Cost Model – Energy Benefits DirectAire & SmartAire

Overview & Explanation

A cost model (See figure 1) has been created to provide the user a simplified method for directly comparing the energy cost of a typical non-directional grate to the Tate DirectAire directional grate product, the DirectAire product used with EC Fan technology, and the DirectAire used with the SmartAire product. This document provides an overview of the cost model along with a detailed explanation on its use.

Figure 1 - Simplified Energy Model Directional vs. Non-directional Grates

Usage and Practical Example

In-floor Cooling Cost Model

User Inputs - Data Center Characteristics

New or Retrofit	New
User IT Load (kW)	1720
Number of IT Racks	200
IT Racks per Row	15
Calculated Rack Density Average (kW)	8.6
Maximum IT Load Per Rack (kW)**	12.5
Per kWHr Cost	0.08
Locally Control SmartAire or Client Sensor Network	Local Control M & S Units
Expected IT Equipment Actual Power Usage (50-100%)	70%

*Note: Cells in **Red** denote user input fields

Figure 2 - User Input

User input is simplified to allow the typical IT or facility manager to make an educated decision in the use of these products. The only required input appears at the top of figure 1. The user must first choose whether the model to be configured is a new site or a retrofit of an existing facility. This will impact the payback calculations to be discussed later in this document.

The user then enters their total average IT load. This IT load is often easily found by taking the current UPS output kW values that can be retrieved directly at the UPS(s) units user interface. Also the design load of the site maybe entered, but the user is cautioned that this value maybe greater than the true current IT load.

The next input is simply the number of IT racks or devices served by an airflow panel. A one to one ratio of racks to airflow panels is assumed for all calculations. The user also enters the number of IT rack per row. This count refers to the number of contiguous racks installed per row.

From these data inputs the average IT load will be calculated on a per rack basis. Next the user must enter the actual IT load of the densest rack in place in the data center environment. It should be noted that a large difference (greater than double the average rack load) may result in higher than expected energy usage in the environment. This is explained in detail below.

Next the energy cost, in cents per kWh is required to accurately determine the expected simple Payback in Months. When in doubt, please use an average value for your area. (http://www.eia.doe.gov)

The user must then choose the type of SmartAire units under consideration. If the customer has an existing sensor network, than choosing the SmartAire-C type units would be correct, otherwise choosing a combination of SmartAire-M and SmartAire-S units is recommended due to their locally control configuration.

The final value for user entry is the expected IT equipment Actual Power Usage. This is not a reference to the processor utilization, but more a reference to the percentage of peak IT load that is expected on average. Modern IT hardware can ramp up and ramp down power usage depending on load and this percentage of full load for normal operation is the desired percentage value here. Note that typical IT hardware can drop as load as 50% during idle states, but more typical values are in the 70% range.

The example data center has a total IT load of 1.72MW or 1720kW. This is a moderately sized data center, with approximately 200 racks fitting into an 8000 square foot area with a density of approximately 215 watts/square foot. The model determines that the average density per rack is approximately 8.6kW. A survey of the data center reveals that the densest rack is approximately 12.0kW. The site is located in New Mexico, and has an average cost per kWhr of $0.08. The user has chosen to use locally control SmartAire units (SmartAire-M and SmartAire-S) due to the lack of an existing sensor network. The data center is recently built, and is deployed with modern IT hardware with an expected utilization rate of 70%. This means that although the site will peak at a full 1720kW, the average load of the site is approximately 1200kW when measured over time due to server hardware idle operation.

Initial Results

	Base Case	Option #1	Option #2	Option #3
	Typical Grate	DirectAire w/Belt Drive		DirectAire w/SmartAire &
Perimeter CRAH Unit Design	**w/Belt Drive Centrifugal Fans**	**Centrifugal Fans**	**DirectAire & EC Fans**	**EC Fans**
Rack Density for Calculation (kw)	12.0	12.0	12.0	8.6
Expected TAC %	50%	93%	93%	93%
Total Required CFM to be delivered (CFM)	603782	324614	324614	232640

Figure 3 - Initial Results

With the user input values present in the model, the tool will determine first the correct load to use in the Rack **Density for Calculation** row. This value differs depending on the technology under consideration. The maximum IT Load per Rack is used for all inputs except for Option #3, as the SmartAire product allows for local control of airflow to the equipment, making the total airflow required equal to the average airflow required per panel, regardless of density variations. In all other models, each tile must flow sufficient volume to handle the densest rack in the environment. For this reason, large difference in average and peak load will result in much higher airflow requirements for the data center, and therefore greater energy usage.

From this previous value the estimated total data center CFM required will be calculated in the respective row. This value is calculated by taking the peak kW load present in the data center, and multiplying this value by the 126 CFM/kW expected with average IT equipment. This value is then multiplied by the number of racks or airflow panels in the environment. This model has two expected values in the **Expected TAC %** row, 50% and 93% respectively for a typical grate, a DirectAire grate, DirectAire with EC Fans, and DirectAire, SmartAire and EC fans.

The following row, **Total Required CFM to be Delivered,** now takes the expected TAC percentage and the required CFM for the IT equipment in the data center and calculates the required CFM required to be provided into the raised floor plenum accounting for bypass air due to the effect of the TAC variable.

Secondary Results

CRAH Units Required (CFM/Tonnage specified below)	32	18	18	13
Total Fan Power Required (kw)	386.4	207.8	146.1	56.4
Estimated Annual Energy Consumption (kWh)	3385046	1819917	1279629	493827
Fan Annual Energy Cost $	**$270,804**	**$145,593**	**$102,370**	**$39,506**
Recommended Solution (Yes/No)	**YES**	**YES**	**YES**	**YES**

Figure 4 - Secondary Results

The **CRAH Units Required** row determines the number of 50 ton CRAH units capable of delivering 19,000 CFM each required to cool the total IT load present. It should be noted that the user can configure these values to suit their configuration. This value simply takes the **Total Required CFM to be Delivered** and divides this value by 19,000 CFM or the CFM value per CRAH or CRAC unit. When considering retrofit options this value will be reduced with each new configuration, suggesting that the user can place the additional units no longer required into standby mode. Since this calculation is done on an airflow basis alone, and in our example will require approximately 32 units for a typical grate configuration, while Option #1 and #2 will require 17,and Option #3 reducing the demand to 12. The larger the difference between the peak and average load, and the lower the TAC value, the greater number of CRAC units will be required to simply move the additional volume of air required to meet the demand of the racks and the resultant bypass air.

Total Fan Power Required now takes the total CFM required from the previous row, and multiplies that value in thousands of CFM (kCFM) by industry published data defining the energy required to move each kCFM. This ratio (kW/kCFM) determines the average power required to move the air into the data center raised floor. This value is displayed below the model, and at the time of this writing, assuming belt driven centrifugal blowers is calculated based on manufacture's data at the typical underfloor static pressure ranges from 0.02 to 0.20" of H20. For the model, the value has been fixed at 0.64 kW/kCFM.

Determining the total energy to operate the fan systems covered in the earlier rows is determined in the **Estimated Annual Energy Consumption (kWh).** This row simply takes the power requirements to move the required CFM and multiplies this value by 24 hours in the day, and then by 365 days annually. The **Fan Annual Energy Cost $** row is simply calculated by taking the kWh consumption annually and multiplying this value by the user inputted cost per kWh.

Final Airflow Results

Technical Results	Base Case Typical Grate w/Belt Drive Centrifugal Fans	Option #1 DirectAire w/Belt Drive Centrifugal Fans	Option #2 DirectAire & EC Fans	Option #3 DirectAire w/SmartAire & EC Fans
Expected Load Per CRAC or CRAH Unit (Tons)	15.3	27.2	27.2	37.6
Capacity Utilization of CRAC/CRAH units	30.6%	54.3%	54.3%	75.2%
Required CFM Per Rack (CFM)	1,509	1,509	1,509	1,082
Required CFM Per Panel (CFM)	3,019	1,623	1,623	1,163
Required Static Pressure Required to Meet Demand	0.20	0.05	0.05	0.08
Total Required CFM by IT Equipment (CFM)	216355	216355	216355	216355
Expected CRAC or CRAH Delta T (F)	9.0	16.7	16.7	23.2

Figure 5 - CFM Requirements and Recommendations

A technical results section appears at the bottom of the cost modeling tool. The values in figure 5 refer to these sections. Note that any cell with a red triangle in the upper corner will display additional cell calculation information in the mouse cursor is placed over it.

The **Expected Load Per CRAC or CRAH Unit** and the **Capacity Utilization of CRAC/CRAH Units** displays the expected capacity, in tons of each unit, as well as percentage of nameplate capacity the unit is achieving.

The **Required CFM Per Rack (CFM)** now determines the average CFM required per rack based on the 126 CFM/kW value built into the model. This CFM is then used to determine the required airflow rate based on the CFM required per rack, and the effect of the TAC row.

The following row, **Required Static Pressure Required to Meet Demand** now uses formulas appearing in equation 1, 2 and 3 below to determine, based on the **Required CFM Per Panel (CFM)** data.

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Equation 1 – Calculating required static pressure for a given CFM for a 56% non-directional grate

Equation 2 – Calculating required static pressure for a given CFM for a 68% Directional grate

Equation 3 – Calculating required static pressure for a given CFM for a 68% Directional grate equipped with SmartAire

This result is the required static pressure that must be maintained evenly across the floor to ensure the required flow rate per panel. If this calculated static pressure is calculated to be greater than 0.20" or results in a panel flow rate above the panel flow rate at 0.20" the result **NO** will be displayed in the **Recommended Solutions** row for each column not within the panels flow rate specifications. The final airflow results column displays whether the solution above is recommended for data center user. This value is determined by evaluating the maximum airflow that can pass through the panel is sufficient to meet the air flow requirements of the IT equipment.

The next airflow row estimates the **Required CFM Per Panel** to meet this load demand based on the TAC value. It can be seen that for the non locally control solutions that the peak load of 12.5kW is used to determine the demand CFM of 1500 CFM. The grate design with a TAC of 50% requires 3000 CFM of air to be delivered from the panel to meet this demand load. The DirectAire grates with the much higher TAC of 93% require only 1613 CFM per panel. Finally, the locally controlled SmartAire/DirectAire design needs only an average of 1032 CFM per panel to meet the average load of 8.6W, for a total delivered CFM of 1110 CFM. The required static air pressures are list below, and we can see that all solutions meet the recommended solutions criteria. (Static Pressure < 0.20")

The **Expected CRAC or CRAH unit Delta T** will display the expected temperature differential back at the cooling units in the data center, based on the TAC values given. These values are useful in determining the efficiency of the cooling units and will show less than ideal use of the cooling capacity the units offer.

Capital Cost and Operational Cost Results

Cost Per DirectAire	---	-$125	-$125	-$125
Number of SmartAire M Required				28
Total Cost of SmartAire M				-$32,760
Number of SmartAire S Required				172
Total Cost of SmartAire S				-$172,000
Number of SmartAire C Required				0
Total Cost of SmartAire C				$0
Total Cost of DirectAire and/or SmartAire	---	-$25,000	-$25,000	-$229,760
CRAH Unit Reduction	---	$490,000	$490,000	$665,000
Fan Upgrades (EC Tech)	---	$0	-$198,000	-$143,000

Figure 6 - Cost Impact

Figure 6 now shows the calculations required for determining the cost of the upgrade for each solution. An additional cost per DirectAire cost of $175 is entered from the user cost inputs, (discussed below) and the required number of panels is brought down from the previously entered user data. DirectAire unit cost in new build configuration is the differential cost between the DirectAire panel and a traditional Grate. A $2000 cost for the DirectAire and SmartAire are used for the appropriate column. It should be noted that these prices are elevated estimates for these items, and may not truly reflect the market prices for these items. Next the total cost for the DirectAire and SmartAire upgrades are summed. Calculations for SmartAire costs are computed based on the number of SmartAire-M, SmartAire-S, and SmartAire-C units required. The total cost of the SmartAire units and DirectAire units are calculated.

For new builds, the **CRAH Unit Reduction** include a per CRAH unit estimated cost of $35K, as these units would not be required for a new build using the respective technology. Calculations for the addition of the SmartAire product now take into account the use of EC fan technology at the air handling/CRAH unit level. This technology, coupled with pressure sensors throughout the floor, and the use of SmartAire products allow for precise control of the fan speed to deliver the required airflow to all racks as needed. The calculations are similar to the above calculations, although one important additional detail is required. The fan speed required per the expected IT hardware utilization results in a significantly lower kW/kCFM compared to the previous examples. The figure below illustrates these fixed values that are used for the calculations.

Site Assumptions	Typical Grate	DirectAire	DirectAire & EC Fans	DirectAire, SmartAire & EC Fans
Average Delta T of IT equipment (F)	25	25	25	25
Calculated CFM per kW (CFM)	126	126	126	126
Fan Energy (kw) Required Per kCFM	0.64	0.64	0.45	0.24

Figure 7 - Fixed Site Assumptions

Fan Energy (kW) Required Per kCFM for the DirectAire, SmartAire & EC Fans segment is calculated using the following formula.

Equation 4 – Calculating required static pressure for a given CFM for a 68% Directional grate

This IT hardware utilization establishes the turn down percentage of the EC fans to match the requirements of the IT hardware in partial load conditions. Note that the above equation will default to a value of 0.21 kW/kCFM if a value of less than 50% is entering in the utilization

Next, for solutions using EC fans, the cost for this upgrade is estimated in the Fan Upgrade Row. The **Fan Upgrades (EC Tech)** segment determines the additional of the DirectAire/SmartAire combination section takes into account the additional cost of the DirectAire/SmartAire pair, and the additional cost of the EC Fan upgrade. This upgrade is currently factored at approximately $11K per 19kCFM of fan capacity.

(Upgrade of a 50 ton CRAH unit, market research) The user can adjust these values to correctly compensate for the cost of their upgrades.

First Cost Savings	---	$465,000	$267,000	$292,240
Annual Energy Savings	---	$125,210	$168,433	$231,298
Payback in Months (simple)	---	0.0	0.0	0.0
3 Year Savings	---	$840,631	$772,300	$986,133
PUE Impact	1.80	1.70	1.66	1.61

Figure 7 - Upgrade Cost, Payback and 3 Year Savings

The results of the payback calculator analyzes the **First Cost Savings** for new builds, or in the case of Retrofits, **Cost of Upgrade** is indicated, as no capital expenditures savings are expected at the CRAH unit reduction level for a retrofit.

Next the **Total Energy Saving** that can be expected annually is shown, allowing for the **Payback in Months (simple)** to be calculated taking into account the cost and savings. The payback value will display 0 months when an upfront cost savings is expected. Finally a **3 Year Savings** is shown to take into account the reoccurring annual energy savings and the impact of first cost savings or upgrade costs.

PUE Impact	1.80	1.70	1.66	1.61

Figure 8 – PUE

The last line of the model shows the impact of PUE through the use of the various airflow technologies. A baseline PUE of 1.80 is chosen, and in each successive model the new PUE is calculated. This calculation simply takes the baseline PUE, subtracts the fan energy in the baseline example from the calculated total IT load for the facility, and then adds the new resultant fan energy usage for the new example to the facility load remainder. This new total facility load is then divided by the IT load entered by the user to produce the new PUE value displayed.

This model tool is meant to provide the user with a simple estimate of the energy savings that can be realized when investing in directional grates. This investment assumes the user has a method for reducing fan CFM output, either through the selective shutdown of individual cooling units, or through the use of variable speed fan technology. Please refer to Tate's whitepaper entitled, "Optimizing Capacity and Efficiency in a Diverse and Variable Load Environment" to better understand the benefits that can be realized with the use of EC fan technology in retrofit situations.

Variable Interaction Notes

As the user controls certain input values, it is important to understand the effect of these variables on the model's outputs.

The first user input is whether the installation is **new or a retrofit**. A new build will dramatically influence the initial upfront cost through a reduction in CRAH units required for the initial build out. A retrofit will assume the user is starting at the baseline grate configuration, and will simply turn off or place into standby those CRAH units no longer required. The EC fan upgrade will then assume the user only upgrades the required units for each phase, the EC only option and the EC fan plus SmartAire assumes the user only upgrades the number of units determined in the model.

The **User IT Load, Number of Racks and Maximum IT Load Per Rack** impact the estimated CFM required per panel and per rack. All solutions except for the SmartAire design will use the Maximum IT Load per Rack to determine the required CFM per panel instead of the average load per rack. This is due to the fact that the model cannot accurately predict the number of racks at the peak requirement, requiring each panel to provide sufficient airflow to meet the peak demand. The SmartAire solution does not require the peak to be considered, as the total airflow volume must remain the same per the user's input total kW. In this way, any peak rack demand can be met, as the difference in airflow is made up directly by the rack(s) that have a lower load and airflow demand due to the average rack load value.

Due to these factors, the larger the difference in peak load and average load, the greater the bypass air percentage will be, resulting in greater airflow requirements to meet the peak load demand. This fact illustrates the need to create a data center environment with as homogenous of a load profile rack to rack as possible. This however is rarely ever the case in most datacenters, which further justifies this function in the model.

Per kWHr Cost will only impact the annual savings of the site, which will then impact the length of the payback time period. As energy cost increase the payback will shortened in a linear fashion.

Finally the **Expected IT equipment Utilization** allows the user to determine what percentage off of the peak 100% load does their IT hardware shift over time. The peak User IT load entered in the first step is the measured or designed maximum load. This load will likely be rarely met, which allows the SmartAire product to deliver only the required airflow during non peak utilization. The user should carefully inspect their historical IT energy usage over each hour, day and week to determine what their true average load percentage is of their peak measured load.

Site and Mechanical Assumptions

Site Assumptions	Typical Grate	DirectAire	DirectAire & EC Fans	DirectAire, SmartAire & EC Fans
Average Delta T of IT equipment (F)	25	25	25	25
Calculated CFM per kW (CFM)	126	126	126	126
Fan Energy (kw) Required Per kCFM	0.64	0.64	0.45	0.24

Mechanical Assumptions for Above Calculations	
CRAC or CRAH unit	CRAH
Enter Tonnage of Unit	50
kW Draw CRAC or CRAH Fans - Belt Driven	12.16
kW Draw CRAC or CRAH Fans - EC	8.55
CFM per CRAC or CRAH Unit	19000
Purchase cost of CRAC or CRAH Unit	$25,000.00
Install cost of CRAC or CRAH Unit	$10,000.00
EC Fan Upgrade Cost	$11,000.00
Cost of DirectAire Panel	$300.00
Cost of SmartAire - M	$1,170.00
Cost of SmartAire - S	$1,000.00
Cost of SmartAire - C	$765.00
Cost of Typical Grate in New Build Situation	$175.00

Figure 5 - Site and Mechanical Assumptions

A segment of the cost calculator is shown in Figure 5 above. This section allows the user to make adjustments to the inner workings of the cost modeling tool to closely match their desired conditions. These variables are only meant to be adjusted by an advanced user with a thorough understanding of their environment and particular variations in their cooling hardware.