal capacity of the air conditioning system to be delivered to the data center. These include the effect of the return air temperature on the nominal capacity, as well as the mixing of the air within the data center. The air conditioning of these data centers is almost all provided by

CRAHs (computer room air handlers, which are cooled by an outside source like chilled water) and CRACs (computer room air conditioners, which house their own compressors).

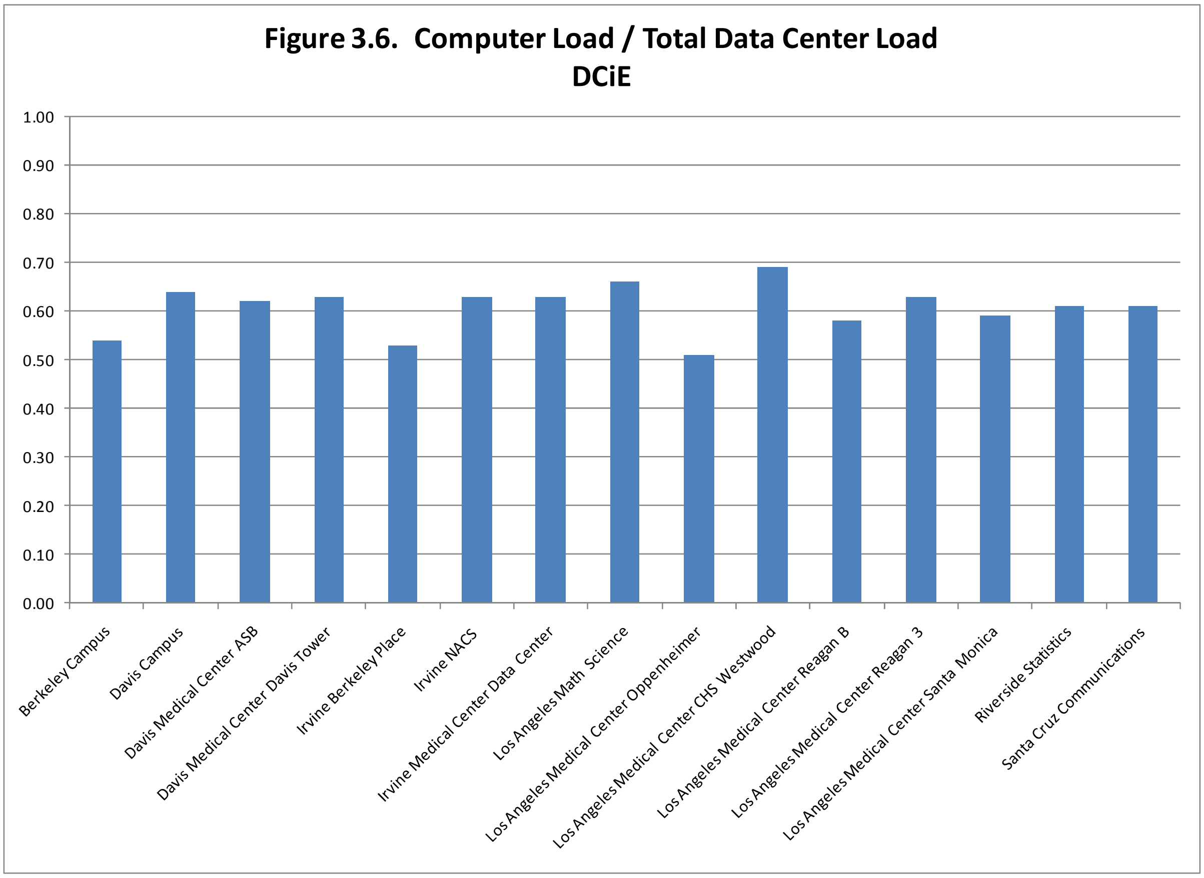


Figure 3.6 shows the ratio of the electricity used by the computing equipment to the total data center electricity use. Losses in the power supply units in the servers are included in the computer load. This is an index of Data Center Efficiency (DCiE), as created by Green Grid. All of the analysis in this report addresses the data center only, not the whole building it is housed in. Where the data center is served by a central chilled water plant, the analysis accounts for the data center's portion of that load.

The UC data centers are all relatively similar in DCiE rating and compare well with many existing commercial data centers. The new data center being planned for UC Berkeley and others under design in California plan to have DCiE ratings of over 0.9. This will be achieved through the separation of hot and cold aisles, air side economizers, high efficiency air handlers instead of CRAHs and an efficient chiller plant. A DCiE of 1.0 is the maximum theoretically possible.

The analysis in this report is largely based on spot measurements or observations of loads, such as at a UPS control panel. In some cases monitoring was performed and it was found that the computing load is quite constant over the week or two of data. The analysis assumes that these computing loads are relatively constant at the level observed throughout the year. It is likely that the loads are growing over the course of the year as new capacity is added. The impact of air conditioning varies throughout the year because the efficiency of the air conditioning systems varies as the outside air temperature varies. The efficiency numbers used in this report for air conditioning system are meant to represent an annual average efficiency.

Figure 3.7. Total Data Center Load / Computer Load
PUE

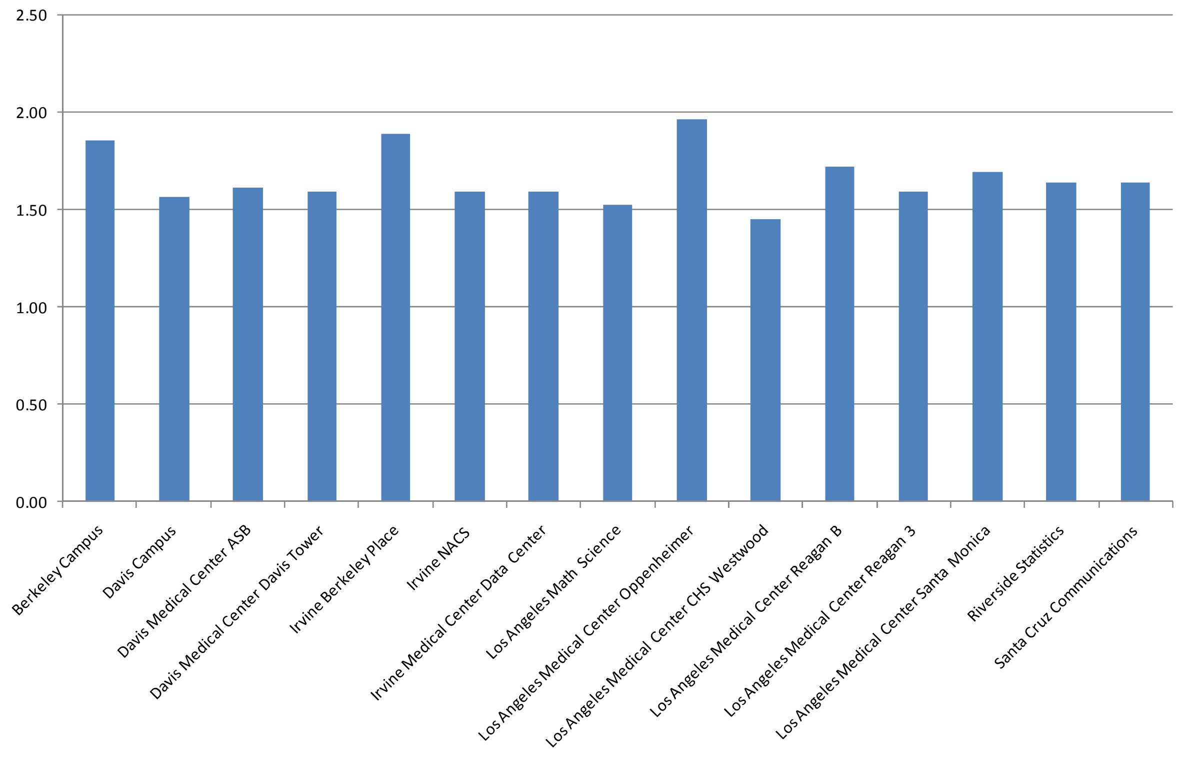
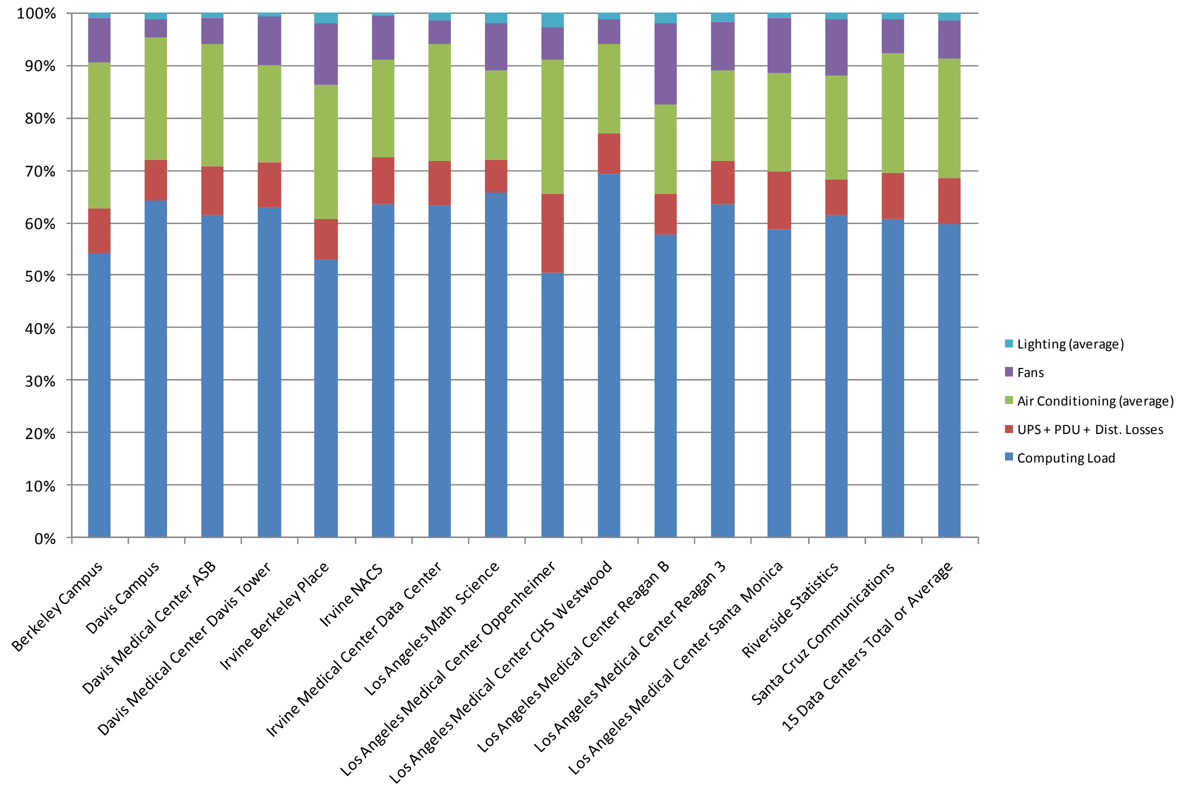


Figure 3.7 shows the Power Usage Effectiveness (PUE) of the data centers. The PUE is the inverse of the DCiE, showing the ratio of total electricity use to the electricity use of the computing equipment.

Figure 3.8. Percent Total Electric Load by End Use



The breakdown of electricity by end use for each of the data centers is shown in Figure 3.8. Note that in the data centers cooled by central plants the electricity used in the plant is included in this breakdown. This graph shows the magnitude of the computing load, the associated electrical losses in the UPS and power distribution, the air conditioning load (including compressors, condensers and pumps), the air handler fans that distribute the air in the data center and the lighting. The UPS is the main load in the distribution losses and its contribution to the overall load can be seen here. The need for this load should be evaluated for the research loads the UPS systems serve.

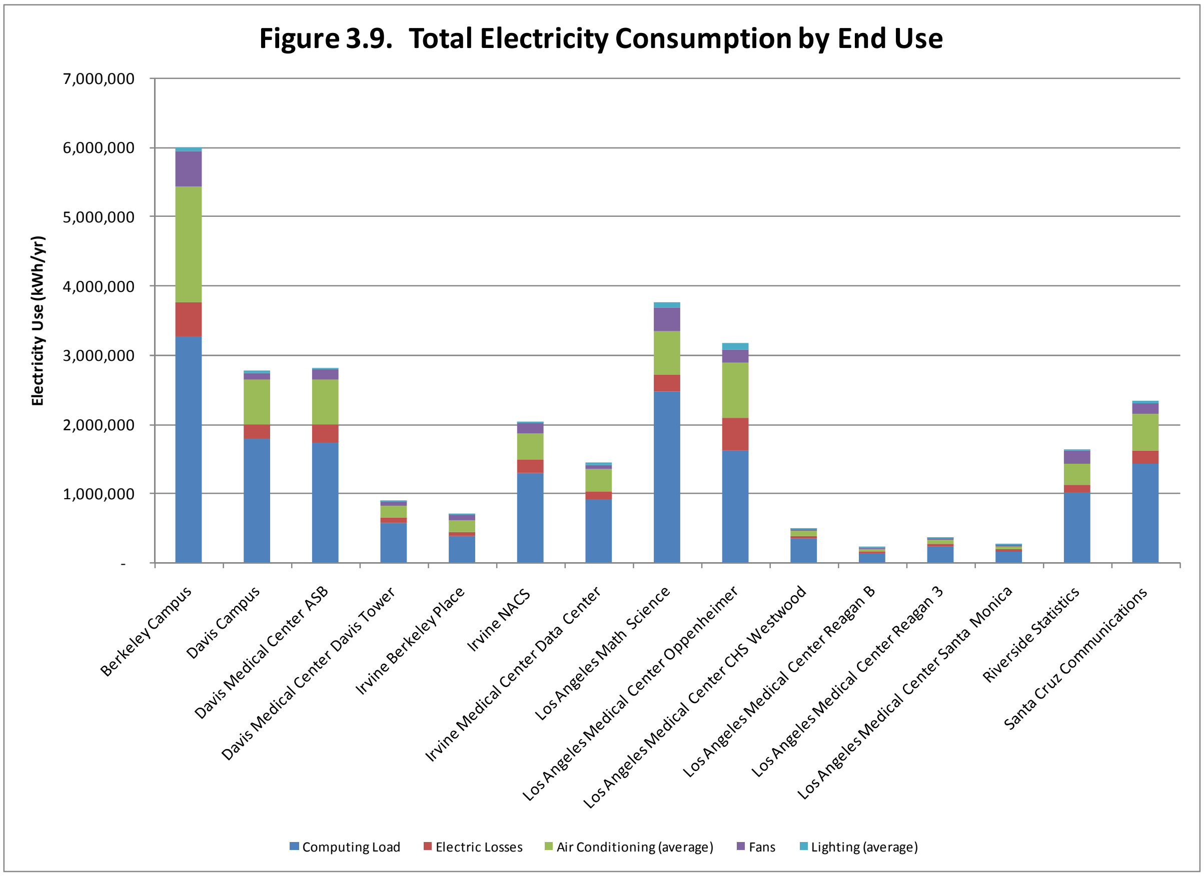


Figure 3.9 shows this breakdown of electricity use in absolute number of kilowatt hours (kWh), rather than in percentages. This figure shows which data centers offer the greatest potential for savings based on existing electricity use of the components.

The data center at UC Berkeley is relatively new and houses the largest computing load. It does not have the benefit of an efficient central chilled water plant, which contributes to its relatively high load.

Figure 3.10. Annual Electricity Cost by End Use

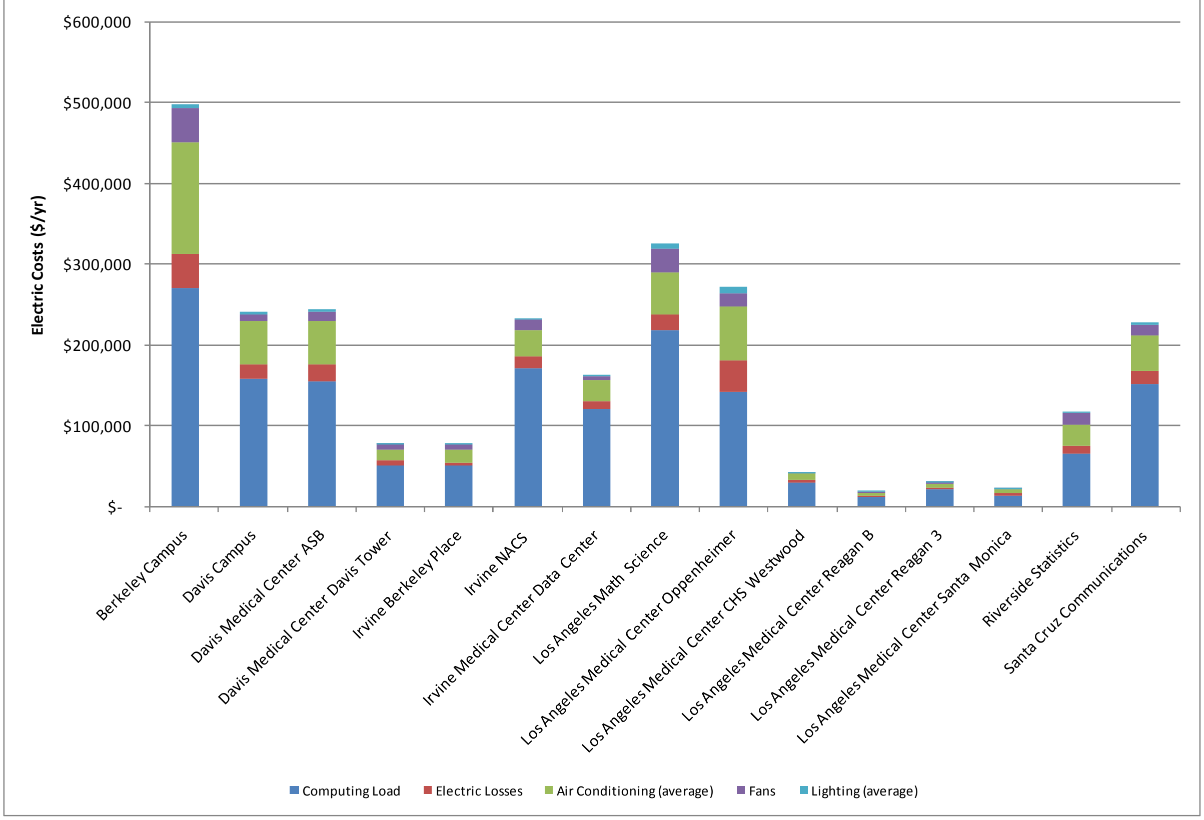


Figure 3.10 shows a similar breakdown, addressing total utility costs. The campuses which pay higher electric rates show greater costs for each component. Note that the standard electric costs used for the Strategic Energy Plan are based on the campus recharge rates. The actual costs may vary for data centers that are not on the main campus electric grid.

This figure shows the overall cost of the components of data center energy use that this report is addressing, namely air conditioning and fans. The total annual amount that all 15 data centers spend on air conditioning is $542,000, and $176,000 on fans, for a total bill of $718,000 per year. The air conditioning compressors represent a higher proportion of the total air conditioning and fan bill at data centers than they do at conventional buildings because the compressor loads at most other campus buildings (classrooms, offices, or laboratories) drops to zero when the outside air is below 55 or 60ºF.

If the load can be reduced in the computing equipment or in supporting equipment such as the UPS, the resulting savings will include the reduced load plus the compressor and fan energy needed to remove that load. The more inefficient the air conditioning system is, the more this increases the importance of using efficient computing equipment.

4. DATA CENTER DESIGN FACTORS

4.1 Temperature and Humidity Requirements

ASHRAE establishes environmental guidelines for Datacom Equipment. The 2004 version of these standards recommends that air entering the IT equipment be at a temperature between 68°F and 77°F and between 40% and 55% relative humidity. This temperature and humidity range is shown in Figure 4.1 in the area bounded by the red lines.

The temperature and humidity operating points and setpoints of the CRAC/H units (where available from the control panel or monitoring systems) are shown in Table 4.1. There is a wide variety of setpoints, often calling for temperatures or humidities, sometimes calling for tighter control than the ASHRAE recommended range, and other times calling for points outside the range. If the units were providing the 2004 ASHRAE prescribed conditions through a well controlled system, they could be set at 72.5ºF with a sensitivity of 4.5ºF and at 47.5% RH with a sensitivity of 7.5% RH.

There is a general capacity in the data centers to operate at warmer temperatures without affecting the performance of the IT equipment.

Note that these conditions address the air entering the cabinets, but the CRAC/H controls typically control the conditions of the air entering the CRAC/H. Any mixing or bypass in the room reduces the effectiveness of this control. Physical separation of the hot and cold aisles will allow the control of air entering the CRAC/Hs because it will be the same condition as the air leaving the CRAC/H.

Table 4.1 Observed Temperature and Humidity Parameters at UC Data Centers

Data Center	Berkeley Campus											Davis Campus		Davis MC ASB			Davis MC Davis Tower			Irvine Berkeley Place	
Unit	1	2	3	4	5	6	7	8	9	10	11	1	3	1	2	12 ton	1	2	3	1	2
Return Air Temperature (F)	72	73	72	72	72	72	70	73	75	72	72	68	67	80	76		76	69	65	69	76
Return Air Humidity	44%	44%	45%	45%	46%	46%	49%	45%	44%	46%	47%	53%	47%	48%	53%	38%	45%	57%	55%	43%	41%
Cooling	50%	75%	25%	25%	25%	50%	75%	100%	100%	50%	50%	Yes	100%	Yes	Yes		Yes	Yes	Yes	100%	0%
Heating	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No		No	No	No	No	No
Humidification (Available/On)	Yes/No	Yes/Yes	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/Yes	Yes/No	Yes/No	No/No	No/No	No/No	No/No		No/No	No/No	No/No	Yes/No	Yes/No
Dehumidification (Available/On)	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	No/No	No/No	No/No	No/No		No/No	No/No	No/No	Yes/Yes	Yes/No
Temperature Setpoint(F)	71	71	71	71	71	71	71	71	71	71	71	65	65	66	66	66	67	66	64	71	75
TS Sensitivity	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	3	2		
Humidity Setpoint	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%					45%				35%	35%
HS Sensitivity	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%					5%					
Notes																					
High Temp Setpoint	73	73	73	73	73	73	73	73	73	73	73	67	67	68	68	68	71	69	66		
Low Temp Setpoint	69	69	69	69	69	69	69	69	69	69	69	63	63	64	64	64	63	63	62		
High Humidity Setpoint	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%					50%					
Low Humidity Setpoint	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%					40%					

Table 4.1 Observed Temperature and Humidity Parameters at UC Data Centers (continued)

Data Center	Irvine NACS		Irvine MC Data Center		Los Angeles Math Science	Los Angeles MC Oppenheimer			Los Angeles MC CHS Westwood		Los Angeles MC Reagan B		Los Angeles MC Reagan 3		Los Angeles MC Santa Monica	Riverside Statistics			Santa Cruz Communications		
Unit	1	4	1	3	1-8	1	5	6	1	2	1	2	1	2	1	1	2	3	1	4	5
Return Air Temperature (F)	72	75	76			67	67	68	64	66	69	65	69	72	66	74	71	73	76	75	76
Return Air Humidity		47%	37%			47%	60%	56%	35%	35%	53%	59%	56%	47%	53%	67%	67%	73%		38%	
Cooling		Yes				77%		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	100%	200%	Stage 1		Yes	
Heating		No				0%		No	No	No	No	No	No	No	No	No	No	No		No	
Humidification (Available/On)		No/No				No/No	Yes/No	No/No	Yes/No	Yes/No	Yes/No	Yes/Yes	Yes/Yes	Yes/No		No/No	No/No	No/No	No/No	No/No	No/No
Dehumidification (Available/On)		No/No	No/No			1	Yes/Yes	No/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No		Yes/Yes	Yes/Yes	Yes/No	Yes/No	No/No	No/No
Temperature Setpoint(F)	72	75		55		65	68	68	62	62	68	68	55	55	66	70	70	73	72	72	72
TS Sensitivity	4	2		2		2	2	2	2	2	2	2	2	2					4	4	4
Humidity Setpoint				45%		50%	50%	50%	50%	50%	45%	45%	50%	50%	45%	33%	40%	50%	45%		35%
HS Sensitivity				5%		10%	5%	5%	10%	10%	5%	5%	5%	5%					10%		10%
Notes					Under Construction	1 of 5 w/o Humidity Control	1 of 2 w Humidity Control	1 of 5 w/o Humidity Control											No Humid. Can dehumidify by slowing fan		
High Temp Setpoint	76	77		57		67	70	70	64	64	70	70	57	57					76	76	76
Low Temp Setpoint	68	73		53		63	66	66	60	60	66	66	53	53					68	68	68
High Humidity Setpoint				50%		60%	55%	55%	60%	60%	50%	50%	55%	55%					55%		
Low Humidity Setpoint				40%		40%	45%	45%	40%	40%	40%	40%	45%	45%					35%		

The CRAC/Hs are controlled according to the return air temperature, which is related to the average room temperature. The air entering some of the servers may be at the average room air temperature. At other servers the air may be below that temperature if they are near the supply air registers. Unfortunately, some servers receive warmer than the average room temperature because of the mixing of hot aisle air into the cold aisles. Without proper separation of the hot and cold aisles, these higher temperatures are dealt with by setting the return air temperature setpoint lower.

The situation is further compounded by the fact that temperature is controlled based upon the return air temperature. So the values recorded are showing that air is returning to the air conditioners/handlers at much lower temperature than required at the inlet to the IT equipment. Some of the centers are actually returning air at the bottom end of the recommended range meaning that all the IT equipment is operating below the recommend range. Return temperatures ideally would be 20 degrees hotter than the supply or in the 90-100 range. Each of the centers has a huge opportunity to raise the bulk temperature in the center.

The ASHRAE Technical Committee TC 9.9 which covers Mission Critical Facilities, Technology Spaces, and Electronic Equipment/Systems has adopted in 2008 an expanded envelope for the allowable temperature and humidity of the air entering the IT equipment. The new envelope has a temperature range from 64.4^{0}F to 80.6^{0}F. This increases the allowable supply air dry bulb temperature by 3.6^{o}F.

The new envelope also includes a dew point limitation to control humidity. The recommended dew point is between 41.9^{0}F and 59^{0}F, with a relative humidity cap at 60% RH. This creates a square box on a psychrometric chart, with a corner taken out of it. This lowers the allowable relative humidity to as low as 30% with the right dry bulb temperature. This new range is shown in Figure 4.1, bounded by the blue lines. This expands the 2004 envelope in all directions.

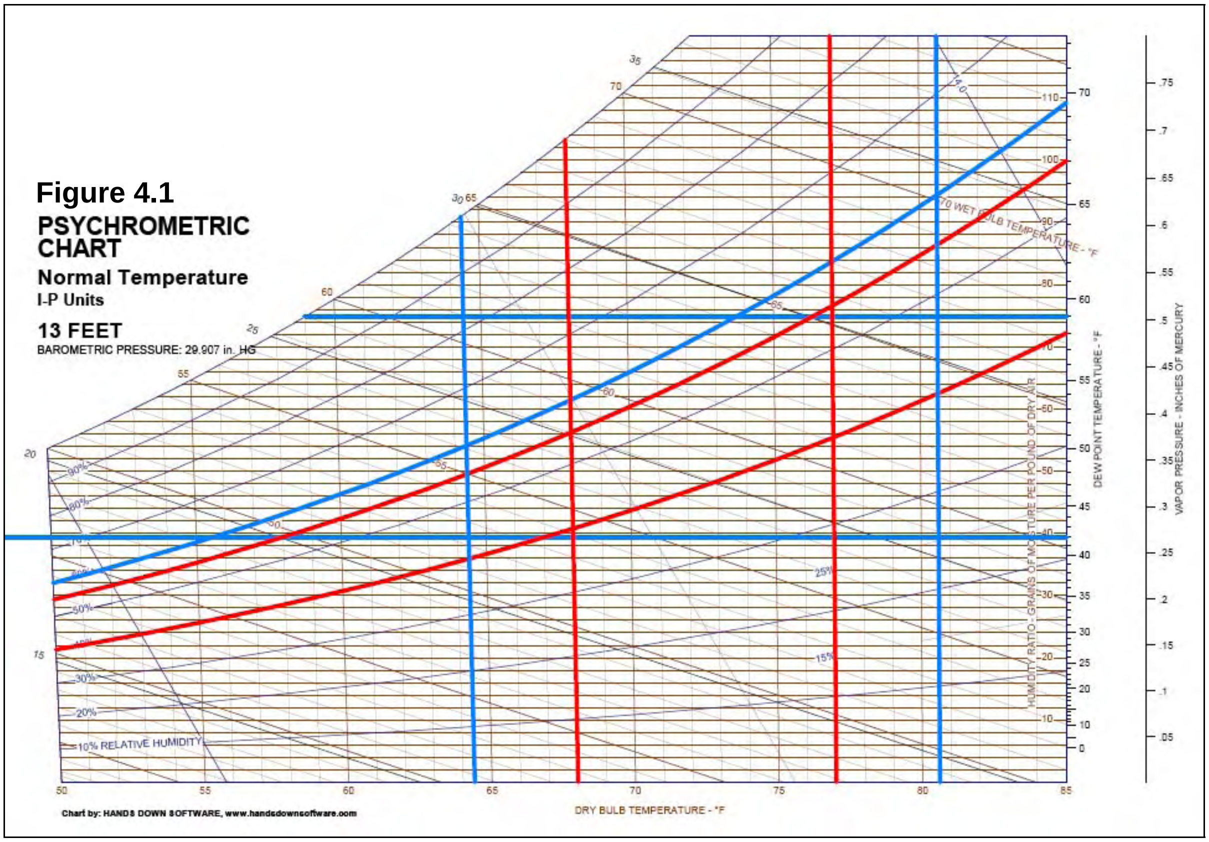


Figure 4.1
PSYCHROMETRIC CHART

This report generally addresses the impact of keeping temperatures below 77^0F, based on the 2004 standards. This is a more conservative approach for calculating savings. In addition, the internal fans which cool servers are sometimes controlled to switch to high speed above 77^0F inlet air temperature. This effect needs to be considered in each data center to calculate the impact of different supply air temperatures.

The campuses are encouraged to implement the 2008 standards by setting the CRAC/H temperature and humidity setpoints and sensitivities to match the new performance envelope. Most CRAC/H units do not have the dew point measuring capability needed to accurately define the new envelope. This may need to be provided by a central supervisory control which can make these measurements and control the CRAC/Hs appropriately.

Humidity guidelines are not necessarily significant for data centers in California. The data center at UC Davis, the two at UC Davis Medical Center, and the one at UC Santa Cruz do not utilize any humidity control. The data center at UC Irvine NACS enables humidification only during dry Santa Ana wind periods. The other data centers utilize their CRACs and CRAHs to control humidity, using the onboard control systems.

The general recommendations in this report address increased central control of the CRAC/Hs. This control can be used to adjust the units consistently to avoid simultaneous humidification and dehumidification (a common data center problem, although not observed in any of the UC data centers), as well as ensuring that the supply air temperatures are properly controlled throughout the data center.

Proper monitoring of humidity can be used to make appropriate control decisions. Data center operators are likely to find that fine control of humidity has little benefit. In many cases it may not be warranted at all. It is unlikely to be warranted for a tighter control than recommended in the new TC9.9 guidelines.

4.2 Computer Load Density

A data center being designed today may be designed for 10 kW cabinets assuming the use of conventional servers (42 servers at 225 W typical load each) or 20 or more kW cabinets assuming the use of blade servers. California utilities use 225 W as a guideline for the average load of a typical server, although the nameplate on some may be higher. A number of UC data centers already include some 10 kW cabinets. These are typically found in new research clusters. The density of legacy server cabinets is significantly lower. The ASHRAE Thermal Guidelines book includes a form for server manufacturers to use to report typical power draw as well as nameplate power. These actual loads should be used whenever available.

Densities of 20 and 30 kW per cabinet are sometimes discussed for new data centers as well. This density is not considered in this report because none of these cabinets have been observed. In addition, this higher density cabinet often involves water based cooling in the cabinet. This report concentrates on cabinets cooled by air from outside the cabinet, as found in all the current data centers.

A typical density of cabinets for an entire data center being designed today is 25 cabinets per 1,000 sf of data center floor area, based on physical layout constraints. Filling a data center with 10 kW cabinets would create a power density of 250 W/sf. If the same cabinets held 15 kW of servers, the overall density will be 375 W/sf.

Cabinets with 30 kW of load are employed in some commercial data centers. This density may require a cooling system that uses more than just air at the cabinet. This supplemental cooling could be chilled water or refrigerant.

As a target for this report a load density of 200 W/sf will be used as a likely maximum target for the UC data centers.

4.3 Air Flow Requirements

How much air does it take to cool a high density data center? A typical temperature rise through a server is in the range of 21^{0}F. This obviously varies, but in general design temperature rise is increasing and is over 25^{0}F for some servers. Using a 21^{0}F temperature rise design point results in an air flow requirement of approximately 1,500 cfm for a 10 kW cabinet and 2,000 cfm for a 13 kW cabinet.

The temperature rise in some blade servers is in the range of 50ºF. In a data center full of these servers, the air leaving the servers will always be hotter than the outside air, so it will always be advantageous to use outside air for cooling, rather than return air.

4.4 Types of Cooling Equipment and Relative Efficiencies

4.4.1 Chilled Water - Campus

In many UC data centers chilled water is delivered from the main campus loop to the computer room air handlers (CRAHs). Chilled water piping may run under the raised floor or overhead. The campus loop chillers typically are quite efficient, often using thermal energy storage to shift electric loads to the night. A marginal chiller plant efficiency of 0.72 to 0.8 kW/ton was used for this plant efficiency, including the chiller, chilled water pumps, condenser water pumps and cooling tower loads. The efficiency of these chiller plants was taken from the systemwide Strategic Energy Plan.

4.4.2 Chilled Water – Local, Air Cooled

In some data centers chilled water was also delivered to the CRAHs but the source of the chilled water was local, air cooled chillers. An average chiller plant performance of 1.2 kW/ton was used for the UCLA Medical Center Oppenheimer existing chiller plant because of the poor physical condition of its air cooled condenser. Replacement of this unit was being actively pursued at the time of the survey. A new air cooled chiller would have a full load performance of about 1.1 kW/ton when it is 95ºF outside, with its full load performance improving to about 1.0 kW/ton at a typical outside air temperature of 75ºF.

4.4.3 DX – Air Cooled

Some computer room air conditioning (CRAC) units have integral compressors, direct expansion evaporator coils and air cooled condensers. They use no chilled or condenser water. Refrigerant piping leads from the CRAC unit in the data center to the air cooled condenser outside at grade or on the roof which uses fans to blow air across the condenser.

The typical new Liebert compressor is rated with a full load EER (energy efficiency ratio) of 11.7 Btu/Wh, which implies a performance of 1.03 kW/ton. When this is combined with a typical air cooled condenser, the performance is 1.23 kW/ton. The performance improves with cooler outside air temperatures down to about 70ºF. At 70ºF, the performance levels off at about 0.76 kW/ton for the compressor, or about 0.9 kW/ton for the compressor and condenser. For this analysis an average performance of 1.1 kW/ton is used for this equipment to factor in degraded performance from initial installation.

Note that this is the only cooling configuration which does not involve piping chilled or condenser water through the data center. There were no data centers cooled completely with this technology; water is currently piped through all 15 data centers.

4.4.4 DX – Dry Cooler

Some CRACs have integral compressors, direct expansion evaporator coils and water cooled condensers, all mounted within the CRAC unit. Water is circulated between the CRAC condenser and a dry (or fin fan) cooler at grade or on the roof. The dry coolers use fans to blow air across the water coil.

The dry cooler units have an efficiency similar to the DX – Air Cooled units, except that they have another heat exchange step of water, or a glycol water solution, between the condensing refrigerant and the outside air. At the UC Berkeley installation the compressors and condensers were specified at 1.1 kW/ton, fully loaded on a hot day. The system was designed to return water to the condensers at 111ºF at an outside air temperature of 100ºF. It was observed to deliver 99ºF water at an outside air temperature of about 70ºF. This 29ºF approach on a cool day, compared to the design 11ºF approach on a hot day, implies that the system is not achieving all it was designed for and that the performance probably suffers. The site sometimes uses water sprinklers to boost the cooling output on hot days, further indicating that the cooling does not perform as designed. A performance of 1.35 kW/ton was used for this type of system in this report.

4.4.5 DX – Cooling Tower

This configuration is similar to the DX – Dry Cooler configuration, except that the water is cooled in a closed circuit cooling tower instead of a dry cooler. The use of a cooling tower allows the water temperature to be lowered closer to the wet bulb temperature, lowering the condensing temperature of the equipment and making the compressor operate more efficiently. At UC Irvine Medical Center, where this technique is used, limitations on the cooling tower keep its temperature in the low 90's on hot days, rather than the high 70's a cooling tower should produce on design days, so there may be an issue to be resolved at that site. The tower serves other small building condensing loads in addition to the data center. The performance of this compressor and condenser (pumps and tower) is set at 1.0 kW/ton for this report.

4.4.6 Cooling Capacity of CRAC/H Versus Return Air Temperature

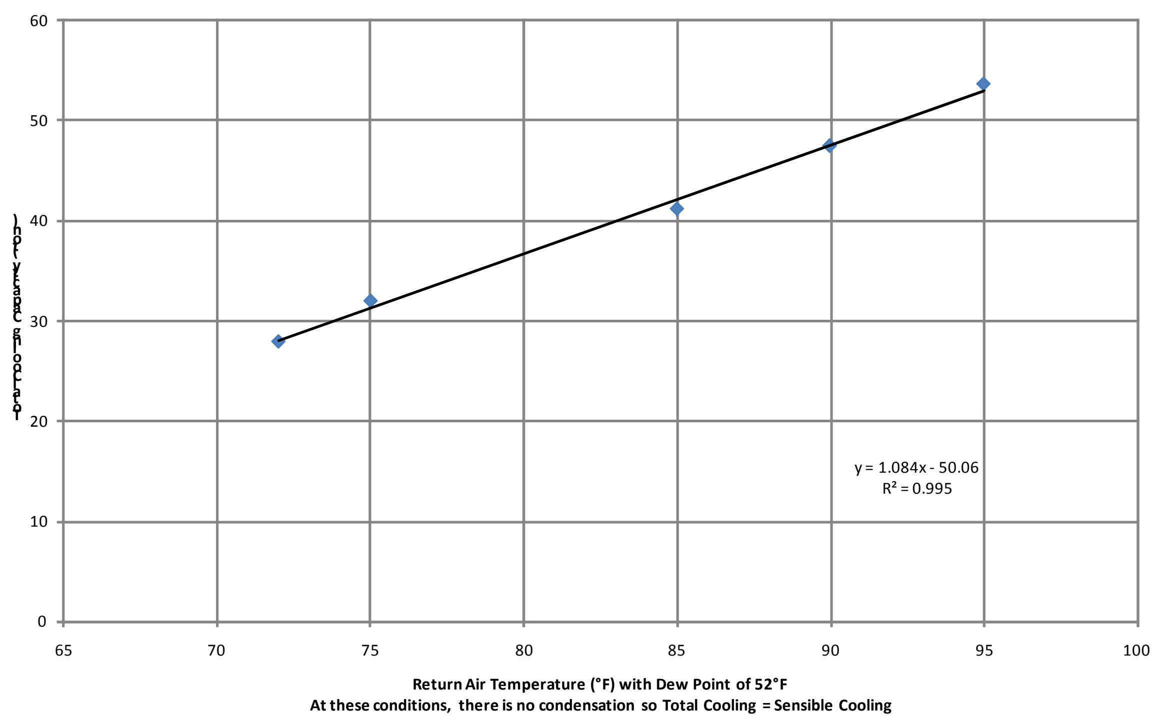
The effect of the return air temperature on the cooling capacity of a new CRAC is shown in Figure 4.2. The unit is a nominal 50 ton CRAH (designated by the model number including

“600,” or 600,000 Btu/hr). One ton of cooling is defined as 12,000 Btu/hr. This unit will deliver 50 tons of cooling when the air is returned to it at a temperature of 92^0F. This will happen in some data center designs. However, in the free mixing layouts of most UC data centers, the return air temperature is typically controlled by the CRAH to be 72 to75^0F. At these return air temperatures the capacity of this unit is reduced to approximately 30 tons, or a 40% reduction in capacity.

Return air temperature setpoints are typically set for 72^0F to75^0F because they draw in general room air in most cases. This air is often the same temperature that is reaching some of the servers. In order to maintain a cool enough entering air for these servers, the lower return air temperature setpoint is maintained.

Note that some return air thermostats were set for 68^0F, although the return air entering the units were still 72^0F to 75^0F. Although all of the data centers have more than adequate nominal capacity in their air handlers to meet the cooling load, some cannot deliver the low setpoints because the air handlers do not have the capacity to deliver meet the loads at these low temperatures.

Figure 4.2. Total Cooling Capacity of a Liebert UH600C (50 ton nominal) CRAH with Different Return Air Temperatures



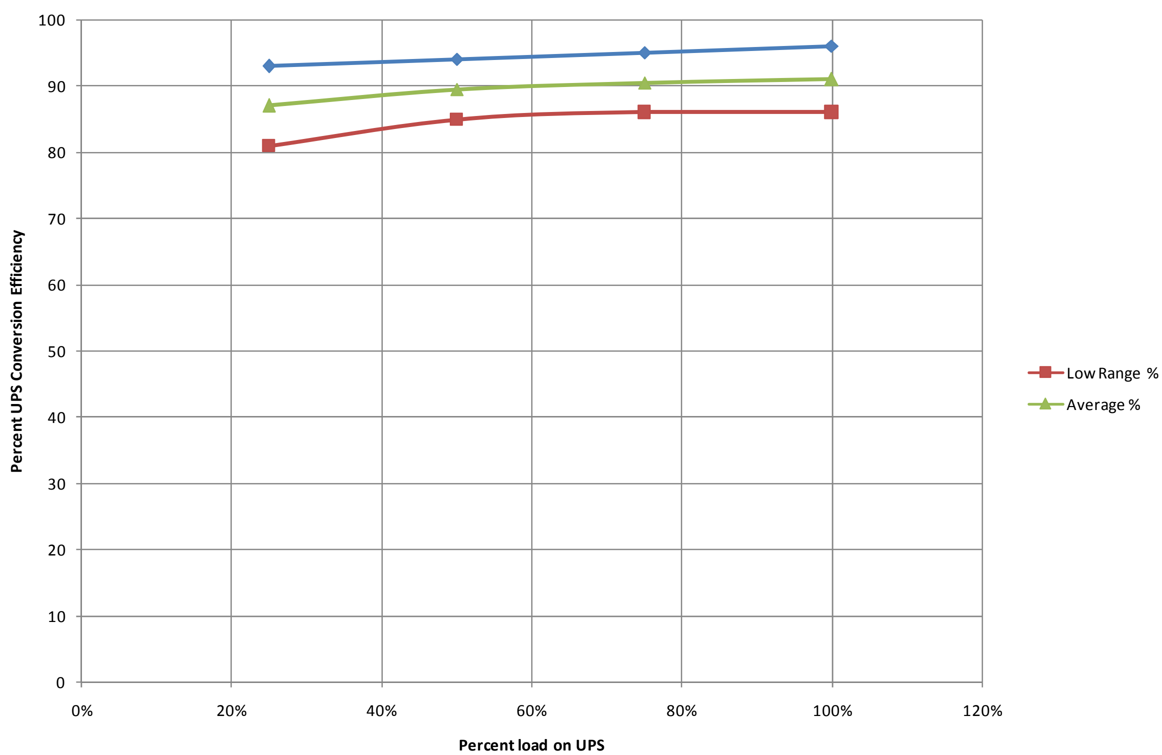
4.5 Uninterruptible Power Supplies

The efficiency of the individual UPS units in the data centers was calculated whenever power input and power output were displayed by UPS control panel. These efficiencies were calculated at 87%, 88%, 91% and 96% for different UPS units with load ranges from 37% to 90%.

In other cases the efficiency of the UPS was projected using Public Interest Energy Research (PIER) published data for typical UPS efficiency, according to percent load. This is illustrated in Figure 4.3. The average efficiency line was used to project UPS efficiency for these calculations.

Note that the inefficiency of the UPS causes heat loss in the air conditioned space of the data center. This heat must be removed by the air conditioning compressor and fan, so the inefficiency of the UPS is compounded in its energy impact.

Figure 4.2. UPS Part Load Efficiency for Existing Double Conversion UPS - High, Low and Average (PIER Data)



4.6 Airside Economizers

Airside economizers are increasingly being used to cool large data centers. Intel has just published an "IT @ Intel Brief" titled *Reducing Data Center Cost with an Air Economizer*, August 2008. It describes a Proof of Concept test of using up to 100% outside air to cool production servers.

The test was performed in a dry, temperate climate (New Mexico) over 10 months using 900 heavily loaded blade servers, divided equally between two side by side compartments. One used standard air conditioning; the other used a similar air conditioning system, with an airside economizer. There was a physical separation between the hot and cold aisles in both cases.

The economizer was controlled to maintain between 65 and 90ºF air inlet to the servers. This meant modulating to less than 100% outside air to maintain a 65ºF supply air temperature when it was cold outside, operating at 100% outside air at all outside air temperatures above 65ºF. The air conditioning would operate above 90ºF outside air temperature to maintain the supply air temperature at 90ºF. No attempt was made to control humidity and the outside air was filtered only by a standard household air filter.

The blade servers in the room without the economizer received a supply air temperature of 68ºF. These particular servers heat the air passing through them by 58ºF, so the server exhaust temperature was 128ºF.

Note that the manufacturers of these servers specify that their products can operate in temperatures up to 98ºF, so the 90ºF supply air represents a small operating cushion.

The results of the test include the following:

- The temperature of the supply air in the unit with an economizer ranged between 64 and 92ºF, and the humidity ranged from 4 to more than 90%.
- The servers and the interior of the compartment in the unit with an economizer were covered with a layer of dust.
- There was only a minimal difference between the 4.46% failure rate in the economizer compartment and the 3.38% failure rate in the main data center over the same period. The failure rate in the conventionally air conditioned test room was 2.45%, lower than in the main data center.

Intel concluded "We observed no consistent increase in server failures as a result of the greater variation in temperature and humidity, and the decreased air quality, in the trailer…Air economizers seem particularly suited to temperature climates with low humidity…A data center equipped with an air economizer could substantially reduce Intel's environmental footprint by reducing consumption of both power and water…We plan to further test the possible hardware degradation using a server aging analysis…If subsequent investigation confirms our promising Proof of Concept results, we expect to include air economizers in future data center designs."

While Intel has not completely endorsed the concept yet, note that their version of an airside economizer is more extreme than as recommended in this report. This report recommends full air filtration and savings are based on a supply air temperature of 75ºF instead of 90ºF, as used at Intel.

4.7 Electricity Balance

During the course of this analysis the electricity use of the data centers was evaluated in a variety of ways, depending upon the type of information available at each site. The analysis included a combination of historical monthly electric billing, instantaneous input and output readings from UPS equipment, temporary monitoring of computer and cooling loads, manual logging of UPS load information, and temporary monitoring of other building loads to subtract from data center energy use. This analysis is included in Appendix G.

This analysis is the basis of the calculation of the DCiE and PUE data center efficiencies shown in Section 3.

Note that after the computing load, the next highest load in these data centers is the air conditioning load. In approximately half of these data centers air conditioning was provided by the campus chilled water plant. In these cases the air conditioning load could not be measured with an electric meter, and there were no chilled water Btu meters in place to measure the air conditioning load of the data center. In each of these cases the electric equivalent of the central plant chilled water was used, as determined for the Strategic Energy Plan. This marginal performance is typically 0.72 to 0.80 kW/ton, including the central plant chiller, pumps and cooling tower. In half of the data centers where chilled water was in use, an electric balance based on metered energy use could not be established.

4.8 4.8 Air Conditioning Definitions

IT equipment which uses 1 kW of electrical energy converts basically all of that energy into heat which must be removed with air conditioning. The electric load of 1 kW produces 3,413 Btu per hour of heat.

The air conditioning capacity of one ton represents the ability to remove 12,000 Btu per hour of heat. (This comes from the amount of cooling a one ton slab of ice will do over a 24 hour period.)

A 1 kW load therefore requires 0.28 tons of air conditioning. (ton/12,000 Btu/hr x 3,413 Btu/kWh) Conversely, one ton of air conditioning capacity will remove 3.5 kW of electrical heat load.

5. POTENTIAL ENERGY SAVING PROJECTS

A variety of energy saving opportunities for these data centers is evaluated in this report. They include the following general categories:

- Measure 1. Hot and Cold Aisle Physical Separation
- Measure 2. Utilize Airside Economizers for Free Cooling
- Measure 3. Utilize Waterside Economizers for Free Cooling
- Measure 4. Utilize Energy Efficient Air Conditioning Equipment

Each measure incorporates a number of separate pieces, which may be different for different data centers. The measures are also highly interdependent. For example, if much of the cooling load can be converted to free cooling, as some new data centers are doing, then the efficiency of the air conditioning for the remaining cooling load becomes less important.

The cost and savings for many combinations of these four measures is tabulated in the calculations in the appendices. The combinations that are physically possible are listed for each data center in Section 6. Airside economizers, for example, are not physically possible at some data centers and so are not included for those data centers in Section 6. Where the data center is already cooled by the campus chillers, a more efficient alternative was not explored.

The most attractive of these options for each data center in Section 6 is included in the Summary Table at the beginning of the report.

5.1 Measure 1. Hot and Cold Aisle Physical Separation

Well designed data centers with relatively high power densities have been configured with hot aisles and cold aisles for a number of years. This typically means underfloor air supply to cold aisles with the front face of the servers on both sides of the cold aisle drawing air from the cold aisle and discharging it to the alternating hot aisles. Hot aisle air is typically expected to collect in the ceiling area and find its way back to the CRAC/H inlet, which is several feet below the ceiling, and below the top of the cabinets. All of the UC data centers in this study employ a hot and cold aisle layout to some extent.

This is a great improvement over a general scattering of servers throughout the room. This improvement was necessitated by increasing use of higher density cabinets. The hot and cold aisle works in a general way to deliver the cooler air to the server and return the warmer air to the air handler.

However, the design does not eliminate incursion of the hot aisle air into the cold aisle. This can cause spot cooling problems at individual servers. These local cooling problems are addressed by lowering supply air temperatures(as observed in the UC data centers), running extensive computational fluid dynamics models, experimental shifting of tiles, and so on.

Nor does the hot and cold aisle design eliminate cold aisle “bypass air” from flowing directly back to the air handler without passing through a server. The Uptime Institute surveyed operating conditions in 19 data centers covering 204,000 square feet. They found that the bypass air percentage ranged from 20% to 90%, with an even distribution between; that is, depending on the data center design, 20% to 90% of the supply air returns to the air handlers without passing through a server and doing any effective cooling. The average for all of the sites was 60% bypass.

Bypass air was observed at all of the UC data centers. At some sites the return air temperature is warmer than the thermostat setpoints on the CRAC/H units. This implies that the air conditioning cannot keep up with the load. However, as seen in the previous chapter, every data center has excess cooling capacity. The problem is that at the relatively cool return air temperature (often room temperatures around 72ºF) the capacity of the CRAC/H units is greatly reduced.

This problem can be addressed by placing a physical barrier between the hot aisle and the cold aisle to keep the supply air and return air from mixing. The barriers can be plastic sheeting, sheet metal, or other materials. The ceiling plenum is often used as part of the return air path to the air handlers. The separation is also created by installing face plates in positions in the cabinets where equipment is not installed. Special brush devices are also available to limit air flow through cable openings in floor tiles. Physical separation can be achieved by isolating the cold aisles or isolating the hot aisles. These different configurations are shown in Figures 5.1 and 5.2, respectively.

Figure 5.1: First Configuration – Cold Aisle Isolation

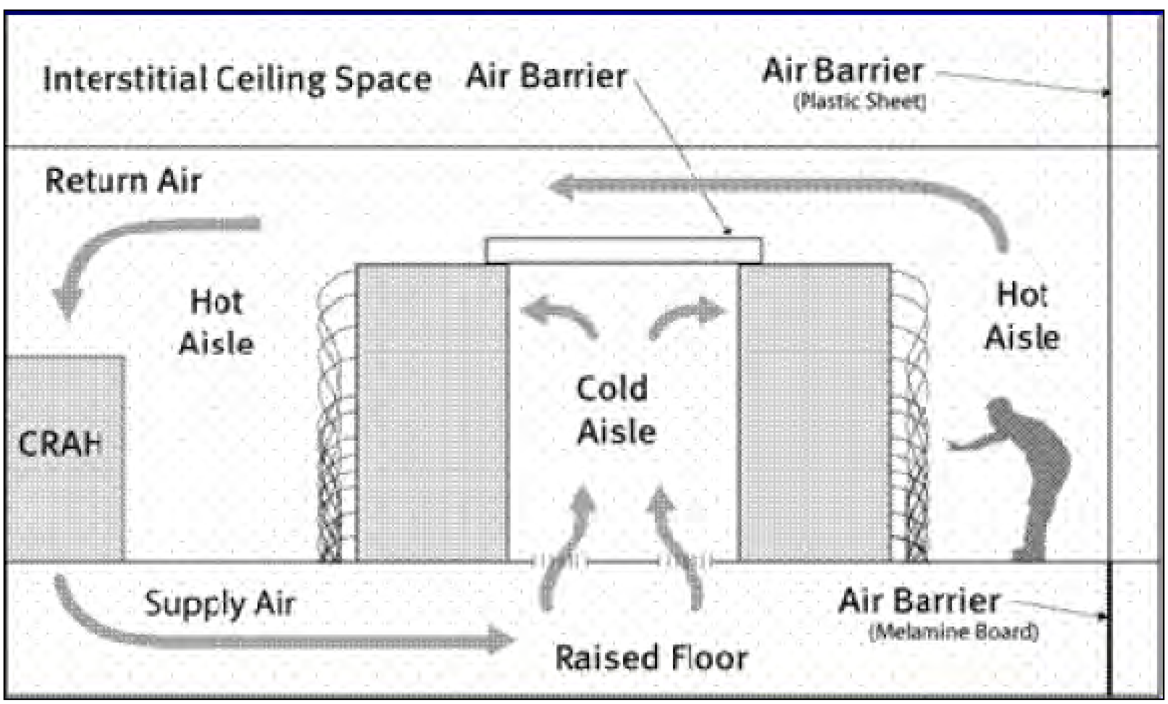
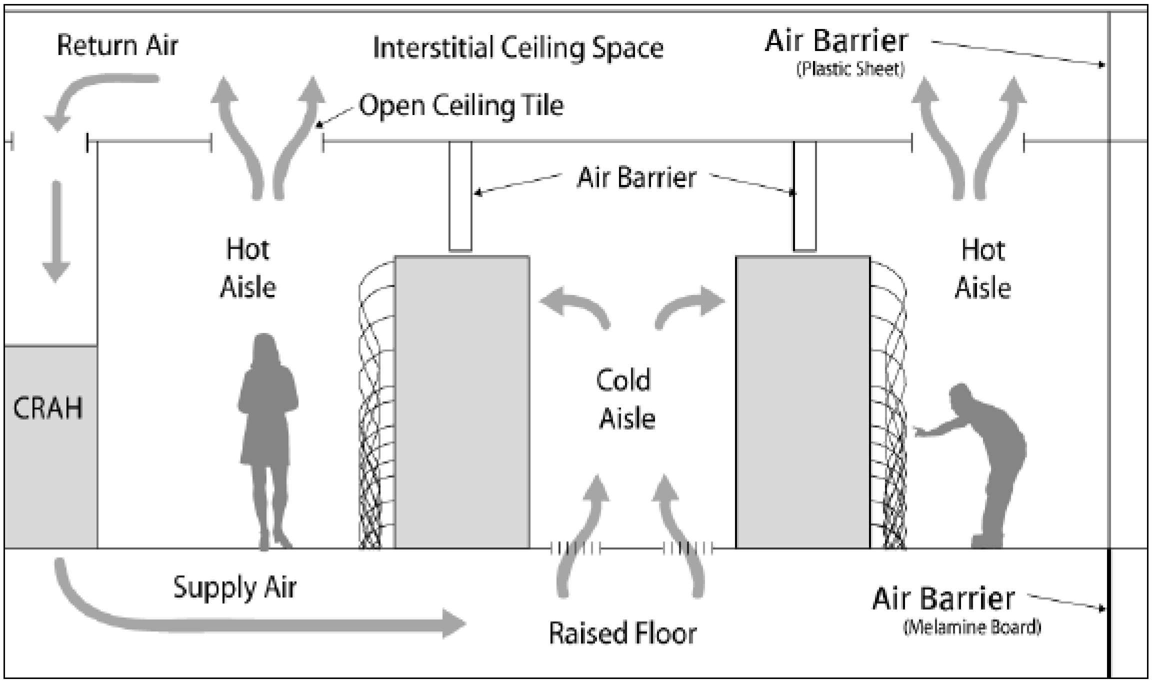


Figure 5.2: Second Configuration – Hot Aisle Isolation and Ceiling Plenum Return



Reference: William Tschudi, Lawrence Berkeley National Laboratory, SVLG Data Center Summit, LBNL Air Management Project, June 26, 2008

Physical separation of hot and cold aisles is a concept which is several years old and is employed only minimally in the UC data centers. It is employed in a growing number of Silicon Valley data centers, in new and retrofit situations. It is also the basis of design for a new data center being designed for UC Berkeley, as well as other energy efficient data centers being built in the state.

The physical separation of hot and cold aisles can only be achieved where hot and cold aisles are in use. They are in use to some degree in all of the UC data centers, particularly in the newer facilities or where there is a high computing density.

Where hot and cold aisles do not exist, they can be created through the normal turnover of servers in the data center. Servers are expected to have useful lives of 3 to 4 years, so in that period of time all of the new units can be installed in a proper configuration.

The physical separation of the hot and cold aisles creates a situation where the supply air flow from the air handlers should match the air flow that is being drawn through the servers by their internal ventilation fans (plus additional flow to make up for leakage and bypass which still exist). This typically means a significant reduction in total supply air flow.

When the nominal air flow of all the CRAC/Hs in the 15 data centers is totaled, the air flow rate is 679,000 cfm. This is an air flow rate of 12 cfm per square foot. When the internal loads of the data centers are totaled, the cooling load is about 2,300 kW, or 650 tons. This compares to the provisioned capacity of approximately 1,650 tons. The temperature rise across the flow of air necessary to remove this much heat is 10.6^0F. This is approximately half of the typical temperature rise across a server. Therefore, if all of the air flow could be properly controlled, approximately half of the air flow in the data centers could be eliminated.

In reality, leakage cannot be completely eliminated. Savings from this measure are calculated assuming a significant portion, but not all, of the bypass air can be eliminated. Fan power reductions are expected to be linear with air flow reductions when the data center is served by CRAC units. CRAC units have direct expansion coils which are subject to icing up if air flow is reduced too much. Thus manufacturers do not typically allow the installation of VFDs on these units. CRAH's, on the other hand, use chilled water coils which will not ice up even if air flow is significantly reduced.

For CRAH's this recommendation includes the installation of VFDs on the supply fans. Simultaneously slowing the air flow across all coils in parallel will result in static pressure savings in addition to air flow fan power savings. For example, it is preferable to operate five CRAHs at 80% air flow, rather than operating four CRAHs at full air flow. The same amount of air is delivered in either case, but the static pressure loss through the cooling coils and filters is less. Pressure drop is proportional to the square of the air flow so 80% air flow requires only 64% of the static pressure from the fan to push the air through the coil.

The other benefit of this measure is that the supply air temperature can be raised from its current temperature (typically 55 to 65^{0}F) to approximately 75^{0}F. In the new design the supply air temperature could be 75^{0}F and with some leakage the air delivered to the worst case server would be 77^{0}F or below. The average 75^{0}F supply air and the 21^{0}F rise across the servers would give a return air or hot aisle temperature of 96^{0}F.

By raising the supply air temperature 15^{0}F, the efficiency of the air conditioning equipment will improve significantly. This project would be expected to save approximately 20% of the air conditioning compressor and condenser energy use. Note that this air conditioning efficiency improvement is clear in the case of the local compressor, but it applies to the efficiency of the central plant chillers as well, if that is what serves the data center. Although it may only be a small percentage of the chiller plant load, every increase in chilled water return temperature improves the efficiency of the central plant chillers in a similar way.

The energy-saving and thermal management benefits of hot and cold aisle separation can be greatly enhanced by implementing sophisticated monitoring and control, such as Federspiel Controls' DASH system, or an equivalent. These systems use wireless sensors to monitor server inlet air temperatures and provide direct feedback to the cooling system. The system "learns" the effects of changes in the cooling system and modifies the operation of the cooling units accordingly, to prevent "fighting" between units and optimize temperature setpoints. The result is additional energy savings.

Where hot and cold aisle separation is recommended, the cost of implementing a wireless control system like DASH has been included in the overall cost of the project for all but the smallest data centers. Some of the benefits of such a control system can be achieved by networking the existing CRAC/H controllers through a system like Liebert SiteScan, although this may not give as much temperature feedback and advanced control sequences.

Note that the implementation of this measure must include consideration of the fire control system at each data center. Current installations of curtains at other data centers include fusible links so that the curtain drops to the floor if the temperature at its ceiling support goes above 135ºF (typical). This may be an adequate design in most data centers, and is included in the cost estimate for this project.

The data centers that rely on Halon or FM 200 tend to have fewer nozzles, compared to the number of water sprinklers in other data centers. In the case of a small fire the adjacent curtain may drop because of the fusible link, but there may be other curtains still in place restricting the flow of the gas. Design for adding air barriers to any data center must include allowance for the fire and life safety system, and must meet the requirements of the appropriate Fire Marshal.

The separation of the hot and cold aisles relies on other changes in addition to the barriers mentioned above. Most data centers have already started to employ blanking plates in the cabinets where there is no server. This should be completely implemented as a first step to hot and cold aisle separation.

In addition, leaks between the hot and cold aisles should be minimized by the use of brushes and other constraints to air flow whenever cables pass from one aisle to the other. This also is employed to some extent in most UC data centers. Other leaks in ceiling tiles and wall openings are equally damaging.

Note that this measure generates a significant portion of its energy savings by allowing the supply air temperatures to be raised while ensuring protection of the IT equipment.

5.2 Measure 2. Utilize Airside Economizers for Free Cooling

An airside economizer is a set of dampers that takes the return air heading to the air handler and discharges it to the outside whenever it is warmer than outside air. The cooler outside air is drawn into the air handler instead, thereby reducing the air conditioning load. This is a common component of an air handler for office space, and is in fact required by Title 24 for all but the smallest air handlers.

The airside economizer has not been used in data centers in the past because of concerns over humidity control and air filtration. In addition, it is not an option with standard CRAC or CRAH suppliers.

However, design concepts have changed because of a variety of factors. The lower use of paper printing in data centers has lessened humidity concerns, although a few UC data centers still do printing inside the data center. In general the industry is recognizing that tight humidity control is not required for today's IT equipment. This is reflected in manufacturers' data sheets and in the ASHRAE guidelines, and should continue to be relaxed even further in the future. Some UC data centers exercise no humidity control, with no adverse effects. All could be doing this.

This has led a number of existing and new commercial data centers to employ airside economizers. Operating experience so far indicates that significant economies of operation can be achieved while maintaining appropriate internal conditions. The economizer would utilize outside air for its cooling requirements. Should humidity conditions ever fall outside the necessary range, the economizer can always be reset to minimum outside air and the current method of humidity control can be employed.

Conventional air filtering is typically used by data centers with airside economizers. This includes prefilters and MERV 7 filters. A study of airside economizer data centers by LBNL found particulate levels higher than in data centers without airside economizers, but a factor of 10 lower than recommended levels from equipment manufacturers. It also suggested that better filtration using MERV 11 filters could be expected to achieve particulate levels equivalent to data centers with no airside economizers.

The LBNL study found that in one airside economizer data center the relative humidity was controlled within the historical bounds of 40 of 55% RH. In another airside economizer data center it was on the low side of the recommended range, but was still mostly within the allowable range (20 to 40%). This may be a factor of how the data center chose to control it.

Where the data center currently uses 60^{0}F air to cool, an airside economizer would eliminate most mechanical cooling for all hours below that temperature. It would reduce, but not eliminate, the cooling load whenever the outside air temperature is between 60 and 75^{0}F.

If an airside economizer is employed where hot and cold aisle separation has been previously employed, the potential energy savings increases significantly. Mechanical cooling is eliminated for most hours below 75^{0}F, rather than below 60^{0}F. The load is reduced for all hours below an outside air temperature of 90^{0}F because outside air will still be cooler than the 90^{0}F return air.

Airside economizers are evaluated for every data center that has access to outside air. This, unfortunately, may be an expensive proposition for some data centers due to the large number of small air handlers that need damper control and due to the difficulty of running ducting that may be required.

5.3 Measure 3. Utilize Waterside Economizers for Free Cooling

Another option for providing free cooling to the data center is the waterside economizer. Waterside economizers involve using cold water from the existing cooling tower to provide cooling to the data center. In particularly cold climates these are sometimes used to cool the chilled water down to 45^{0}F during the winter months. Weather conditions in California are not cold enough to support this approach. Waterside economizers are usually used in California to precool air with a cooling tower water loop, while letting the chilled water system provide the final cooling if necessary.

Waterside economizers are typically only used in California in commercial building air handlers where it is physically impossible to get enough access to outside air to allow the use of an airside economizer. They are typically required by Title 24 where airside economizers are not used.

In the case of the UC data centers waterside economizers would typically involve a water loop cooled by a closed circuit cooling tower to within 5^{0}F or so of the outside air wet bulb temperature. This water would be supplied to heat exchange coils in the return air going to the air handlers.

In the current data centers the return air temperature is typically 75^0F or so, although a higher return temperature is recommended. In order to perform significant cooling on this overcooled air, the cooling tower water would need to be at least 10^0F lower in temperature. This implies that a waterside economizer could provide cooling for the hours of outside wet bulb temperature of 60^0F or less.

The performance of waterside economizers is evaluated for each of the data centers. For the most part a waterside economizer is an option to be considered instead of, rather than in addition to, an airside economizer.

As with the airside economizer, the performance of a waterside economizer would be greatly enhanced if the data center also employs hot and cold aisle separation. The highest wet bulb temperature in California is typically 72^0F. If this is used to create 77^0F water, this could be used year round to cool the 90^0F return air. At lower wet bulb temperatures it could supply all of the cooling necessary at the data center.

Just as with the airside economizer, this is an expensive option to retrofit into an existing data center. It would typically involve a new coil installed on top of the CRAC/H's. Note that the manufacturers offer this second coil as an option on all equipment, but it was not seen at any of these data centers.

Cooling water would be piped to each of these coils and out to a closed circuit cooling tower. Control valves would be required at each coil.

In several data centers the CRAC compressors are cooled by water rather than air. This is true at UC Berkeley, UC Irvine Berkeley Place, and UC Irvine Medical Center. In these cases it may be possible to use the existing condenser water, provided it came from an efficient cooling tower, and run it through the waterside economizer coil before it enters the compressor condenser in the CRAC. This would minimize the amount of piping which needs to be added.

It is possible that where hot and cold aisle separation is retrofitted in data centers cooled by central chilled water systems, a more conventional water side economizer could be used. This would cool the chilled water loop with a cooling tower instead of central chillers, resulting in a much warmer loop. However, a warmer loop may be adequate if the return air temperature is much warmer due to the hot and cold aisle separation. This is addressed specifically for several data centers below.

5.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

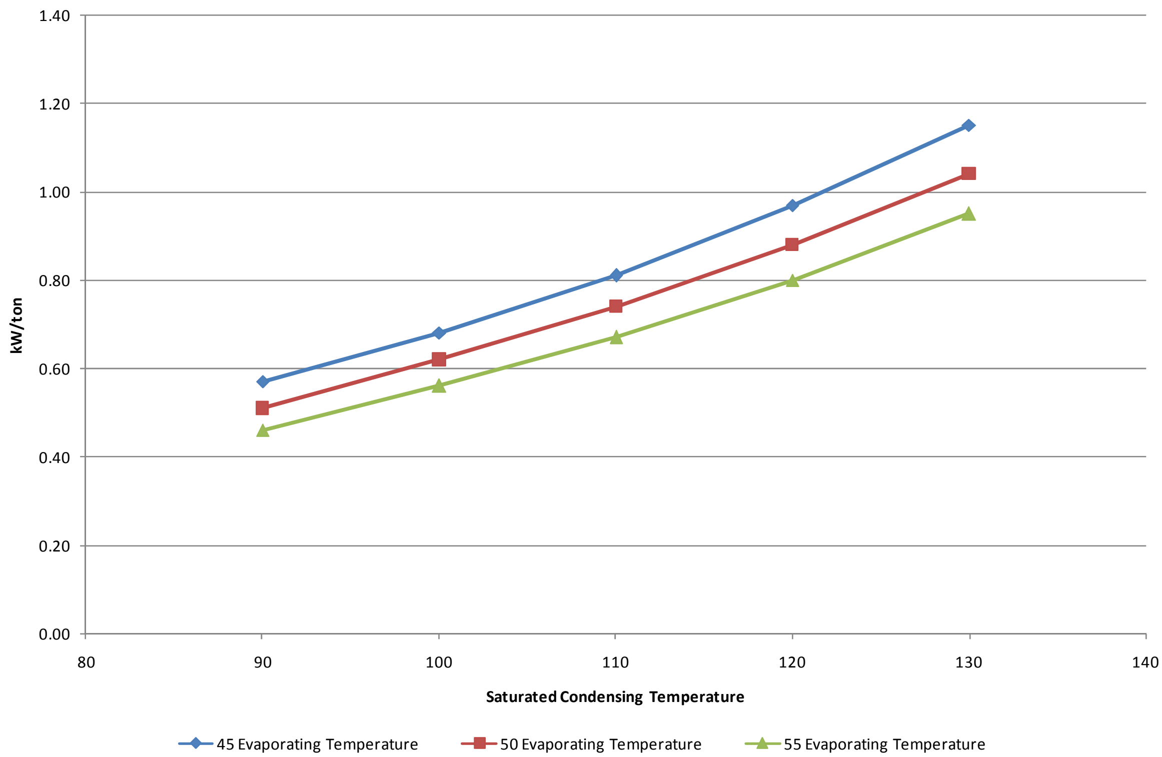
The efficiency of the air conditioning equipment at the 15 UC data centers varies significantly, by as much as a factor of two. The most efficient cooling available is chilled water provided by central plants, where available. Marginal chilling efficiency at the large central chillers is estimated to be 0.72 to 0.8 kW/ton, including the compressors, the cooling towers and the pumps. A number of these utilize thermal energy storage as well, so they may be avoiding peak billing charges.

By comparison, the air cooled direct expansion CRACs are estimated to have an efficiency of approximately 1.1 kW/ton. This is a typical full load efficiency. Part load efficiency can be better or worse, depending upon the number of compressors and the type of control system.

Lower ambient temperatures may improve efficiency if the condenser is properly controlled. A flat marginal efficiency of 1.1 kW/ton was used to evaluate these units.

A less efficient system involves CRACs whose internal compressors and condensers are served by a water loop which is cooled by outside air in a dry cooler. This adds an extra heat exchange step and extra pumping, worsening the overall efficiency. This approach is used when there are multiple CRACs and an effort is made to limit multiple or long refrigerant runs to remote air cooled condensers. This cooling approach is found at several data centers.

Figure 5.3 Liebert Compressor Efficiency at Different Operating Conditions (kW/ton)



A better approach for this configuration is to send the water to a cooling tower or a closed circuit cooling tower. This takes advantage of the significant wet bulb depression that normally occurs throughout the state. The lower water temperature will improve the efficiency of the CRAC compressors. This is illustrated in Figure 5.3 for typical Liebert CRAC units.

Designers sometimes avoid the use of cooling towers on the basis that the increased costs of water and water treatment, relative to a dry cooler, may not be justified. Almost all large cooling systems in California use cooling towers whenever possible. This is particularly important for data centers because they have such a greater annual cooling load than commercial buildings.

6. PROJECTS BY DATA CENTER

The following section describes the work required at each data center to implement the individual measures. Not all measures are applicable to all data centers. Measures 2 and 3 (Airside and Waterside Economizers) are mutually exclusive. In some cases, savings may have been calculated even though costs for a measure at a particular site are prohibitive. Most project combinations are listed in the Appendices. Only those with reasonable constructability and economic benefit are listed here in the text.

Note that the savings presented for each measure are interactive. The combination of different measures should reflect the impact of each on the other. For example, the savings from an airside economizer are quite different, depending on whether the data center is using a hot and cold aisle configuration with physical separation or not.

6.1 UC Berkeley Campus Data Center

6.1.1 Measure 1. Hot and Cold Aisle Physical Separation

The physical layout of the UC Berkeley data center uses hot and cold aisles for the majority of the servers. The CRACs are located at the ends of the aisles. Even though there is significant seismic steel bracing above the servers, there appears to be room to install curtains and other devices for physical separation of the hot and cold aisles. There is little room in the ceiling plenum so hot aisle air would probably be collected and run along the ceiling back to the CRAC inlets. The data center has taken another step in this direction by installing blank face plates where no servers are installed in the cabinets to block this path for bypass air.

The room has FM 200 fire protection so the modified design must be compatible with this.
The CRAC manufacturers do not approve of VFDs for their evaporator fans, so the air flow reductions will be accomplished by shutting down a number of units.

6.1.2 Measure 2. Utilize Airside Economizers for Free Cooling

This data center is on the third floor of a building and has large glass windows on the exterior walls. The data center managers have used window film and foam boards in these windows as an excellent retrofit to reduce the heat load from the exterior windows.
The CRACs which condition this data center are distributed on the interior as well as the exterior of the data center. This physical layout makes the use of an outside air economizer very difficult. Ducting would have to be run across the ceiling of the data center. A number of windows would have to be replaced with louvers, which would be difficult work on the third floor. The large number of individual CRACs would each require an individual set of economizer dampers.

As a result, Measure 2 is not pursued at this data center. A waterside economizer will be pursued in lieu of this.

6.1.3 Measure 3. Utilize Waterside Economizers for Free Cooling

This data center has 11 CRACs which are currently water cooled. The water is supplied from a series of dry coolers on the roof. An arrangement for the waterside economizer is to pipe the condenser water delivered to each CRAC first through a coil to cool return air entering the CRAC, and then to the condenser unit in the CRAC. This is proposed in conjunction with Measure 4 because the new cooling tower needed for a waterside economizer can serve double duty in cooling the condensers as well.

6.1.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

At this data center the approach to achieving more efficient air conditioning operation is to add a closed circuit cooling tower to the condenser water loop. The present air cooled operation does not take advantage of the wet bulb depression available most of the year. The data center staff sometimes sprays water on the existing dry coolers to lower their temperature on the hottest days. This project would provide that result all year long. The existing dry coolers can be left in place as a backup to the new cooling tower. This closed circuit cooling tower can be installed by itself (Measure 4) or as a part of Measure 3, which provides the savings for Measure 4 as well.

6.1.5 Additional Considerations

It is not clear why a glycol solution is used in the condenser water loop. Glycol solutions are generally used to prevent freezing, but there seems little chance of freezing in the Berkeley climate. Even in a power failure the emergency generator will keep the data center operational. Removal of the glycol will reduce friction losses in the piping and will increase the heat capacity of the loop.

Table 6.1: UC Berkeley Data Center Project Summary

Total Measure 1 Savings	616,529	kWh/yr
Total Measure 1 Savings	51,172	$/yr
Cost	247,455	-
Simple Payback	4.8	Year

Measure 1 + 3 + 4 Savings	1,925,389	kWh/yr
Measure 1 + 3 + 4 Savings	159,807	$/yr
Cost	953,865	-
Simple Payback	6.0	Year

Measure 3 + 4 Savings	1,143,839	kWh/yr
Measure 3 + 4 Savings	94,939	$/yr
Cost	706,410	-
Simple Payback	7.4	Year

Measure 4 Savings	748,586	kWh/yr
Measure 4 Savings	62,133	$/yr
Cost	315,215	-
Simple Payback	5.1	Year

6.2 UC Davis Campus Data Center

6.2.1 Measure 1. Hot and Cold Aisle Physical Separation

The data center at UC Davis is well laid out in an effective hot and cold aisle configuration. The CRACs are along the south wall at the end of the aisles. Hot and cold aisle physical separation would likely be implemented by enclosing the hot aisles with an overhead panel, as well as curtains on the north end of the aisles. The south hallway could also be used as a part of the hot aisle to return air to the front louvers on the CRAC units.

Since these CRACs use direct expansion coils the manufacturers do not recommend varying the air flow rate with VFDs. If there turns out to be excess air flow available, an individual CRAC could be turned off.

Note that in two rows some of the cooling is done with small overhead air handlers (Liebert XDV). These can be easily integrated into the physical separation of the hot and cold aisles.

Measure 2. Utilize Airside Economizers for Free Cooling

The CRACs serving most of the data center load are aligned against the south exterior wall of the data center under windows. This is a good configuration for adding airside economizers with ductwork over the CRACs. This would involve exhaust, return and outside air dampers, prefilters and MERV filters, and controls integrated with the CRACs.

Note that the Liebert XDV units do not lend themselves to use of airside economizers. With proper controls the XDV units would become the last in the loading order of cooling so that the economizer would be used to the maximum extent. With the proposed hot and cold aisle physical separation it would be much easier for air from the cold aisles (and cold ceiling area) to reach the hot aisles, including the higher density cluster served by the XDV units. There would not be a shortcut path for cold air back to the hot aisles. Most of the cold air would not reach the hot aisle without first finding a server to flow through and cool, even if it is in a different aisle. For air traveling through the aisles at low flow rates there is very little pressure drop to hinder the air flowing to where it is needed.

6.2.2 Measure 3. Utilize Waterside Economizers for Free Cooling

The CRACs serving this data center also lend themselves to the installation of a waterside economizer. This would include a new cooling water coil placed in front of the return air entry on the vertical face of the CRAC unit. Cooled water would be provided to these coils from a closed circuit cooling tower which would be installed at grade outside the building adjacent to the existing condensers. The controls would be integrated so that the first choice in cooling always came from this cooling tower water coil.

This is an alternative to the airside condenser. It would not be beneficial to install both.

6.2.3 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

At this facility the air conditioning equipment consists of multiple small compressors with air cooled condensers. Neither of these lends itself to high efficiency operation.

The best alternative for this data center for high efficiency air conditioning is probably to tie into the campus chilled water loop. Campus chilled water is already delivered to the building to cool the rest of the building (and part of the data center). It would probably require a larger pipe tying into the campus loop, as well as chilled water coils, potentially located in front of the return air grills of the existing CRACs, as discussed for the cooling tower coils. The existing DX compressors and condensers could be kept for back up cooling. Again, this is not easily adapted to the Liebert XDV units so they would become the last in the loading order of cooling.

If campus chilled water were not available, consideration could be given to installing water cooled condensers in place of the air cooled units.

6.2.4 Additional Considerations

This is the only data center which receives a significant amount of air from a non data center source. In this case the original multizone air handler that served the whole building still provides its original flow into the data center. This is estimated to add approximately 7 tons of cooling to the 85 tons of capacity in the data center.

The multizone air handler was observed to operate with a low cold deck temperature, presumably removing moisture from the air before it gets to the data center. However, significant condensation was observed during the summer coming from the CRAC drains. It may be that the hot deck damper serving the data center zones leaks uncooled air into the data center. The campus may want to seal off this portion of the deck to ensure that only preconditioned air is added to the data center.

Table 6.2: UC Davis Data Center Project Summary

Total Measure 1 Savings	123,691	kWh/yr
Total Measure 1 Savings	11,008	$/yr
Cost	98,157	-
Simple Payback	8.9	Year
Measure 1 + 2 Savings	585,862	kWh/yr
Measure 1 + 2 Savings	52,142	$/yr
Cost	310,882	-
Simple Payback	6.0	Year
Measure 1 + 3 Savings	588,458	kWh/yr
Measure 1 + 3 Savings	52,373	$/yr
Cost	374,653	-
Simple Payback	7.2	Year
Measure 2 Savings	275,225	kWh/yr
Measure 2 Savings	24,495	$/yr
Cost	212,725	-
Simple Payback	8.7	Year

Table 6.2: UC Davis Data Center Project Summary (continued)

Measure 2 + 4 Savings	379,914	kWh/yr
Measure 2 + 4 Savings	33,812	$/yr
Cost	567,266	-
Simple Payback	16.8	Year

Measure 3 Savings	263,541	kWh/yr
Measure 3 Savings	23,455	$/yr
Cost	276,496	-
Simple Payback	11.8	Year

Measure 3 + 4 Savings	371,502	kWh/yr
Measure 3 + 4 Savings	33,064	$/yr
Cost	631,037	-
Simple Payback	19.1	Year

Measure 4 Savings	181,752	kWh/yr
Measure 4 Savings	16,176	$/yr
Cost	354,541	-
Simple Payback	21.9	Year

6.3 UC Davis Medical Center ASB Data Center

6.3.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center has some hot and cold aisle configuration, but is not as complete as some. There are main frames and tape drives that make this somewhat difficult. It could take a year or two for the campus to rearrange equipment on a replacement basis to achieve a more complete hot and cold aisle configuration.

The T bar ceiling in this data center is plenum rated so it could make a convenient path for returning hot air to the return air grills of the CRACs.

Most of the units in this data center are CRACs, which have DX coils. VFDs are not recommended for these supply fans. Any excess ventilation after physical separation of the hot and cold aisles will be handled by shutting off individual CRACs.

6.3.2 Measure 2. Utilize Airside Economizers for Free Cooling

Some CRACs are located along an external wall with large painted windows. These are along the north side of the building where there is some architectural screening from the street. This is a good place for the installation of an airside economizer.

Other CRACs are located on interior walls or in the UPS rooms. The UPS rooms have exterior walls, so these are candidates for airside economizers, assuming the walls can be penetrated. One or two interior CRACs will be more difficult to configure with airside economizers. It may be possible to move them to the north wall if this measure is pursued.

6.3.3 Measure 3. Utilize Waterside Economizers for Free Cooling

A waterside economizer could be used in this data center. This would include the installation of new cooling water coils above the CRAC units in the return air stream. The coils would receive water from a loop circulated to a new closed circuit cooling tower, probably located at grade adjacent to the existing CRAC condensers.

6.3.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

At this facility the air conditioning equipment consists primarily of multiple small compressors with air cooled condensers. Neither of these lends itself to high efficiency operation.

The best alternative for this data center for high efficiency air conditioning is probably to tie into the campus chilled water loop. Campus chilled water already serves one CRAH in the data center, but this was not expanded to the other cooling units. This could be accomplished by replacing the CRACs with CRAHs, or by placing chilled water coils in the return air openings of the existing CRACs, as recommended for the waterside economizers. The CRAC compressors and DX coils could be maintained for backup capacity.

Table 6.3: UC Davis Medical Center ASB Data Center Project Summary

Total Measure 1 Savings	114,931	kWh/yr
Total Measure 1 Savings	10,229	$/yr
Cost	126,739	-
Simple Payback	12.4	Year

Measure 1 + 2 Savings	580,220	kWh/yr
Measure 1 + 2 Savings	51,640	$/yr
Cost	392,645	-
Simple Payback	7.6	Year

Measure 1 + 3 Savings	582,834	kWh/yr
Measure 1 + 3 Savings	51,872	$/yr
Cost	428,436	-
Simple Payback	8.3	Year

Measure 2 Savings	277,082	kWh/yr
Measure 2 Savings	24,660	$/yr
Cost	265,906	-
Simple Payback	10.8	Year

Measure 2 + 4 Savings	374,950	kWh/yr
Measure 2 + 4 Savings	33,371	$/yr
Cost	620,447	-
Simple Payback	18.6	Year

Measure 3 Savings	265,319	kWh/yr
Measure 3 Savings	23,613	$/yr
Cost	301,697	-
Simple Payback	12.8	Year

Measure 3 + 4 Savings	366,245	kWh/yr
Measure 3 + 4 Savings	32,596	$/yr
Cost	656,238	-
Simple Payback	20.1	Year

Measure 4 Savings	169,909	kWh/yr
Measure 4 Savings	15,122	$/yr
Cost	354,541	-
Simple Payback	23.4	Year

6.4 UC Davis Medical Center Davis Tower Data Center

6.4.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center is a small congested room on a middle floor in the new hospital. The servers are not arranged in a hot and cold aisle configuration. It is not clear that they could be easily rearranged because the room is fairly small and congested already. There is no T bar ceiling to utilize for ducting. While a full hot and cold aisle configuration would be difficult to implement in this room, the location of the server cabinets could be better oriented to the supply of the cold air from the CRAHs. The air could be directed down a cold aisle, rather than in all directions. The layout of the room would need to be addressed as equipment is moved in and out of the space.

6.4.2 Measure 2. Utilize Airside Economizers for Free Cooling

There is no access to outside air from this room in the interior of the hospital. This measure is not pursued for this data center.

6.4.3 Measure 3. Utilize Waterside Economizers for Free Cooling

This room has no obvious access to condenser water to use for precooling the CRAH return air. This measure is not pursued for this data center.

6.4.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

The air conditioning units in this data center utilize chilled water from the campus central plant as their primary source of cooling. Backup cooling is provided by integral DX compressors. Reliance on the central plant chilled water whenever possible is the proper choice for cooling this data center. This measure is not pursued for this data center.

Table 6.4: UC Davis Medical Center Davis Tower Data Center Project Summary

Total Measure 1 Savings	43,800	kWh/yr
Total Measure 1 Savings	3,898	$/yr
Cost	11,012	-
Simple Payback	2.8	Year

6.5 UC Irvine Berkeley Place Data Center

6.5.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center is largely configured in a hot and cold aisle layout. There are some loads, such as a mainframe and some tape backup which are not aligned with this. Over a year or two of reorientation upon equipment upgrade, most of the loads could be properly aligned for hot and cold aisle physical separation. The ceiling plenum can probably be used as a return air path from the hot aisles to the air handlers.

The data center is cooled with CRACs so there is not an opportunity to install VFDs on the supply fans. Any reduction in total air flow through the hot and cold aisle separation will be handled by shutting off one or more CRACs.

6.5.2 Measure 2. Utilize Airside Economizers for Free Cooling

Airside economizers are a potential project for this data center. The CRACs are on exterior walls which are partially below grade. However, there appears to be adequate room above or below the ceiling to penetrate the exterior walls to allow the installation of outside air economizers to these CRACs. This would involve exhaust, return and outside air dampers, prefilters and final filters, and a controls integration with the CRACs.

The exterior wall construction material is lightweight and access to the wall from inside and out is relatively easy.

6.5.3 Measure 3. Utilize Waterside Economizers for Free Cooling

This data center is also a candidate for a water side economizer. This measure would use cooling water coils in the return air openings at the top of the CRACs. The water would be cooled by a closed circuit cooling tower which would likely be installed near the other mechanical equipment on the roof. This measure would be combined with Measure 4 so that the cooling water which currently goes to the CRAC compressor could first pass through the new water coil on the top of the CRAC. On the roof the water would normally go to the proposed closed circuit cooling tower. This option is likely mutually exclusive with the air side economizer in Measure 2.

6.5.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

At this facility the air conditioning equipment consists primarily of multiple small compressors with water cooled condensers. The water rejects the heat in a dry cooler located on the roof of the building. This configuration does not lend itself to high efficiency operation.

One option to deliver high efficiency air conditioning to this data center is to tie it into the campus chilled water loop. It is believed that this loop is too distant for this to be economical.

The alternative is to improve the performance of the existing compressors by cooling the condenser water with a closed circuit cooling tower. This would give a lower temperature than the existing dry coolers, particularly during the warm summer months. The lower condensing temperature will allow the CRAC compressors to operate more efficiently. The existing dry coolers can be kept for backup to the new cooling tower. The existing pumps can probably be used to circulate the condensing water as they do now.

Table 6.5: UC Irvine Berkeley Place Data Center Project Summary

Total Measure 1 Savings	75,511	kWh/yr
Total Measure 1 Savings	9,967	$/yr
Cost	73,050	-
Simple Payback	7.3	Year

Measure 1 + 2 Savings	211,214	kWh/yr
Measure 1 + 2 Savings	27,880	$/yr
Cost	207,383	-
Simple Payback	7.4	Year

Measure 1 + 3 + 4 Savings	198,857	kWh/yr
Measure 1 + 3 + 4 Savings	26,249	$/yr
Cost	272,912	-
Simple Payback	10.4	Year

Measure 2 Savings	105,386	kWh/yr
Measure 2 Savings	13,911	$/yr
Cost	134,333	-
Simple Payback	9.7	Year

Measure 3 + 4 Savings	64,964	kWh/yr
Measure 3 + 4 Savings	8,575	$/yr
Cost	199,862	-
Simple Payback	23.3	Year

Measure 4 Savings	54,137	kWh/yr
Measure 4 Savings	7,146	$/yr
Cost	131,219	-
Simple Payback	18.4	Year

6.6 UC Irvine NACS Data Center

6.6.1 Measure 1. Hot and Cold Aisle Physical Separation

The NACS data center in Engineering Gateway has been largely converted to a single long cold aisle serving air to all cabinets. There are two hot aisles, one on either side, that take the discharge air from the server. There are two CRAHs in each of the hot aisles.

There is good potential to provide physical separation of the hot and cold aisles. The easiest way to do this would be to enclose the cold aisle which runs down the middle of the room. This would leave the UPSs and PDUs in the hot aisle, which might not be a problem, depending upon their temperature requirements. If this is a problem additional cold supply areas could be set up around them with the use of additional curtains.

The physical separation would include blank face plates for the cabinets and likely the use of the ceiling space as a return air plenum. The facility has already installed some leak control equipment, such as Koldlok brushes around wiring penetrations through the floor.

6.6.2 Measure 2. Utilize Airside Economizers for Free Cooling

One of these four CRAHs is on an exterior wall adjacent to a window. Another of the two could be moved into a similar position in a store room. This leaves two without easy access to outside air. The data center plans to expand in the near future to areas further away from the perimeter wall. Because of the difficult access to outside air, airside economizers are not pursued for this facility.

6.6.3 Measure 3. Utilize Waterside Economizers for Free Cooling

The use of waterside economizers is a good project for this facility. Even though there is efficient cooling provided now by the campus central plant, the physical separation of hot and cold aisles will create a cooling load that can be served a good part of the time by a waterside economizer.

This application would include condenser water coils in the return air openings of the existing CRAHs. This water would be pumped to a new closed circuit cooling tower located on the roof of the building. Integration with the CRAH controls would keep the chilled water valves closed as long as loads could be met by the waterside economizer.

6.6.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

Due to the efficiency of the campus central plant chilled water used to cool the data center now, no alternative source of cooling is proposed.

6.6.5 Additional Considerations

The data center personnel indicated that there are a number of issues with the 14 year old CRAHs, including rusted out sections which provide internal bypass. Repair of these problem areas or replacement of the units may be necessary to achieve full capacity and full energy savings from these projects.

In addition, integration of efficiency efforts with buildout of new data center area would provide potential benefits to the existing space and the adjacent space to be occupied by data center equipment.

Table 6.6: UC Irvine NACS Data Center Project Summary

Total Measure 1 Savings	151,723	kWh/yr
Total Measure 1 Savings	20,027	$/yr
Cost	102,844	-
Simple Payback	5.1	Year

Measure 1 + 3 Savings	398,796	kWh/yr
Measure 1 + 3 Savings	52,641	$/yr
Cost	492,012	-
Simple Payback	9.3	Year

Measure 3 Savings	75,511	kWh/yr
Measure 3 Savings	9,967	$/yr
Cost	389,168	-
Simple Payback	39	Year

6.7 UC Irvine Medical Center Data Center

6.7.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center is largely organized in a hot and cold aisle configuration. The ceiling plenum is already in use for return air, ducted directly to the return of the CRAC s. There are back door fans on several of the hottest cabinets that already duct exhaust heat directly into the ceiling plenum. It would be relatively easy to physically separate the hot and cold aisles in this data center.

6.7.2 Measure 2. Utilize Airside Economizers for Free Cooling

The location of this data center on the fifth floor of a glass walled building on a prominent street makes the use of airside economizers unlikely. These would require taking out several windows and installing louvers, altering the appearance of the building on the street side. In addition, the cost of working at this elevation would make the project much more expensive even if it could be permitted.

6.7.3 Measure 3. Utilize Waterside Economizers for Free Cooling

A waterside economizer appears to be a better choice for this data center. This would utilize cold water from a new closed circuit cooling tower on the roof to precool the return air entering the CRAH through a new cooling coil. The cooling tower water would pass through these coils and then through the condenser it currently cools. The current cooling tower does not appear to be adequately sized for this task so this measure will be incorporated into Measure 4, which includes replacing the cooling tower.

6.7.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

The condensing water used by the CRACs comes from a 100 ton open cooling tower on the roof, which serves a few other building loads as well. The temperature of the water climbs to 90 to 92^{0}F during the hottest days. This is a fairly high temperature for an area where the 0.4% design wet bulb temperature is 71^{0}F.

It is recommended that this be replaced with a closed circuit cooling tower on the roof to provide a better wet bulb approach, in the range of 5^{0}F. A closed circuit cooling tower would keep the loop cleaner, reducing maintenance and improving heat transfer.

6.7.5 Additional Considerations

The data center is planning on adding new server cabinets in what is now the network operation center. These will utilize some form of in-cabinet cooling, possibly with chilled water, so they will not add load to the existing CRACs. The potential for performing most of this cooling with cooling tower water rather than chilled water should be investigated. The cooling tower water can be delivered at 66^{0}F or cooler for all but 35 hours of the year.

Table 6.7: UC Irvine Medical Center Data Center Project Summary

Total Measure 1 Savings	72,182	kWh/yr
Total Measure 1 Savings	9,528	$/yr
Cost	98,536	-
Simple Payback	10.3	Year

Measure 1 + 3 + 4 Savings	284,317	kWh/yr
Measure 1 + 3 + 4 Savings	37,530	$/yr
Cost	328,013	-
Simple Payback	8.7	Year

Measure 3 + 4 Savings	88,791	kWh/yr
Measure 3 + 4 Savings	11,720	$/yr
Cost	229,477	-
Simple Payback	19.6	Year

Measure 4 Savings	31,711	kWh/yr
Measure 4 Savings	4,186	$/yr
Cost	137,546	-
Simple Payback	32.9	Year

6.8 UC Los Angeles Math Science Data Center

6.8.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center has just installed eight new CRAH units which receive chilled water from the campus central plant, with a back up from a new local chiller. These replaced CRAC units and saved a significant amount of energy as a result. They also bring a great deal of cooling capacity which will allow the data center processing load to be increased significantly.

The research side of this data center is primarily configured in a hot and cold aisle arrangement, while the administrative side is not. It is recommended that the cabinets on the administrative side be relocated in the process of server upgrades over the next year or two. This configuration will probably be necessary to build out to take advantage of all the new cooling capacity.

Currently only six of the eight CRAHs are in use due to their excess capacity. It is recommended that all eight of the CRAHs be retrofit with VFDs to give the data center the flexibility to meet varying load conditions in the future. Operating VFDs is more efficient than turning off individual fans. For example, if 6 of the 8 CRAHs are in operation, the fan power draw is 75% of full load. If all of the CRAHs were in operation with VFDs delivering 75% of the design airflow, the fan power draw would be about 50% of full load.

The use of physical separation between the hot and cold aisles should allow the same amount of cooling with less air flow (and higher delta T), getting more benefit from the VFDs.

6.8.2 Measure 2. Utilize Airside Economizers for Free Cooling

This data center is located on the fourth floor of the building, although it is at grade on an uphill side of the building. One of the data center walls is an exterior wall, with windows which have been covered over. This access to outside air gives the potential for the use of an airside economizer. It is not pursued in this report because only several of the eight CRAHs are located near this wall. Ducting outside air across the room to these units in large volumes (400 ton total) would be very difficult. Airside economizers are therefore not pursued.

6.8.3 Measure 3. Utilize Waterside Economizers for Free Cooling

The economizer approach recommended for this facility is the waterside economizer. This would involve installing precooling coils in the return air openings of the CRAHs. The coils would receive cold water from a closed circuit cooling tower, probably located on the roof.
The effectiveness of this precooling coil depends upon whether the hot and cold aisle physical separation is implemented.

6.8.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

The chilled water from the campus central plant is considered to be very efficient so no alternative is proposed here.

6.8.5 Additional Considerations

The newly installed 400 tons of CRAH might be converted to waterside economizer through a different approach. If the hot and cold aisle physical separation is implemented, the return air temperature to the CRAHs will be roughly 95^{0}F. Under the current design, full load cooling will be provided with 42^{0}F chilled water and 75^{0}F return air. The same coils should be able to provide the same amount of cooling with 62^{0}F cooling water and 95^{0}F return air (both 20^{0}F higher than the current design points). It may be possible to cool the data center by heat exchanging its chilled water loop with cooling tower water whenever the cooling tower is 62^{0}F or lower, or whenever the ambient wet bulb is 57^{0}F or lower. This alternate to the standard proposed waterside economizer eliminates the need for new piping and coils in the data center.

Note that the data center is in the process of adding a new UPS unit. When installation is complete all of the computer load will be backed up by UPS units with a total capacity of 750 kVA. This is not reflected in the Appendix data sheets because these represent the actual conditions observed during the survey.

Table 6.8: UC Los Angeles Math Science Data Center Project Summary

Total Measure 1 Savings	395,952	kWh/yr
Total Measure 1 Savings	34,844	$/yr
Cost	231,211	-
Simple Payback	6.6	Year

Measure 1 + 3 Savings	827,729	kWh/yr
Measure 1 + 3 Savings	72,840	$/yr
Cost	1,012,162	-
Simple Payback	13.9	Year

6.9 UC Los Angeles Medical Center Oppenheimer Data Center

6.9.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center has a good start on cabinet layout in hot and cold aisles. There are some large pieces of equipment, such as a mainframe and a storage unit, which are being moved out of the room, allowing for future expansion of the existing layout.

The ceiling in this data center is quite high (approximately 15 feet) so the ceiling plenum is not an appropriate place to collect return air. This will make the physical separation of the hot and cold aisles more difficult. The underfloor supply to the cold aisles is already accomplished. The cold aisles could be enclosed so that the remainder of the data center becomes the hot aisle. This may be an issue for the cooling of small equipment that is not in the cabinets, or personnel comfort.

If the hot aisle air is to be collected and returned to the CRAHs, more elaborate ducting will be required. Alternatively the installation of a dropped ceiling could be used to control air flow. This would require significant modifications to lighting, fire protection, and other systems.

6.9.2 Measure 2. Utilize Airside Economizers for Free Cooling

This data center is on the ground floor and on an exterior wall, which are good attributes for an airside economizer installation. However, the seven CRAHs spread throughout the room make it a difficult candidate for an airside economizer, as outside air would have to be ducted to each of the CRAHs. This measure will not be pursued in this data center.

6.9.3 Measure 3. Utilize Waterside Economizers for Free Cooling

Waterside economizers are the more logical choice for this data center because of the difficulty of controlling air flow. This measure would involve installing a closed circuit cooling tower, probably in the parking garage near the existing data center chiller plant. Cooled water would be pumped through new pumps to new cooling coils on the return air inlets to the CRAHs throughout the data center. The cooling water piping would follow the path of the existing chilled water piping.

6.9.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

The existing two 120 ton chillers are 22 years old and in very poor condition, particularly the condenser fins. These are not particularly efficient chillers to begin with as they have reciprocating compressors and are air cooled. The condition of the condenser fins decreases the efficiency significantly.

The data center is planning to replace these units soon, as they anticipate a potential chiller failure which could shut down the data center. Plans have been drawn up to install two 140 ton air cooled screw chillers. These chillers will have a peak rating at about 1.2 kW/ton, typical for air cooled chillers. They will have VFDs on the compressors, which may improve part load performance somewhat.

A new alternative for chillers in this size range is the water cooled Turbocor chiller, which is a small centrifugal chiller with VFD speed control. The inherent efficiency of centrifugal chillers, particularly at part loads, could be beneficial to the data center. The electric draw of Turbocor chillers and their supporting equipment would be in the range of half of the air cooled chillers proposed. They would require a cooling tower, which adds some complexity and water requirements. There is already a cooling tower in the parking garage adjacent to the data center chillers, so this requirement should not limit the potential for a convenient installation. The simple payback shown for this measure is fairly long, but since there is a budget to replace the compressors already, the marginal cost of more efficient chillers will be a better investment.

6.9.5 Additional Considerations

The 175 tons of CRAH might be converted to waterside economizer through a different approach. If the hot and cold aisle physical separation can be implemented, the return air temperature to the CRAHs will be roughly 95^{0}F. Under the current design, full load cooling will be provided with 42^{0}F chilled water and 75^{0}F return air. The same coils should be able to provide the same amount of cooling with 62^{0}F cooling water and 95^{0}F return air (both 20^{0}F higher than the current design points). It may be possible to cool the data center by heat exchanging its chilled water loop with cooling tower water whenever the cooling tower is 62^{0}F or lower, or whenever the ambient wet bulb is 57^{0}F or lower. This is an alternate to the standard proposed waterside economizer which eliminates the need for new piping and coils in the data center.

Table 6.9: UC Los Angeles Medical Center Oppenheimer Data Center Project Summary

Total Measure 1 Savings	234,768	kWh/yr
Total Measure 1 Savings	20,660	$/yr
Cost	254,320	-
Simple Payback	12.3	Year

Measure 1 + 3 Savings	778,925	kWh/yr
Measure 1 + 3 Savings	68,545	$/yr
Cost	669,946	-
Simple Payback	9.8	Year

Measure 3 Savings	163,602	kWh/yr
Measure 3 Savings	14,397	$/yr
Cost	415,626	-
Simple Payback	28.9	Year

Measure 4 Savings	483,552	kWh/yr
Measure 4 Savings	42,553	$/yr
Cost	650,000	-
Simple Payback	15.3	Year

6.10 UC Los Angeles Medical Center CHS Westwood Data Center

6.10.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center has a cooling load of just 13 tons in cabinets that are not densely packed. The room is in poor shape in terms of air containment, with many ceiling tiles missing and a number of openings in the floor. The performance of the system can probably be improved by eliminating these air bypasses. This project includes improving the layout of the server cabinets over time and providing better separation of hot and cold aisles as possible.

6.10.2 Measure 2. Utilize Airside Economizers for Free Cooling

There is no access to outside air from this small room in the medical center so this measure is not pursued.

6.10.3 Measure 3. Utilize Waterside Economizers for Free Cooling

There is no obvious access to cooling tower water near this room. The roof is probably 15 stories away, so no addition of waterside economizers is proposed.

6.10.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

The data center is served by chilled water from the campus chilled water plant, so a better efficiency chiller will not be available.

6.10.5 Additional Considerations

Some air is supplied to this room from an air handler other than the CRAH. It enters through several registers in the ceiling. There is significant mold growth around these diffusers. This suggests perhaps that the air being introduced is not properly dehumidified, which may cause condensation when it enters the colder data center. There is need for very little outside air in this small room. Reducing this flow to a minimum should be considered because it seems to be introducing unneeded humidity into the room, increasing the cooling load.

Table 6.10: UC Los Angeles Medical Center CHS Westwood Data Center Project Summary

Total Measure 1 Savings	22,776	kWh/yr
Total Measure 1 Savings	2,004	$/yr
Cost	11,931	-
Simple Payback	6	Year

6.11 UC Los Angeles Medical Center Reagan B Data Center

6.11.1 Measure 1. Hot and Cold Aisle Physical Separation

This is a new, small data center with a very light load. It contains a number of empty cabinets. These are currently arranged in a hot and cold aisle configuration without physical separation. Employing curtains and ceiling plenum return would offer improved efficiency and cooling capacity for the room.

6.11.2 Measure 2. Utilize Airside Economizers for Free Cooling

There is no access to outside air from this basement location.

6.11.3 Measure 3. Utilize Waterside Economizers for Free Cooling

There is no access to condenser water from this room.

6.11.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

This data center is already served by an efficient campus chiller plant, so no change is proposed.

Table 6.11: UC Los Angeles Medical Center Reagan B Data Center Project Summary

Total Measure 1 Savings	43,450	kWh/yr
Total Measure 1 Savings	3,824	$/yr
Cost	17,632	-
Simple Payback	4.6	Year

6.12 UC Los Angeles Medical Center Reagan 3 Data Center

6.12.1 Measure 1. Hot and Cold Aisle Physical Separation

This is a new, small data center with a very light load. It contains a number of empty cabinets. These are currently arranged in a hot and cold aisle configuration without physical separation. Employing curtains and ceiling plenum return would offer improved efficiency and cooling capacity for the room.

6.12.2 Measure 2. Utilize Airside Economizers for Free Cooling

There is a window in this room which potentially could be used for access to outside air. The low load, however, does not justify a project.

6.12.3 Measure 3. Utilize Waterside Economizers for Free Cooling

There is no access to condenser water in this room.

6.12.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

This data center is already served by an efficient campus chiller plant, so no change is proposed.

6.12.5 Additional Considerations

There are plans for increasing the processing load in this room and adding new CRAHs, perhaps in an adjacent room. This should be done with consideration of hot and cold aisle separation for maximum future data center capacity.

Table 6.12: UC Los Angeles Medical Center Reagan 3 Data Center Project Summary

Total Measure 1 Savings	36,967	kWh/yr
Total Measure 1 Savings	3,253	$/yr
Cost	17,632	-
Simple Payback	5.4	Year

6.13 UC Los Angeles Medical Center Santa Monica Data Center

6.13.1 Measure 1. Hot and Cold Aisle Physical Separation

This is a small data center with a very light load. It contains a number of empty cabinets. There is a small potential to improve performance through better separation of hot and cold aisles in this room.

6.13.2 Measure 2. Utilize Airside Economizers for Free Cooling

There is no access to outside air from this basement room.

6.13.3 Measure 3. Utilize Waterside Economizers for Free Cooling

There is no access to condenser water from this room.

6.13.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

This data center is already served by an efficient campus chiller plant, so no change is proposed.

Table 6.13: UC Los Angeles Medical Center Santa Monica Data Center Project Summary

Total Measure 1 Savings	28,382	kWh/yr
Total Measure 1 Savings	2,498	$/yr
Cost	9,636	-
Simple Payback	3.9	Year

6.14 UC Riverside Statistics Data Center

6.14.1 Measure 1. Hot and Cold Aisle Physical Separation

This is a large, but relatively low density data center. There is a small amount of hot and cold aisle arrangement to the cabinets. However, there are many low density racks, mainframes, printers and other low load areas. Hot and cold aisle physical separation is recommended for the addition of future loads. It is understood that the dropped ceiling does not have plenum rated wiring so using this for return air would be problematic.

6.14.2 Measure 2. Utilize Airside Economizers for Free Cooling

This data center is on the first floor of the building but it has no exterior walls. The exterior walls are across halls from the data center, but these are the main passageways in the building. In addition, wall penetrations would probably involve brick walls, which will not be easy or inexpensive.

6.14.3 Measure 3. Utilize Waterside Economizers for Free Cooling

This data center lends itself to a waterside economizer configuration. This would involve a new closed circuit cooling tower on the roof, near the existing DX condenser. Cold water would be circulated to cooling coils in the return air inlets of the existing CRAHs and CRAC.

6.14.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

The CRAHs in this data center are already served by an efficient campus chiller plant so no recommendations are made for them. One of the air handlers is a CRAC, with its own less efficient compressors. Use of this unit should be limited as feasible; unfortunately it exclusively serves an academic colocation room.

Table 6.14: UC Riverside Statistics Data Center Project Summary

Total Measure 1 Savings	150,847	kWh/yr
Total Measure 1 Savings	9,805	$/yr
Cost	147,809	-
Simple Payback	15.1	Year

Measure 1 + 3 Savings	367,327	kWh/yr
Measure 1 + 3 Savings	23,876	$/yr
Cost	431,087	-
Simple Payback	18.1	Year

6.15 UC Santa Cruz Communications Data Center

6.15.1 Measure 1. Hot and Cold Aisle Physical Separation

This data center is well configured with hot and cold aisles already. The main CRACs are on an aisle perpendicular to the cabinet aisles. The cold aisles could be contained, with the hot aisles open to the perpendicular aisle. This would put most of the data center on the hot aisle side. The ceiling plenum may be available to use as a return plenum.

Alternatively, the hot aisles could be contained and provision made for ducting their air to the return air inlets of the CRACs. These already have some duct work extending their intakes nearer to the ceiling.

The research cluster has its own Liebert XDV fan coils mounted on top of the cabinets. This can easily be integrated into a hot and cold aisle physical configuration.

6.15.2 Measure 2. Utilize Airside Economizers for Free Cooling

The basement location of this room does not lend itself to an outside air economizer.

6.15.3 Measure 3. Utilize Waterside Economizers for Free Cooling

A waterside economizer could be used to provide much of the cooling load of this data center. It would involve a new closed circuit cooling tower on the roof of the building. This would be piped to cooling coils on the return air inlets to each of the CRACs. This would take the primary cooling load and the existing compressors would provide additional cooling as needed.

6.15.4 Measure 4. Utilize Energy Efficient Air Conditioning Equipment

Most of the cooling in this data center is done by CRACs serving the main part of the room. These are not particularly efficient cooling units. There is not a campus chiller loop to take advantage of in this building. Instead, the most likely efficiency improvement is to install evaporatively cooled condensers to replace the air cooled condensers on the roof. Alternatively, the campus condenser water loop could be used to perform this condensing function.

Table 6.15: UC Santa Cruz Communications Data Center Project Summary

Total Measure 1 Savings	145,766	kWh/yr
Total Measure 1 Savings	15,597	$/yr
Cost	119,083	
Simple Payback	7.6	Year

Measure 1 + 3 Savings	554,992	kWh/yr
Measure 1 + 3 Savings	59,384	$/yr
Cost	432,979	
Simple Payback	7.3	Year

Measure 3 Savings	227,816	kWh/yr
Measure 3 Savings	24,376	$/yr
Cost	313,896	
Simple Payback	12.9	Year

Measure 4 Savings	121,291	kWh/yr
Measure 4 Savings	12,978	$/yr
Cost	77,990	
Simple Payback	6	Year