Guide for Quickly Estimating Air Management Energy Savings in Small Data Centers: Air Management Look-up Tables

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Magnus Herrlin, Ph.D.
Lawrence Berkeley National Laboratory
One Cyclotron Road
Berkeley, CA 94720

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Table of Contents **Page**

Abstract

This report presents estimated energy savings for small data center chiller (refrigeration) and fan equipment in a new tabular format for various air management upgrade scenarios. Air management is not only important in its own right but air management is also a pre-requisite to other energy savings measures. If the scenarios included do not fit a particular data center, a previously developed Air Management Tool (DOE, 2014) can be used to calculate a wide range of data centers and air management scenarios.

With the guidance provided in this document, the look-up tables are easy to understand and use. This document can be considered a User's Guide to the tables, including two hands-on examples demonstrating their use and interpretation.

Not surprisingly, the overall trend seen from the look-up tables is that fan and chiller energy savings improve with more elaborate air management. The maximum percentage energy savings for the supply fans can be very high (>80%), whereas the maximum savings for the chillers are significantly lower (20%). However, under certain circumstances there may be additional chiller savings available.

With constant air volume (CAV) computer room air conditioner (CRAC) units, their modularity can impact fan energy savings significantly. Higher CRAC modularity (larger number of units but smaller) is favorable. Still, turning units off may pose operational risks associated with local overheating of IT equipment.

There is a drastic fan energy reduction associated with retrofitting CAV CRAC units with variable air volume (VAV) fans. However, the results also suggest that the cost effectiveness of driving air management too far in small data centers is questionable.

Purpose and Background

The purpose of this report is to provide a quick way of estimating the potential energy savings with air management in small data centers by using look-up tables. Air management is important, not only for improving energy efficiency, but also for managing the thermal environment.

Due to a number of implementation barriers in small data centers, including lack of expertise and funding, it would help to consider well-defined, rapidly deployable "packages" of individual air management measures that require only marginal customization. Such packages were developed in a "Master" document based on computer modeling "*Air Management in Small Data Centers*" (LBNL, 2016). A related document provides important updates to the measurement tool section "*Demonstration: Portable Air Management Measurement Tools*" (LBNL, 2018)

Only a limited number of simulation tools are available to estimate energy savings from air management in data centers. We used the U.S. Department of Energy's (DOE) "*DOE Data Center Air Management (AM) Tool*" (DOE, 2014), which was validated in 2010 with computational fluid dynamics (CFD) modeling with funds from Pacific Gas and Electric "*Data Center Air Management Research, Emerging Technologies Program Application Assessment Report #0912*" (PG&E, 2010).

For the Master document, a total of six air management packages were assembled and simulated. The percentage energy savings associated with implementing these packages were calculated and discussed for a limited number of air management scenarios. This report used these data to develop the look-up tables.

Some text in this report was copied directly from the Master document to produce a stand-alone document, especially for readers with good data center knowledge. For the sake of brevity, however, the data collection process, measurement tools, the simulation tool, and the prototypical data center are not discussed. For that information, please consult the documents referenced above.

1. Introduction

Data centers are among the most energy intensive facilities around, and air management is generally the first step in making the infrastructure support systems energy efficient. Since the data center environment is constantly changing, air management is not a one-time effort but rather an on-going process. Good air management in data centers is not only imperative for energy efficiency but also for managing the thermal environment, which is a proxy for equipment reliability. Good air management is critical to achieving the right balance between energy savings and thermal conformance. However, implementing air management correctly can be a real challenge, especially in small data centers. This document provides a pragmatic approach to alleviate that challenge for operators and owners.

The principles of air management are simple enough: funnel the cold supply air directly to the heat-generating electronic equipment and then remove the hot exhaust air as effectively as possible, minimizing the opportunity for mixing of the supply air and the exhaust air. The goal of air management is to provide as little supply air as possible at as a high temperature as possible without adversely affecting the thermal environment for the information technology (IT) equipment.

Unfortunately, air management is often misunderstood. Installing blanking panels or sealing the raised floor will not save energy per se. Such measures are rather examples of “enablers.” These enablers will only allow energy savings when they are implemented in conjunction with two “activators.” First, we need a way to reduce the supply air volume from the cooling system, which saves fan energy. Second, we need a way to increase the supply air temperature, which saves refrigeration energy.

There are a number of barriers to good air management in small data centers. For example, organizations need to have the expertise to implement air management effectively, which leaves out the bulk of small data centers. Furthermore, most small data centers do not have metering equipment, a monitoring system, or the expertise necessary to quantify their air management.

Judging from talks at data center conferences and articles in industry journals, it would appear that air management is common practice in data centers. Recent industry intelligence from the Uptime Institute and IDC shows that air management is, in fact, is not a standard practice in small data centers.

Small data centers are here defined as having less than 5,000 square feet of active floor area. Estimates suggest that a majority of all servers in the United States are hosted in such data centers. That means that the energy-savings opportunity is highest in these small environments (as a group) since large data centers are generally more energy efficient as well as hosting fewer servers. To achieve significant energy savings, the small facilities need to be targeted.

Consequently, a holistic approach is needed for saving energy with air management in small data centers. It would help to install well-defined, rapidly deployable “packages” of individual air management measures. Such packages must all include a way to reduce the supply airflow rate and/or increase the supply air temperature.

Simple and inexpensive solutions with clearly stated benefits are necessary to attract small data center owners and operators. This document may prove to be useful in the important, but difficult journey of making small data centers more energy efficient.

2. Air Management Packages

The interaction between individual air management measures can be strong; some measures will not result in savings without the implementation of other measures. Therefore, it makes sense to consider "packages" of air management measures rather than just individual measures.

Simulation tools can provide an estimate of potential fan and chiller energy savings by implementing a certain combination (package) of air management measures. The DOE Air Management Tool (2014) was used as the simulation tool for this and the previous work to calculate the energy savings.

The different quality/implementation levels of each individual air management measure used in the Air Management Tool are L (Low), M (Mid), and H (High). Table 1 on the next page shows a summary of what "L", "M", and "H" levels stand for with regard to each air management measure as well as typical implementation examples. A few of the measures will be discussed in some detail below.

Measure 7 (Equipment Class or EC-Class) has been assigned "H" since nearly all of today's electronic equipment adheres to the preferred IT equipment front-to-rear cooling airflow scheme (class), which supports hot and cold aisles.

Measure 8 (CAV/VAV CRAC) has only two values — "L" and "H"— where L = CAV (constant air volume fans) and H = VAV (variable air volume fans). To reduce the airflow, select CAV unit(s) can be shut off or all VAV units can be turned down. The latter is a much more efficient way to operate, since the fan energy is proportional to (nearly) the cube of the airflow. Turning off select CRACs not only reduces energy savings compared with turning down all CRACs, there also may be operational risks with turning equipment off.

The raised floor plenum is seldom a constant-pressure plenum; the pressure in the floor varies throughout the cavity. Turning a CRAC unit off can have unpredictable results on the airflow distribution entering the data center space, which, in turn, may affect the intake air temperatures to the IT equipment. Backdraft can also occur in CRACs that are off.

Measure 9 (CRAC Modularity) uses two models: One with two (2) CRACs (assigned M) and one with three (3) CRACs (assigned H). With constant air volume (CAV) CRACs, their modularity can have a significant impact on fan energy savings.

Note that the Air Management Tool does not allow input for the location of the temperature sensors for the control system. It assumes the ideal location; namely, at the electronic equipment intakes. The commonly used location at the air return is much less accurate, and the level of accuracy depends on the calibration with the IT equipment intake temperatures.

Table 1: Description of Each Level (Low, Mid, and High) of Air Management (AM)

AM Measure (AM Tool) (Measures 1 and 2 N/A)	**Level (AM Tool)**	**Typical Implementation**
3: **Aisle Containment**: Level of containment	Low: None Mid: Partial High: Full	Low: No containment. Mid: doors to (cold) aisles, rigid or curtains. High: full containment, doors to and lid over (cold) aisles or direct rack exhaust to return plenum.
4: **Blanking Panels:** Open area of total front rack area	Low: 10%–30% Mid: 5%–10% High: 0%–5%	Low: No or only marginal use of blanking panels. Mid: Fair use of blanking panels in racks, possibly under and between racks. High: Extensive use of blanking panels in, between, and under racks.
5: **Floor Leakage**: Floor leakage of total supply airflow	Low: 35%–65% Mid: 15%–35% High: 5%–15%	Low: Marginal use of grommets and seals. Mid: Major leakage paths sealed. High: Extensive effort to limit all floor leakage.
6: **Tile Placement**: Perforated tiles outside the cold equipment aisles	Low: 15%–25% Mid: 5%–15% High: 0%–5%	Low: Large number of tiles outside cold aisles. Mid: About one in ten tiles outside cold aisles. High: Nearly no tiles outside cold aisles.
7: **EC-Class**: Airflow protocols other than front-to-rear	High: 0%–5%	Low: N/A Mid: N/A High: Nearly no IT racks ventilated other than front-to-rear
8: **CAV/VAV CRAC**: Level of air volume adjustments	Low: CAV (constant) High: VAV (variable)	Low: Constant Air Volume fans. Mid: N/A High: Variable Air Volume fans.
9: **CRAC Modularity**: Number of racks served by each CRAC	Low: 40%–80% Mid: 20%–40% High: 10%–20%	See previous column.
10: **Cable Management**: Blockage of total cavity volume	Low: 25%–35% Mid: 15%–25% High: 5%–15%	Low: Unbundled cabling with a large number of cables, including retired. Mid: Mixture of bundled and unbundled cables. High: Bundled cabling with only active cables.

Defining Small Data Center Air Management Packages

The data center air management packages were especially designed to work in small data centers, allowing cost-effective hands-on replication across many data centers with little or no customization.

Table 2 below outlines the six packages (Reference through P5). The sophistication level of air management increases when moving from the left to the right in the table. Package 5 represents a "state-of-the art" package. Please consult Table 1 for the description of each individual level (L, M, and H) of air management. Although either CRAC Modularity can be used for each package, it is assumed that the modularity will stay unchanged while implementing a more advanced package (that is, moving to the right in Table 2).

Table 2: Small Data Center Air Management Packages

AM Measure (AM Tool)	Reference	P1	P2	P3	P4	P5
1: Recommended Range[1]	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F
2: Allowable Range[2]	N/A	N/A	N/A	N/A	N/A	N/A
3: Aisle Containment	L	L	L	M	M	H
4: Blanking Panels	L	M	M	M	H	H
5: Floor Leakage	L	M	M	M	M	H
6: Tile Placement	L	M	H	H	H	H
7: EC-Class	H	H	H	H	H	H
8: CAV/VAV (CRAC)	L (CAV)	L (CAV)	H (VAV)	L (CAV)	H (VAV)	H (VAV)
9: CRAC Modularity	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)
10: Cable Management	L	L	L	L	M	M

[1] The ASHRAE Recommended Range is used throughout.

[2] The ASHRAE Allowable Range does not enter the energy calculations.

The principle is that inexpensive measures are introduced first. An effective measure is one that is easy and inexpensive to implement and is a good enabler for energy savings (e.g., to place perforated floor tiles in the cold aisles only). In Table 2, this measure is indeed phased in the quickest, starting with package P1. Full aisle containment, on the other hand, only appears in the most sophisticated package (P5). This measure can be expensive, and it also requires other measures to be in place to secure the support for hot and cold aisles. Although this table suggests a logical sequence of upgrades, many data centers have been upgraded in a more haphazard fashion. Those data centers may be difficult to fit into this mold.

Modeling Assumptions

For the fan modeling with the Air Management Tool, the "Fan Exponent" for VAV operation was set to 2.8 rather than 3.0, to account for non-ideal conditions. Ideally (according to the fan affinity laws) the fan energy is proportional to the cube of the airflow. This high exponent is the reason that the percentage fan energy savings from air management measures can be very high. The Air Management Tool allows the user to set this exponent to any value between 2.0 and 3.0.

Furthermore, the "Chiller Factor" in the Air Management Tool was set to 2% chiller energy savings per degree F increase in supply air temperature. The Air Management Tool allows the user to set this parameter to any value between 1% and 3%. CRAC units often have values in the lower part of this range whereas CRAH (chilled water) units have values in the upper part.

Finally, the data center has an approximate 2.5 ratio between air handler capacity (airflow and cooling) and IT equipment demand. This ratio is fairly typical. Appendix A lists other important assumptions about the data center used for the modeling.

3. Look-up Tables

The first row in Tables 4-7 on pages 12 and 13 show the relative (percentage) savings achievable for fan energy and for chiller energy, respectively, for each package (P1-P5) compared with the Reference package, which has the lowest air management quality. However, a data center considered for upgrade may not necessarily be of this poor quality. In that case, we need a way to match the data center at hand with one of the package levels before the savings can be estimated. The following describes the methodology.

Step 1: Determine the Achievable (Maximum) Percentage Energy Savings for the Packages

Table 2 descriptions allow the Air Management Tool to calculate achievable (maximum) percentage chiller and fan energy savings for each package compared to the Reference package, assuming either CAV or VAV fans and IT equipment intake air temperature sensing.

Actual percentage savings may be less, since it may not be desirable to reduce the supply airflow or increase the supply temperature to the maximum levels. Step 3 below makes a correction for this situation, including return air temperature sensing.

The savings may also be larger should the data center currently operate with lower supply air temperatures than those shown in Tables 4–7. Step 2 addresses this case when actual data are available.

Step 2: Match the Data Center with one Package and Select the Target Package

One critical point for a particular data center is to select an appropriate air management package. This requires an assessment of the current data center conditions by visual inspection and some measurements.

- Visually inspect the data center with regard to the level of air management for each measure and then match the data to one of the small data center air management packages in Table 2. Select the package with the best fit to the conditions in the existing data center.
- This will now be the Matched package (see blue column in Table 3), with its predicted achievable supply airflow and supply air temperature.
- If the actual supply air temperature is known, that data should instead be used, since it is generally of better quality.

When the package with the closest match to the data center has been identified, a desirable Target package (see green column in Table 3) can be selected. Keep in mind that the supply airflow and supply air temperature for the Target package is a prediction made by the Air Management Tool for “achievable” conditions. The question now becomes, how much energy could be saved by moving from the Matched package to the Target package?

Knowing the airflow ratio and supply air temperature for the Matched data center and for the Target data center enables us to calculate the percentage savings. Tables 4-7 show the energy savings for all upgrade combinations that improve the energy efficiency (15). The combinations that make the energy efficiency worse are grayed out. To find the savings, locate the intersection between the Matched row (e.g., P2) and the Target column (e.g., P4).

Table 3: Example Selection of Matched and Target Air Management Packages

AM Measure (AM Tool)	Reference	P1	P2 **Matched**	P3	P4 **Target**	P5
1: Recommended Range[1]	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F
2: Allowable Range[2]	N/A	N/A	N/A	N/A	N/A	N/A
3: Aisle Containment	L	L	**L**	M	**M**	H
4: Blanking Panels	L	M	**M**	M	**H**	H
5: Floor Leakage	L	M	M	M	M	H
6: Tile Placement	L	M	H	H	H	H
7: EC-Class	H	H	H	H	H	H
8: CAV/VAV (CRAC)	L (CAV)	L (CAV)	H (VAV)	L (CAV)	H (VAV)	H (VAV)
9: CRAC Modularity	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)
10: Cable Management	L	L	**L**	L	**M**	M

[1] The ASHRAE Recommended Range is used throughout.

[2] The ASHRAE Allowable Range does not enter the energy calculations.

Measure 3 (aisle containment) goes from “L” (matched - blue column) to “M” (target - green column). Table 1 is used to figure out what this actually means. “L” means no containment, whereas “M” means doors to cold or hot aisles. Measure 4 (blanking panels) goes from “M” to “H,” and measure 10 (cable management) goes from “L” to “M.” All other measures are unchanged.

Step 3: Decrease Energy Savings for Matched and Target Packages based on Limitations

The achievable (maximum) percentage energy savings determined in Steps 1 and 2 may not be fully realizable. Actual savings may be less than achievable, since it may not be possible or even desirable to reduce the airflow or increase the supply air temperature to the maximum extent.

- Supply fan control
  - CAV control: If a CRAC unit cannot be shut off, no fan energy savings will be possible.
  - VAV control: If fan speed can only be partially reduced, fan energy savings will decrease—sometimes significantly—due to the near cubical relationship between power and airflow rate.

- Supply air temperature control
  - If supply air temperature can only be increased partially, the chiller energy savings will decrease.
  - If return air temperature sensing is used (most common) rather than the assumed IT equipment intake air temperature sensing, the supply air temperature may need to be reduced a degree or two as a safety factor, since return air sensing is less accurate. The level of accuracy depends on the calibration with the intake air temperatures. Again, the chiller energy savings will decrease.

Many (Matched) data centers are operated well below the achievable supply air temperatures for a number of reasons. If that is the case, *additional* savings are available. See example calculations below: Example 1 and Example 2.

Step 4: Determine the Absolute Energy Savings

The fourth and last step is to determine the absolute (rather than percentage) energy savings associated with upgrading from the Matched package to the Target package. Estimating these energy savings requires that an energy baseline be established for the Matched package.

The energy baseline could be determined in a number of ways. Ideally, there would be metering in place to measure the fan and chiller energy directly. Given that this ideal rarely occurs in small data centers, the fan and chiller energy need to be estimated. One potential method would first measure the actual IT electrical draw (UPS output, typically available on the UPS panel) and assume a PUE to arrive at the infrastructure energy. Then, by estimating the energy fraction for chillers and fans, respectively, two baselines could be established: One for chiller energy and one for fan energy. DOE (2017) provides some assistance with these estimates.

When the baseline is estimated per above, the Target package chiller energy and fan energy can be calculated based on the percentage savings established in Step 3. The absolute energy savings in kilowatt-hours would then simply be the energy for the Matched package minus the energy for the Target package. Again, there will be two separate calculations, one for the chiller and one for the supply fan.

Now when we better understand how Tables 4-7 were constructed, we will be ready to extract some results. Supply airflows, supply air temperatures, and percentage savings are those predicted as achievable (maximum) by the Air Management Tool.

Looking at the big picture, the trend in the tables is that both chiller and fan energy savings improve with more advanced air management. Remember that the sophistication level of air management increases when moving from the left towards the right in the tables. However, the magnitude and characteristics of these savings are quite different; the fan savings takes us on a wild ride, requiring some analysis, whereas the chiller savings are more limited but more predictable.

Note that the Reference package and packages P1 and P3 have constant air volume (CAV) CRAC units, whereas the remaining packages have variable air volume (VAV) CRAC units. Clearly, there is a significant energy reduction associated with upgrading to VAV CRAC units. However, the savings between the three VAV packages are not that large. This suggests that the cost effectiveness of driving air management to the P5 package may be questionable. This is especially true when considering that the savings for Package P5 may result in an airflow reduction (see “CRAC Airflow/IT Airflow” as indicated in Tables 4 and 6) of more than 50%, which may not be desirable.

The CRAC airflow can be safely reduced to 60%, but 50% is typically the limit. This limitation has to do with the risk of condensate freeze up on the cooling coil. Consequently, although the tables may indicate very steep airflow reductions, they may not be recommended. Note that a 50% airflow reduction still represents a respectable fan energy reduction of 86%!

Finally, note that although the percentage fan energy savings are higher than the chiller energy savings, the absolute savings may well be of the same magnitude. This stems from the fact that the fan typically uses less energy than the chiller does.

Example 1
Using the example shown in Table 3, the Matched data center P2 is highlighted in blue and the Target data center P4 is highlighted in green. The same colors are used to highlight this example in Tables 4-7.

Two CRAC Units

Tables 4 and 5 show the savings with two equally sized CRAC units. For redundancy, each CRAC is sized to meet the entire load. Normally both units are running but each with reduced cooling. If one unit fails (or needs service) the remaining unit is operated to cover the remaining load.

In Table 4, it should be noted that Target data centers P1 and P3 results in no fan savings (0%). This is because the airflow demand is not reduced enough to allow one of the two CRAC units to be shut off, which is a common situation in small data centers. The achievable airflow ratios (CRAC flow/IT flow) are shown in the far-left column as well as at the bottom of the table.

Table 5 shows the energy reduction of chiller energy as a function of air management sophistication. The trend here is a fairly steady increase in energy savings with an increase in air management sophistication since an increase in supply air temperature (SAT) increases the chiller efficiency. The achievable (maximum) SATs are shown in the far-left column as well as at the bottom of the table.

A data center with two CRAC units, the percentage savings from Table 4 (Fan) and 5 (Chiller) are 17% and 4%, respectively. In this case, the fan savings are about the same for a data center with three CRAC units (see below) simply because VAV fans are used in both the Matched data center and the Target data center.

Added Savings

As we noted above in Step 3, actual savings may be less than achievable since it may not be possible or even desirable to reduce the airflow or increase the supply air temperature to the maximum extent. Now, there is also a case when the actual savings may *increase*. Keep in mind that many data centers operate well below the achievable temperatures given in Table 5 for a number of reasons. If that is the case, those savings need to be added. For example, if we are currently running a 60°F supply air temperature for the Reference package, the savings associated with moving towards the achievable temperature of 64°F would be (64 - 60) x 2%/°F = 8%. The same logic can be applied to all packages.

Three CRAC Units

Tables 6 and 7 show the savings with the same data center but with three (now smaller) equally sized CRAC units. In Table 7, please note that the achievable supply air temperatures (SATs) are slightly higher than for the case with two CRAC units (Table 5). Higher modularity helps air management and allows higher temperatures. Still the % numbers in Tables 5 and 7 are identical simply because all SATs increased by the same number of degrees (2°F). The higher modularity with three CRAC units also allows the VAV flow rates to be slightly lower.

The largest change compared to the case with two CRAC units is for the fan energy with CAV CRAC units (the first two numbers in Table 6). In this case, one of the three CRAC units can be shut off (cooling and air flow) and thereby saving one-third of the fan energy. The cooling capacity of the two remaining units is more than enough. Having the third fan off also reduces the overall cooling load (fan heat). The CRAC unit modularity can indeed play an important role.

Finally, note that although the percentage fan energy savings are higher than the chiller energy savings, the absolute savings may well be of the same magnitude. This stems from the fact that the fan typically uses less energy than the chiller does.

Example 2
For this second example, let's look at Table 3 again. In this case, however, we will assume that we start with Matched package P1 (rather than P2) and end with the same Target package P4. We will go through the same analysis as we did in Example 1.

For improved clarity, the intersection between packages P1 and P4 are highlighted with a dashed box in Tables 4-7.

Two CRAC Units
Again, Tables 4 and 5 show the savings with two equally sized CRAC units where each CRAC is sized to meet the entire load.

In Table 4, it should be noted that moving from P1 to P4 results in fan savings of 76% compared to only 17% in Example 1 (moving from P2 to P4). This is simply due to the much higher CRAC to IT airflow ratio for P1 (worse) compared to P2 (better). And, this is – in turn - due to the fact that Package P1 is less sophisticated than P2. Note that the achievable airflow ratios (CRAC flow/IT flow) are shown in the far-left column and at the bottom of the table.

Table 5 shows the energy reduction of chiller energy as a function of air management sophistication. In this second example the savings are 6%, which is higher than in Example 1. Package P1 has a slightly lower achievable supply temperature than package P2. The achievable (maximum) supply air temperatures (SATs) are shown in the far-left column and at the bottom of the table.

Three CRAC Units
Tables 6 and 7 show the savings with the same data center but with three (now smaller) equally sized CRAC units.

Table 6 shows that the fan savings have decreased to 39% (from the 76% in Table 4) since the starting point for the achievable airflow ratios (CRAC flow/IT flow) was much lower (better). The higher modularity with three CRAC units rather than two also allows the VAV flow rates to be slightly lower.

In Table 7, note that the achievable supply air temperatures (SATs) are slightly higher than for the case with two CRAC units (Table 5). Higher modularity helps air management and allows higher temperatures. Still the % numbers in Tables 5 and 7 are identical simply because all SATs increased by the same number of degrees (2°F).

The largest change compared to the case with two CRAC units is for the fan energy with CAV CRAC units (the two upper-left numbers in Table 6, -33%). In this case, one of the three CRAC units can be shut off (cooling and air flow) and thereby saving one-third of the fan energy (-33%). The cooling capacity of the two remaining units is more than enough. Having the third fan off also reduces the overall cooling load (the fan heat of the non-operating unit no longer needs to be removed). Thus, CRAC unit modularity can play an important role.

Table 4 Look-Up Table with Percentage Fan Energy Savings and CRAC Flow/IT Airflow Ratio for Data Center with Two (2) CRAC Units

Match	**Target** P1	P3	P2	P4	P5
Ref. 2.51 (typical) CAV	0%	0%	-72%	-76%	-87%
P1 - 2.51 CAV		0%	-72%	-76%	-87%
P3 - 2.51 CAV			-72%	-76%	-87%
P2 - 1.6 VAV				-17%	-55%
P4 - 1.5 VAV					-46%
CRAC/IT Airflow	2.51 CAV	2.51 CAV	1.6 VAV	1.5 VAV	1.2 VAV

Table 5 Look-Up Table with Percentage Chiller Energy Savings and Supply Air Temperature (SAT) for Data Center with Two (2) CRAC Units

Match	**Target** P1	P3	P2	P4	P5
Ref - 64F	-10%	-12%	-12%	-16%	-20%
P1 - 69F		-2%	-2%	-6%	-10%
P3 - 70F			0%	-4%	-8%
P2 - 70F				-4%	-8%
P4 - 72F					-4%
SAT	69F	70F	70F	72F	74F

Table 6 Look-Up Table with Percentage Fan Energy Savings and CRAC Flow/IT Airflow Ratio for Data Center with Three (3) CRAC Units

	Target				
Match	P1	P3	P2	P4	P5
Ref. 2.51 (typical) CAV	-33%	-33%	-76%	-80%	-90%
P1 - 1.67 CAV		0%	-26%	-39%	-69%
P3 - 1.67 CAV			-26%	-39%	-69%
P2 - 1.5 VAV				-18%	-58%
P4 - 1.4 VAV					-49%
CRAC/IT Airflow	1.67	1.67	1.5	1.4	1.1
	CAV	CAV	VAV	VAV	VAV

Table 7 Look-Up Table with Percentage Chiller Energy Savings and Supply Air Temperature (SAT) for Data Center with Three (3) CRAC Units

	Target				
Match	P1	P3	P2	P4	P5
Ref - 66F	-10%	-12%	-12%	-16%	-20%
P1 - 71F		-2%	-2%	-6%	-10%
P3 - 72F			0%	-4%	-8%
P2 - 72F				-4%	-8%
P4 - 74F					-4%
SAT	71F	72F	72F	74F	76F

4. Summary

This report presents energy savings for data center chiller and fan equipment in a new tabular format for different air management upgrade scenarios. The tables can be used to quickly estimate the potential chiller and fan energy savings for a number of air management scenarios. Two examples demonstrate the use and interpretation of the tables. If these scenarios do not fit a particular data center, the Air Management Tool can be used directly to calculate a wide range of data centers and air management scenarios.

Although the overall trend of the results is that both fan and chiller energy savings improve with more elaborate air management, the magnitude and characteristics of these savings are quite different. The fan savings increase abruptly with the introduction of VAV fans whereas the chiller savings increase more steadily.

The energy savings for fans can be very high (>80%), whereas the percentage savings for the chiller energy is significantly lower (max 20%). Although the percentage fan energy savings are higher than the chiller energy savings, the absolute savings may be on the same order, since the energy used by the fan is typically less than that used by the chiller. These and other key findings are listed below.

- CRAC Modularity: With constant air volume CRAC units, their modularity can affect fan energy savings significantly. Reduced airflow needs may not allow units to be shut off when only a few large units are used, meaning that no savings can be realized. It is favorable to have more, but smaller, CRAC units. Turning off CAV units may also pose thermal risks for the IT equipment.

- Variable Air Volume CRAC Units: There is a dramatic fan energy reduction associated with upgrading from constant air volume (CAV) CRAC units to variable air volume (VAV) units. The latter is a much more efficient design, since the fan energy is proportional to nearly the cube of the airflow. Energy savings above 80% are possible but it may not be desirable to reduce the airflow to the maximum extent. Additional savings, not estimated in this report, are possible if conventional fans, belt drives and motors are replaced by plug fans and directly driven by variable-speed electronically commutated motors (ECMs), either as retrofits or with new equipment so equipped. See Coles (2012).

- Level of Air Management: The results suggest that the cost effectiveness of driving air management too far is questionable. This is especially true considering that the savings for the very highest-quality air management packages require an airflow reduction of more than 50%, which may not be desirable in a retrofit situation.

- Supply Temperatures: The energy reduction for chiller energy as a function of air management sophistication is a fairly steady increase in energy savings up to around 20%. The savings stem from the higher supply air temperatures allowable with better air management. However, many (matched) data centers are operated well below the achievable supply air temperatures for a number of reasons. If that is the case, additional savings are readily available.

Appendix A: Defining the Data Center Used for Modeling

For the simulations, the Reference data center was chosen to coincide with mostly poor (L) air management quality/implementation level in the Air Management Tool (see Table 2) since most small data centers are not well maintained.

We used two direct expansion (DX) CRAC configurations (modularity):

- Two 30-ton CRACs
- Three 20-ton CRACs.

Besides this difference, the data centers were identical.

Common Data Center Description:

Area: 2,000 ft^2 (45 ft x 45 ft)
Total IT racks: 60
Equipment rows: 4
Supply air path: Raised floor

IT Equipment Data:

Power: 82 kW
Temperature rise: 25°F (mainly modern equipment)
Airflow: 10,400 cubic feet per minute (cfm)

DX-CRAC (common in small data centers) Modularity:

2 x 30-ton (2 x 106 kW) CRAC; maximum CRAC capacity/IT load = 211,000/82,000 = 2.57
13,000 cfm (x2); CRAC maximum airflow/IT flow = 26,000/10,400 = 2.50
One redundant unit, but two running (with reduced cooling), providing 82 kW (23 ton) net sensible cooling.
Fans can either be CAV (ON/OFF) or VAV (modulating).

3 x 20-ton (3 x 70 kW) CRAC; maximum CRAC capacity/IT load = 211,000/82,000 = 2.57
8,670 cfm (3); CRAC maximum airflow/IT flow = 26,000/10,400 = 2.50
One redundant unit, but three running (with reduced cooling), providing 82 kW (23 ton) net sensible cooling.
Fans can either be CAV (ON/OFF) or VAV (modulating).

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