February 23, 2009

Colorado Springs Utilities
Customer & Corporate Services
Enhanced Service Engineering

Scott Clark
Energy, Noise and P2 Program Coordinator
1638 Elwell St., Bldg 6236
Fort Carson, Co 80913-4356

Re: Walk-Through Audit Service: Fort Carson Building 1550 Data Center

On February 20, 2009 Colorado Springs Utilities visited your facility to suggest some ideas for energy savings / cost savings. Since the existing facility is planned for a major renovation, it was agreed that the report would focus on measures to integrate into the new design for best practice energy efficiency rather than renovation ideas for the existing systems. If plans change and there is a desire to utilize existing cooling systems, the report could be re-formatted for that purpose.

If desired, we can meet with a design team to review any of these concepts, discuss the pros/cons, and add further input to help prioritize and select measures to pursue.

Financial detailed calculations outlining costs, benefits, and payback times (or rate of return) are very often required for Owners to consider implementation. The information provided in this walk-through audit does not provide this level of detail.

We hope this information is useful. If there are questions or comments, please feel free to contact Tyrone Johnson or myself.

Sincerely,

Steve Doty, PE
Enhanced Service Engineering

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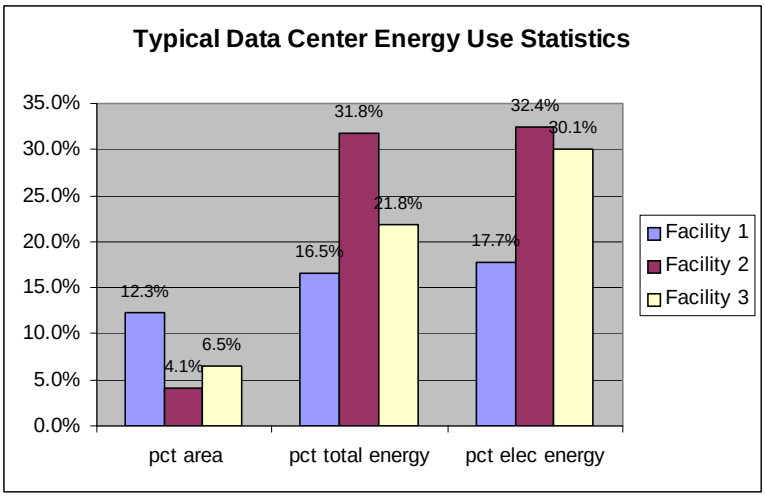
All utility-saving suggestions noted are optional. Nothing in this report is intended to supersede any law, regulation, code, local ordinance, or any Authority Having Jurisdiction, or impede with occupant comfort or facility operations. Safety, health and comfort are intended to take priority over utility conservation. If conflicts between this report and any other legal requirements exist, they are accidental and this report will defer to those requirements.

Energy savings are not guaranteed.

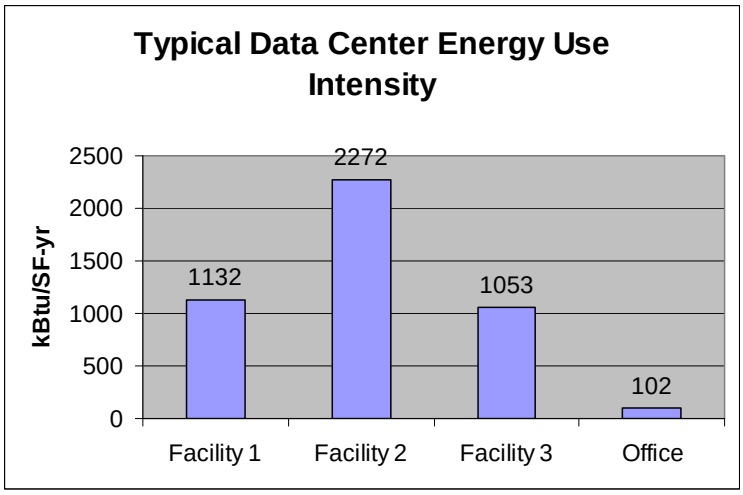
This information is provided in good faith, for use by the customer in conjunction with a qualified Contractor or Engineer.

SUMMARY:

The primary focus of this report is to provide strategic suggestions for 'building in' energy saving design measures for the planned data center renovation. This project is in the planning phase and so it is possible that energy saving suggestions can influence the design and are in time to do so if the customer chooses.



The data center is a small portion of the total building square footage, although probably consumes most of the energy. Still, without sub metering of the data center it is unknown what the energy use is. In other facilities that do have sub metering the following have been established.



Experience has shown data center energy use intensity values to be an order of magnitude higher than a standard office building. The following are values derived from data at other facilities and underscore the appropriateness of focusing energy conservation efforts on the data center.

In addition to energy conservation, there are other drivers for the data center renovation project, including:

- Server upgrade to high density blade units, and the inability of existing systems to properly cool them
- Cooling equipment at the end of its useful life

Thus the project is needed for functional reasons anyway – integrating energy conservation into the normal replacement effort is a very cost effective approach.

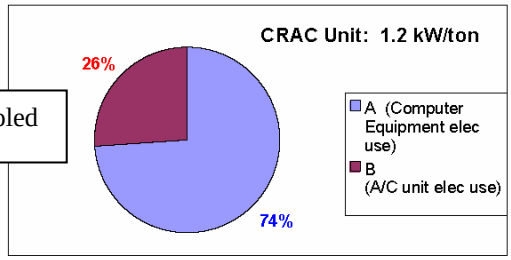
Energy use of the computer room cooling system is directly proportional to the computer energy use; i.e. the cooling system lives to serve the computers and will track energy use proportionally. However, the magnitude of the cooling system use can be influenced by several factors, most notably:

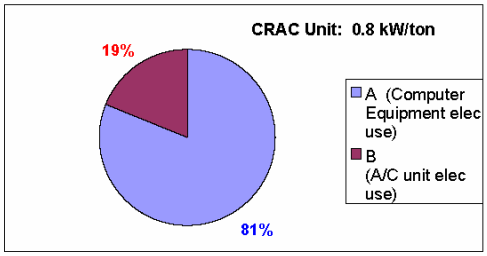
- Cooling system efficiency
- Environment temperature and humidity levels

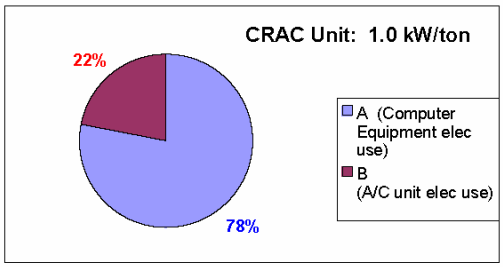
The effect of more efficient cooling systems is shown below. This is a mathematical derivation of processing the heat release from the computer equipment at various cooling COPs. Ancillary energy such as fans and humidifiers is not included.

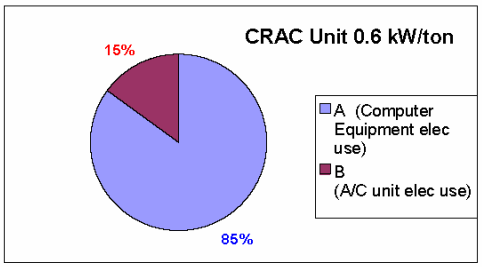
PROPORTIONS OF COMPUTER AND COOLING EQUIPMENT, BASED ON COOLING EFFICIENCY

Air Cooled









Water Cooled

Eff kW/ton	A (Computer Equipment elec use)	B (A/C unit elec use)
1.2	0.74	0.26
1	0.78	0.22
0.8	0.81	0.19
0.6	0.85	0.15

$[{}^{1}/_{1+(0.284 * EFF)}]$ = "A"

$(1-({}^{1}/_{(1+0.284*EFF)}))$ = "B"

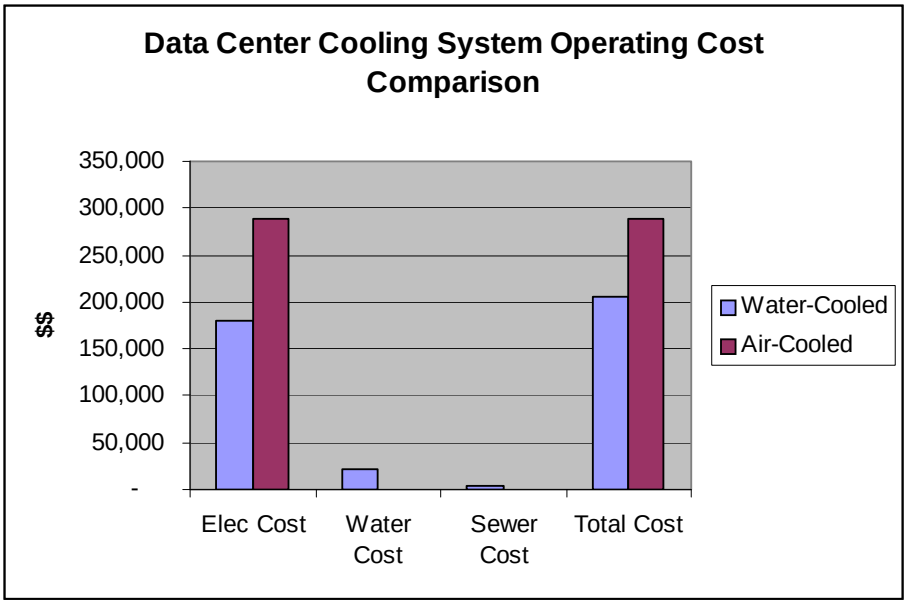
Total kW(h) * A = Computer Equipment kW(h)

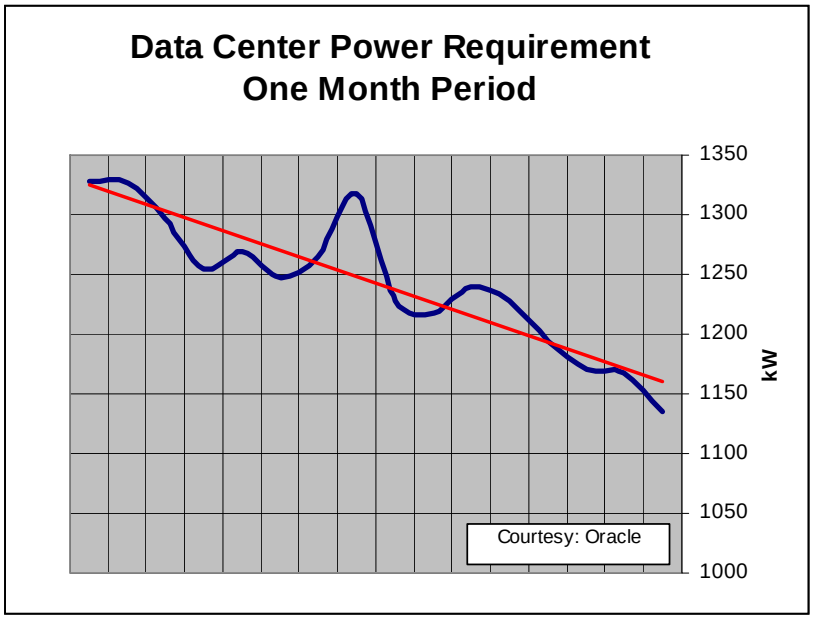
Total kW(h) * B = Coolilng System kW(h)

Source: *Energy Efficiency in Computer Data Centers*, Energy Engineering, Vol. 103 #5 (2006)

Water-cooled systems have an inherent advantage over air-cooled systems in climates like ours where the wet bulb temperatures are significantly lower than dry bulb temperatures in summer (semi-arid climate region). This, with properly specified equipment, allows lower condensing temperatures and corresponding reduced compressor lift and power. Energy loss from cooling tower fans and pumps are parasitic but can be mitigated by prudent design and power budget criteria (e.g. 0.05 kW/ton for cooling tower fan sizing, etc.). Water cost also subtracts from the energy savings potential, but energy savings for water cooled dominate even water and auxiliary power burdens are considered. One of the reasons for

this is the ability to utilize a “water economizer” cycle. With this cycle, the indoor equipment can be cooled by using cooling towers and pumps in winter, but with chillers off. By comparison, the air cooled option would require the compressors to operate year-round. A spreadsheet analysis of the give-and-take of energy and water for air-cooled vs. water-cooled is shown below. A number of assumptions were used in this basic energy model, and are available for full review if desired. The purpose was to provide accounting of the various factors in system selection. In this rough example, the data center load is assumed to be 1.0MW and is estimated to provide annual savings of about $80,000 and a 50% reduction in peak electrical demand. For these reasons, water-cooled systems are recommended for large data centers.





The effects of less stringent environmental conditions are shown below. This graph shows the reduction in cooling system sub metered kW over a 2 week period as the temperatures were increased from 70-72 degF and the humidity levels were lowered from 45-30 percent rH. The effect was particularly pronounced at this site due to the use of direct expansion (DX) cooling equipment operating at relatively low apparatus dew point. Thus, a high degree of simultaneous humidification and dehumidification was observed. This diagram makes the energy case for low room humidity. Obviously, to achieve these savings requires computer equipment that will operate normally without maintaining high rH conditions.

DESIGN INTEGRATION SUGGESTIONS

Notes:

1. The customer should review each suggestion carefully to ensure it does not impact production or product quality.
2. Where savings data are shown individually, they may not be additive. For example, if more efficient cooling equipment saves $1000 per month, and more efficient lighting saves $1000 per month, doing both would not save $2000 per month since the reduced light energy reduces the cooling load. Generally, de-rating individual measures by 30% will allow simple adding with little risk of over-stating the overlapping effect.
3. For a data center, reliability is a key design factor. This report focuses strictly on energy and must be tempered with other project initiatives including reliability and first cost.

Suggested Measures
Reduce Data Equipment Energy Use. This is the #1 measure since all energy used by the cooling system simply mirrors and amplifies that energy use. Reducing one reduces the other automatically and proportionally. Ways to achieve first-tier energy reductions: • Higher efficiency equipment that consume less power. • Virtual servers for low-access data, allowing idling equipment to be turned off. An example of this process was demonstrated on site and appeared to be effective in turning off idling equipment.
Specify Data Equipment With Forgiving Environmental Criteria. Higher temperatures and (especially) lower humidity conditions allow the cooling system to function at higher efficiencies. Several other measures below will key on assumed controlling operating costs related to humidification and dehumidification, but all benefit proportionally by the ability to lower the ambient relative humidity. If the equipment can function normally at these levels, design to 72 degF and 25pct rH. By comparison, traditional design parameters are often 70 degF and 50% rH. Ideally, equipment for data centers will be designed in the future to operate at higher temperatures and be cooled by outside air. This, in addition to being immune to humidity swings or low humidity would allow standard air economizer cooling and simple ventilation for extremely low cooling costs. However, current practice is both temperature and humidity constrained and brings with it the HVAC partner costs.
Water-Cooled Chillers Instead of Air-Cooled. • Summer power requirements are roughly half of air-cooled, reducing infrastructure burden. • Water-cooled systems provide roughly 37% energy savings and 29% utility cost savings over air-cooled systems.
Separate The Chilled Water System Serving The Data Center From The Balance Of The Building. This measure allows optimization of the data center and the building chilled water systems. The value in this measure is in the fact that the two HVAC applications are so different. By separating the two, the following can be optimized: • Chilled water temperatures, especially the ability to elevate temperatures in the data center for reduced dehumidification. • Leveraging water-economizer for the data center and air economizer for the building.

Suggested Measures
Cooling Equipment (Chilled Water Coils) Selected Based On 50 degF Chilled Water, Instead Of 45 degF. This is a key specification requirement that, in turn, enables other measures. Elevating the inlet/outlet temperatures of the cooling water helps make the HVAC task "sensible only". In most systems there is some amount of dehumidification work. Significant to this comment is that all dehumidification and corresponding humidification needed to return the lost moisture is a parasitic energy loss to the cooling-only (sensible only) design intent. The verification step for the chilled water coil selection will be from engineering data sheets for the coils. Depending upon the combination of chilled water temperature, dry bulb and wet bulb temperature, and coil surface area there will be a "sensible cooling" and "total cooling" value for the coil. Whenever the two are different there is dehumidification. For pure sensible cooling performance the two numbers are the same. Review of standard CRAC unit coil selections has shown up to 15% of compressor work is unintended dehumidification, although 5% is more common. The goal is 0 percent on equipment selection. Goal for overall design is "sensible only".
Other "Sensible Only" Design Measures. • 50 degF chilled water design criteria, for equipment selection (above measure) • No dehumidification cycle/ no heaters • High apparatus dew point. This translates to high coil surface temperature for no dehumidification. It is an important design criterion because it steers the size of the coils. In the case of cooling "modules" proposed, it may require additional modules.

Suggested Measures

Water-Side Economizer.

If the chilled water design path is taken, a great benefit is the use of a flat plate heat exchanger and water-side economizer cycle. When outdoor conditions are right, a properly designed flat plate system allows the chillers to be turned off for a number of hours. Raising the chilled water design temperature to 50 degF allows even more hours off. Assuming a properly designed heat exchanger, the hours of "no compressors" can be estimated from weather data and wet bulb temperatures in the area.

The flat plate unit is piped in parallel with other chillers and acts like the "chiller" when in the economizer mode. During economizer mode, the cooling tower operating set point is lowered sufficiently to drive the cooling process. The heat exchanger is needed to relay the cooling effect from the cooling tower water system to the chilled water system, which is a sealed system.

For example, 45 degF chilled water can reasonably be expected from a flat plate when the wet bulb temperature is 35 degF or lower. For 50 degF chilled water, this range is extended to 40 degF wet bulb. The following chart shows the hours when the chillers could be turned off each year. There is still cooling energy expenditure during these times from pumps and cooling towers but is typically 25% or less of operation with a chiller compressor running. Shaded areas are compressor off prediction.

Colorado Springs - Wet Bulb Temperatures
Source: Weather Data From Carrier HAP, April 14, 2003

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0000	18.0	23.9	34.3	39.1	45.0	48.5	50.8	50.8	47.3	41.4	34.3	23.9
0100	17.1	23.2	33.6	38.5	44.4	48.0	50.3	50.3	46.8	40.8	33.7	23.2
0200	16.3	22.4	33.0	37.9	43.9	47.5	49.9	49.9	46.3	40.3	33.0	22.4
0300	15.8	21.8	32.5	37.4	43.4	47.1	49.5	49.5	45.9	39.8	32.5	21.8
0400	15.1	21.4	32.0	37.0	43.1	46.8	49.2	49.2	45.5	39.4	32.1	21.4
0500	15.0	21.2	31.9	36.9	43.0	46.7	49.1	49.1	45.4	39.3	31.9	21.2
0600	15.3	21.5	32.2	37.1	43.2	46.9	49.3	49.3	45.7	39.6	32.2	21.5
0700	16.1	22.3	32.9	37.7	43.8	47.4	49.8	49.8	46.2	40.2	32.9	22.3
0800	17.6	23.6	34.0	38.8	44.7	48.3	50.8	50.6	47.1	41.2	34.1	23.6
0900	19.7	25.5	35.7	40.3	46.1	49.6	51.8	51.8	48.4	42.7	35.7	25.5
1000	22.1	27.6	37.6	42.1	47.7	51.0	53.2	53.2	49.9	44.3	37.6	27.6
1100	24.6	29.9	39.8	43.9	49.3	52.6	54.7	54.7	51.5	46.1	39.8	29.9
1200	26.9	32.0	41.4	45.7	50.9	54.0	56.1	56.1	53.0	47.7	41.5	32.0
1300	28.5	33.6	42.8	46.9	52.0	55.1	57.1	57.1	54.0	48.9	42.8	33.6
1400	29.6	34.6	43.7	47.7	52.7	55.7	57.8	57.8	54.7	49.7	43.7	34.6
1500	30.0	35.0	44.0	48.0	53.0	56.0	58.0	58.0	55.0	50.0	44.0	35.0
1600	29.6	34.6	43.7	47.7	52.7	55.7	57.8	57.8	54.7	49.7	43.7	34.6
1700	28.7	33.7	42.9	47.0	52.1	55.1	57.2	57.2	54.1	49.0	42.9	33.7
1800	27.2	32.3	41.7	45.9	51.1	54.2	56.3	56.3	53.1	47.9	41.7	32.3
1900	25.3	30.6	40.2	44.5	49.8	53.0	55.2	55.2	52.0	46.6	40.2	30.6
2000	23.4	28.9	38.6	43.1	48.5	51.8	54.0	54.0	50.7	45.3	38.6	28.9
2100	21.8	27.4	37.3	41.8	47.5	50.8	53.0	53.0	49.7	44.1	37.3	27.4
2200	20.2	26.0	36.1	40.7	46.4	49.8	52.1	52.1	48.7	43.0	36.1	26.0
2300	18.9	24.8	35.1	39.8	45.6	49.1	51.4	51.4	47.9	42.1	35.1	24.8

45 degF **2760** hours at or below 35 degF wet bulb
50 degF **3690** hours at or below 40 degF wet bulb

High Efficiency Chiller.

Assuming the equipment is properly sized, the full load rating will be more indicative of annual energy use than the part load rating (IPLV) rating. This is not true of most buildings, but the data center load is quite persistent and weather-independent. A full load efficiency of 0.5 kW/ton is commercially available. Coupling this with a cooling tower rated at 65 degF leaving water (58 degF wet bulb, 7 degF approach) and 0.05 kW/ton power budget for the fan, will yield a very efficient primary cooling source.

The IPLV value is very important to regular buildings with wide fluctuations in cooling load and for those buildings an IPLV rating of half the full load rating is a worthy goal. It is mentioned here in case the building itself has any planned upgrades and as reinforcement to the concept of separating the building HVAC from the data center HVAC systems to allow each to be individually optimized.

Suggested Measures
Adiabatic Humidification Systems. The data center cooling load is unique in that it normally requires both cooling and humidification simultaneously. This is a perfect match for the adiabatic cooling system, known more commonly as a 'swamp cooler.' This system saves energy in two ways: • The humidification requires no new energy, such as the electric or steam heaters or infrared lamps in conventional humidification systems. • The added heat to make the steam becomes additional cooling burden; a parasitic loss. The 'free cooling' effect of evaporating water into the air stream can provide about 1% of the cooling work of the data center at average conditions. Adiabatic humidification can be located on-board with the cooling equipment via ultrasonic systems, or can be free-standing equipment. Each requires a water supply and normal upkeep associated with evaporative cooling technology. Humidification from evaporative cooling pads can also be incorporated into the common make-up air unit serving the data center, if located between the heating and cooling coils. This would stabilize humidity within the room and reduce the work of the chilled water coil in this air handler.
Upgraded Vapor Barrier. Even with new equipment, the existing space is to be re-used. Edge conditions were verified above the ceiling and below the raised floor. In general the space is sealed for fire rating only and a true vapor barrier does not exist. The second largest source of demand for humidification in a data center (behind the unintended HVAC cooling coil dehumidification) is loss to adjacent areas. This is controlled by a vapor barrier. Ideally, the entire envelope surrounding a humidified space is vapor tight, i.e. a non-permeable membrane exists. For a new data center enclosure, this would be an appropriate design element. For the existing area it is probably not practical; however some sealing measures are practical and are recommended. • Above the ceilings, seal fully all penetrations and voids at metal decking for the floor above. Numerous small voids were observed. Imagining the space full of water, the potential for vapor "leaks" is very apparent. • Add door seals. Cracks with visible light intrusion were observed on all doors; obviously not vapor tight. • For the primary entrance, there is a security vestibule. This presents a good opportunity to form an air lock, by sealing both sets of doors and instituting a policy that one door is closed before the other is opened.
Variable Air Flow. In most data centers, 10% or more of the cooling energy is attributed to fans. This is because every horsepower expended in circulating air water adds heat to the water and a cooling burden. At part load, the 10% becomes a larger and larger proportion of the total parasitic loss. Thus the argument for variable air flow is good. When CRAC units are over-sized the added losses become a permanent operating cost using constant air flow. Allowing the fan(s) to deliver just the needed air flow will reduce the excess circulation energy and cooling burden it creates. Reduced air flow resistance from higher efficiency fans, amply sized ducts, angled filters and low velocity cooling coil casings all contribute to reduced energy transport from the fans.
Variable Chilled Water Flow. Every horsepower expended in circulating chilled water adds heat to the water and a cooling burden. Allowing the pump to deliver just the needed water flow will reduce the excess circulation energy and cooling burden it creates.

Suggested Measures
Reduce Ventilation to Actual Number of People. Air Handler AHU-2 appears to be dedicated to this space. This is a 100% outside air unit and so is tasked with ventilation and pressurization for the data center. It was explained that originally there were many more occupants in this area than there are now, and so it is presumed that the space is currently over-ventilated. An interesting comment from operations was that humidity levels in the data center rise when it rains and falls during winter – these effects are most likely from the outside air being delivered from this unit. Energy-related measures for this unit: • Reduce outside air to meet intended number of persons. • Reduce corresponding exhaust to maintain a slightly positive pressure in the space.
Reduce Overhead Lighting Power. Every watt of lighting power translates into additional cooling load to remove it. Appropriate overhead lighting levels were observed (30 foot-candles), and the space does not appear over lit. Measures to reduce light energy in the data center: • Task lighting in lieu of bulk overhead lighting • Occupancy sensors to turn off lights when not occupied
Hot Aisle Containment System. A new HVAC approach, this offers some energy savings potential, although the most significant improvement is in computer equipment cooling, especially high density rack mounted 'blade' servers. Traditional room cooling is not effective in such high density areas. Energy savings from this system come from the following principles: • Variable air flow based on demand • Higher differential air temperature creates equal heat transfer with less air flow • Reduced overall circulated air flow mass, which results in less work and horsepower • Lower fan efficiency is countered by reduced amount of air flow • Normal ambient temperatures in the existing raised floor reduce thermal loss to adjacent space. Field measurements of 60 degF in the floor plenum are typical The higher 'return air' temperatures would result in higher efficiencies of cooling equipment if direct expansion (DX) cooling systems are used since that would translate to higher suction pressures. For chilled water, this will not create thermodynamic efficiencies unless chilled water temperatures are also elevated. Note, a preliminary review of this modular cooling rack system was provided by the customer. This is a new design and semi-proprietary. Considerations of cost, reliability, and serviceability need to be examined, and these are beyond the scope of this report. One consideration is ventilation for personnel servicing equipment within the clear plastic-contained environmental space, noting that the room ventilation system will not circulate within it; It is possible that a procedure to leave the aisle doors open on each end, with a box fan, would suffice.

Suggested Measures
Ice Storage. This is not an energy saving strategy and would likely increase overall energy use up to 20%. However, this may provide good operating cost benefits since off-peak electric cost is much less than on-peak costs. The ice system could, for example, be sized for the full data center load over a 12 hour period. A rough analysis of electrical cost savings shows a 1.0MW data center could save around $50,000 per year with the ice system at current rates. Other possible benefits to using thermal storage would be to exchange the cost of the ice system augmentation with generator capacity that would otherwise be there. For a 1.0 MW data center, it would be possible to move 300 kW to off peak as well as about a third of the total kWh per year. Using rules of thumb of $400 per kW of generator capacity and $100 per ton-hour of ice storage capacity, the concept of subsidizing the ice system with avoided generator cost can be evaluated. At 400 tons and 12 hours, the ice system premium could be $480,000. By having generator back up for only the chilled water pump, the generator could be 300kW smaller and save $120,000, thereby paying for a portion of the ice system. Combined with the utility savings the payback for this would be around 7 years, with a 15 year design life. These numbers are approximate and for discussion purposes only. Decisions on what to/to not put on the generator and complexities to add to the data center operations are a larger discussion and require more study, with owner decisions on what priorities are highest and what risks are acceptable.
Metering. Once built, energy management will be enhanced by the ability to quantify the data center energy use and its associated mechanical systems. Information for energy management activities are enabled by each individually and also the ratio of the two. If the power feeds for the computers and the mechanical support systems are separated into main sources, such measurement will be relatively easy and not costly. However if the power sources for the two are sprinkled together the goal of measurement will become impractical. It is recommended that a design criterion be to separate the two functions and provide two basic metering points for power and energy readings to log/trend and manage.