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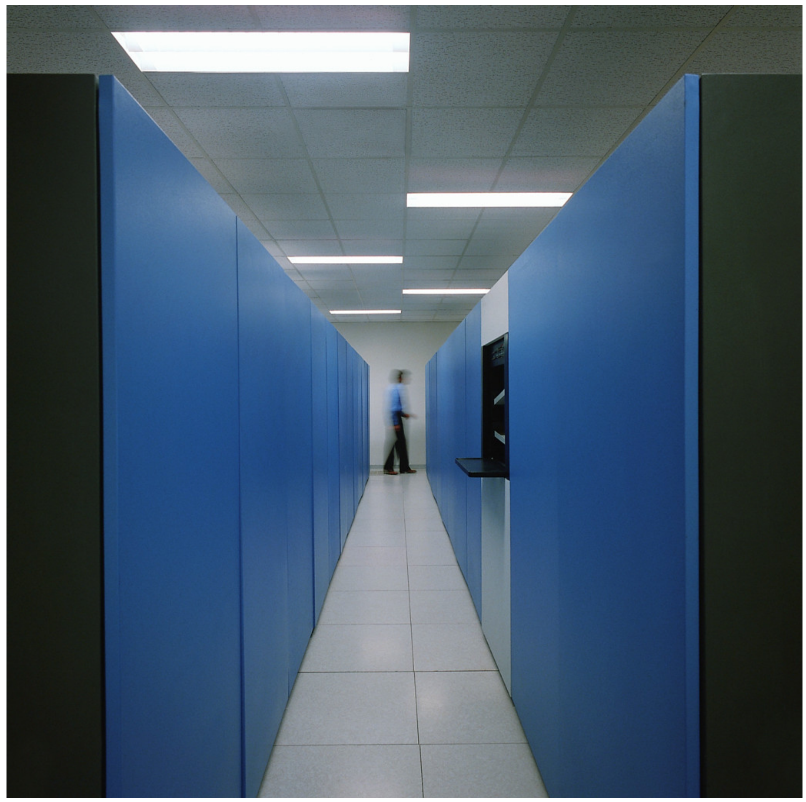
Energy Efficiency in Computer Data Centers



Computer Data Centers use a lot of electricity in a small space, roughly ten times that of a regular office building, per SF. For facilities with both office and Data Center functions, it is not uncommon for 15 percent of the building area to use 80 percent of the electricity.

Most of the energy used in computer data centers is from the equipment itself, which is often beyond the control of energy improvement efforts. Still, the cooling and other 'house' systems serving these machines are substantial energy users and can usually be improved on.

Finding ways to reduce energy consumption without affecting data center reliability is key. Some items are best 'built-in' to a new facility, while others apply equally well to new and existing facilities.

An important first concept is the energy end-use breakdown between computer room equipment and cooling systems that serve them. Depending upon the type and efficiency (kW/ton) of the cooling equipment, the proportion of cooling energy to computer equipment use varies from 15-25 percent, with the higher percentage being from air cooled equipment – the least efficient.

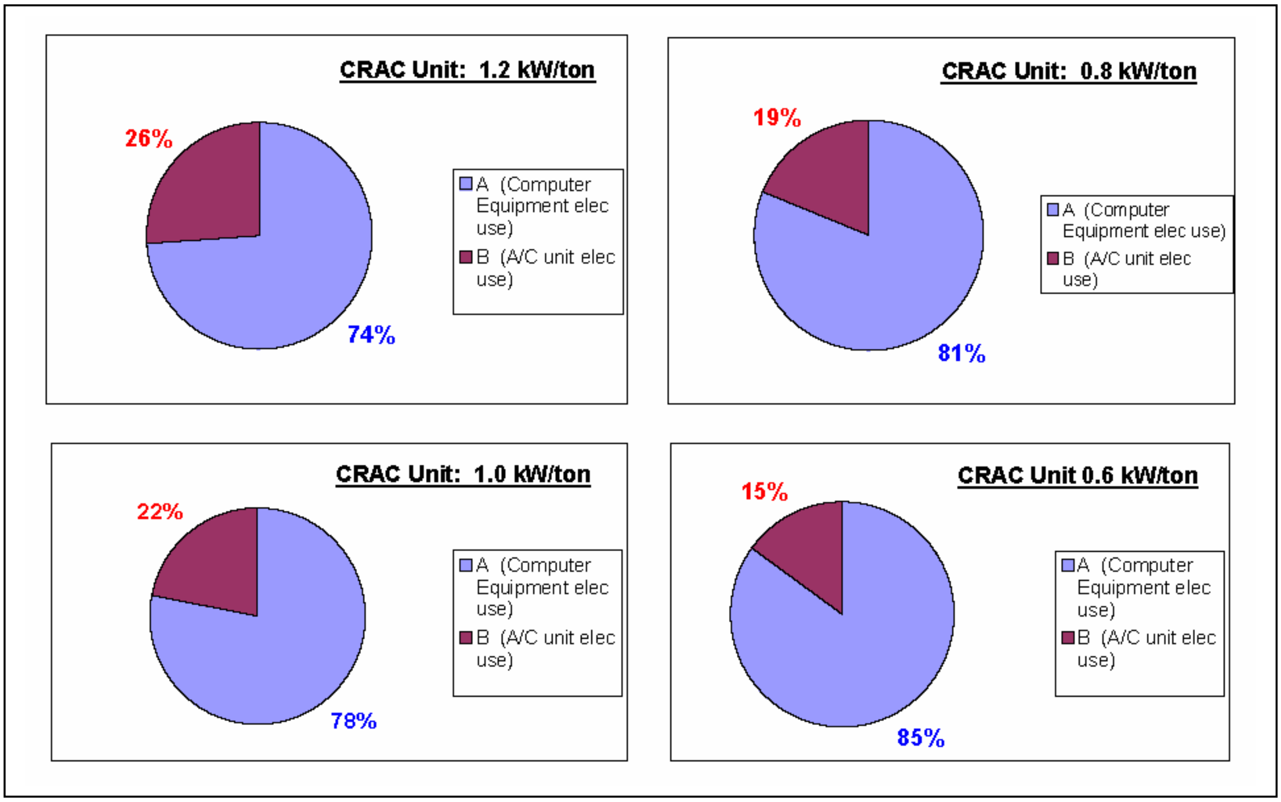


Fig. 1. End-use energy breakdown: Computer Room Equipment vs. Cooling Units

If the computer room equipment efficiency and energy consumption can be affected, this should be the very first place to look for savings, since it dominates all other energy uses. Unfortunately, there is usually not much that can be done to reduce this load, and so the attention is focused on the remaining facility piece. While there are improvements that can, and should be made to the facility piece, the savings achieved may appear small compared to the total bill. For example, if a 20 percent improvement is made to the cooling system energy use through efficiency gains; this would only end up reducing the overall bill by 3-5 percent. Keeping this in mind will avoid disappointment down the road.

If the prospect of reducing your Data Center energy use by 3-5 percent is of interest, read on!

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Here are a few tips that can provide savings in a Computer Data Center.

Please remember that the mission of any Data Center is to reliably process its work, so Energy Conservation Measures (ECM's) should only be considered if they do not impact system reliability.

Lighting directly adds to Data Center kW and cooling load. Each 3-4 watts of extra light becomes a watt of extra cooling energy, in addition to the lighting energy. So, using as little as you can, and using highest efficiency lighting to do it with, is the energy-saving answer. One suggestion is to pare down on the overhead "general" lighting and rely more on task lighting for inspecting equipment. Occupancy sensors can be used to advantage for rarely occupied areas.

Heating should not be needed, since Data Centers are a cooling-only load. As a general rule, picking your Computer Room Air Conditioners (CRAC Units) without heaters is appropriate.

Humidification is normally provided for Data Centers to reduce static and sparks, but don't overdo it. Depending on the equipment manufacturer, 30-35 percent rH may be enough to prevent spark issues. Some humidification will probably be needed; if so, opt for evaporative cooling instead of traditional electric resistance humidifiers. This low-energy source of humidification has a "byproduct" which is cooling - and in the case of a computer room, cooling and humidifying is exactly what you need! Evaporative humidification (ultrasonic, misters, wet pads) requires $1/10^{th}$ or less of the energy per pound of humidity compared to steam generators (boilers, pan heaters, infrared heaters), and the cooling effect of the evaporative process typically provides about 1% of the data center's cooling needs as well. A data center is one of very few HVAC applications that require cooling and humidification at the same time, so this is a natural partner for evaporative humidification.

Humidification should be limited to the Data Center, and not extended to the whole building. Remembering that humidification is expensive, try to keep it contained to the areas it's really needed. Suggestions on this topic include an air lock vestibule, air barrier, and **vapor barrier** between adjacent spaces, all intended to keep the humidity "in." For example a ceiling plenum connecting the Data Center to a general office area would add operating expense, since the moisture will migrate toward the dryer areas.

Cooling and Humidification Controls should be coordinated so the many CRAC units behave as one. There may be local areas needing more cooling due to equipment density, which is fine, but any calls for heating or humidification should be heavily supervised – to avoid adjacent systems bucking each other. Using multiple CRAC units, each with their own "stand-alone" controls is a built-in opportunity for simultaneous heating / cooling and humidification / de-humidification, and should be avoided if possible. Control re-calibration each two years is suggested.

Raised Floor systems are common, with the cold 'supply' air delivered, using the floor cavity as a duct. This means the floor will be a constant 55 degrees, year round. Insulation may be appropriate if the floor is over any unconditioned spaces. Also, the supply 'plenum' will naturally be at a higher pressure than the room, so any condensate drains located in this space should have trap primers and be suitably deep to avoid 'blowing' out the traps with the expensive cold air.

Building Envelope loads from walls, roof, and glass, are probably small compared to the heat load of the computer equipment, but a poor envelope will serve to drive the summer demand up, which then forms the basis of a 12-month ratchet charge from the utility. For this reason, the insulation in the roof and walls should meet energy code minimums, and there should be a minimum glazing and skylights. The best functioning Data Center would be an insulated box with no windows at all.

Cooling:

General:

- The Data Center air "system" will have advantages if treated as a separate system. Other than a small source of ventilation air, the other building air systems should not join with the Data Center air streams. The differences in conditions (temperature and humidity) as well as the 24-7 nature of a Data Center, make the two incompatible. To the extent that the Data Center and other areas share mechanical systems, there will usually be a built-in operational cost penalty.
- Arranging computer equipment for average heat density will make it easier to cool, and avoid the need for excessively low temperatures from common equipment, to satisfy local hot-spots.
- Use high quality cooling coil air filters, and verify that there are no air-bypass pathways, so all the air is routed through the filters. Minimum filter efficiency of MERV-7 is suggested.
- CRAC units circulate a great deal of air. Oversize filter sets, either 4-inch racks or angled filters, will reduce filter air pressure drop, allowing design air flow with a slower motor speed and reduced fan horsepower.
- Cleaning cooling coils annually is suggested, for sustained as-new performance.

If Air-Cooled Compressorized CRAC units:

- Provide ample room around the equipment to "breathe" and to be sure there is no re-circulation of the leaving condenser air back into the condenser air inlets. If the air entering the condensers is higher than regular 'ambient' air, the compressor work and energy cost will increase approximately 1-1.5 percent per degree; so as little as a 5 degree avoidable temperature rise at this location could increase cooling energy cost 5-7 percent.
- Consider evaporative pre-cooling to lower the summer kW/ton from 1.0-1.2 to 0.8 kW/ton. The evaporative pads come off easily for servicing. These clip-on units will make the air-cooled equipment "think" its 70 degrees outside when it's 95.
- Moderate the winter "head pressure control" settings so they only come into play when really needed to maintain normal refrigerant management operations. To the extent

possible, air-cooled equipment head pressures should be allowed to go lower along with outdoor temperatures, since the kW/ton will drop off as it does so. Of course, system reliability must come first with any ECM proposal, and this is especially true with refrigeration machinery.
- Maintain all air-cooled heat exchanger surfaces in a clean state, free from dust, debris, leaves, grass, etc. Annual cleaning is suggested for sustained as-new performance.

If Water-Cooled Compressorized CRAC units:
- For closed systems, utilize a fluid cooler instead of a dry cooler, to reduce head pressure. The fluid cooler can produce colder circulating water, since it's cooling effect is a function of outdoor wet bulb temperature instead of dry bulb temperature. The improvements of this change can be significant in hot weather. For example, on a 90 degree day, a dry cooler may produce 100 degree cooling water temperature, where a fluid cooler could produce 70 degree cooling water temperature. This 30 degree reduction can reduce hot weather equipment demand and energy use by 30-45 percent!
- Utilize closed circuit fluid coolers instead of a cooling tower, to keep the individual condenser heat exchangers clean and functioning efficiently. Fouling will raise head pressure and increase compressor power by 1-1.5 percent per degree.
- Amply size the evaporative fluid cooler to achieve full capacity at 65 degrees leaving water with 58 degree wet bulb temperature (7 degree approach), using only 0.06 kW/ton fan energy.
- Adjust the water control valves to achieve low, efficient head pressure, taking full advantage of the abundant cooling water source of the fluid cooler. Check unit head pressure at summer design load each year and verify these as-new conditions are sustained.

If Chilled Water:
- Provide the Data Center with its own pump and/or own chiller, so that the loop temperature can be adjusted upwards. Select the CRAC units equipment for max capacity with 50 degree water (not 45) so you can get the cooling you need without the dehumidification that comes with colder temperatures. By raising the chilled water temperature above the room dew point, simultaneous humidification / dehumidification will be avoided. At typical conditions of 45 degrees chilled water temperature, 72 degree room temperature, and 50 percent rH room humidity, as much as 15 percent of the cooling capacity is spent on dehumidification. This is like driving around with the brakes on. Note that the elevated chilled water temperature will affect the CRAC unit cooling capacity, so verify equipment capacity of existing equipment if this ECM is attempted. Regular on-site verification that the CRAC units are not de-humidifying is recommended. Elimination of simultaneous humidification and dehumidification can reduce data center HVAC costs by 10-20 percent!
- Monitor chiller condenser approach and utilize predictive maintenance techniques. Keeping the condenser free from fouling will keep it at its highest "as-new" efficiency level.

- Utilize Flat Plate Cooling. Typical Data Centers create a base cooling load that is steady throughout the year, which is much different than most other commercial buildings. This provides the opportunity for flat plate heat exchangers (water-side economizers) in tandem with a water chiller. The flat plate system works best when it is cold and dry outside, so as long as there is a cooling load, the cost of the flat plates can usually be justified. A typical sizing criteria for the flat plates would be 125-150 percent of the Data Center base load, so that all mechanical cooling can be turned off when the outdoor wet bulb temperature is below 40 degrees. This ECM feature should allow a properly designed Data Center over 3600 hours per year operation with no mechanical cooling, which is 42 percent of the year. The cooling equipment is at its highest efficiency when it is off!
- Utilize High Efficiency Chillers and Cooling Towers. Because of the extended run time, the extra cost of the highest efficiency equipment can usually be justified. Chillers that achieve 0.5 kW/ton or better at design conditions and cooling towers sized for full capacity at 65 degrees leaving water with 58 degree wet bulb temperature (7 degree approach), using only 0.05 kW/ton fan energy are readily available. A good rule of thumb for best efficiency is for the chiller auxiliaries (cooling tower fan and pumps) to each have energy use per ton that is 1/10th of the chiller itself.
- Colorado climate allows cooling towers to produce cold condenser water much of the year, so a strategic purchase decision for chillers would be the ability to accept colder condenser water. Some chillers cannot accept condenser water lower than 70 degrees, but others can accept 60 degree condenser at all loads without issue. This 10 degree difference can lower chiller power consumption by 10-15 percent.

Colorado Springs - Wet Bulb Temperatures

3690.0 hours at or below 40 deg wet bulb

	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

Fig. 2. Hours of the year in Colorado Springs at or below 40 degrees wet bulb temp.