How to Save Over 60% on Cooling Energy Needed by a Data Center?
The Roadmap from Traditional to Optimized Cooling

EMERSON™
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Abstract

Data center managers are increasingly in search of methods and technologies for reducing facility energy consumption, while at the same time optimizing cooling efficiencies.
Varying solutions are available to meet these requests and satisfy customers' increasing demanding needs.
This white paper is thus designed to demonstrate how data center cooling efficiencies can be enhanced by replacing currently installed cooling units with advanced technology units.
In the development of this analysis, varying cooling solutions have been taken into consideration. The evaluation covers all elements from a general cooling product portfolio, demonstrating how the system's energy performance can be progressively improved with the adoption of certain technologies, to the use of the utmost efficient solutions currently available on the market.

For analysis purposes, two data centers located in Europe (one in Frankfurt and the other in London), have been used as reference sites. The two data centers are structurally identical: each consists of a 300 kW installation requiring N+1 cooling redundancy and adopt a Direct Expansion (DX) solution. The only difference is due to their varying annual temperature profiles. The two cases will illustrate how cooling efficiency increases occur despite the impact external temperatures may have on data centers.

Moreover, although the wide-spread assumption that Direct Expansion technology is associated with higher energy consumption when compared to chilled-water systems, the current analysis will demonstrate how the latest cooling technologies have allowed that gap to be dramatically reduced.

Introduction

The existing installation of both the Frankfurt and London data center models consist of Direct Expansion units. These data centers operate according to traditional cooling approaches where air conditioning temperature and humidity levels are controlled through the return air path with a set point of 22°C and a relative humidity (RH) of 50%. The six conditioning units initially installed incorporate standard scroll compressors - with R407C refrigerant - as well as traditional fixed speed fans and AC motors. The nominal capacity of each unit is 60 kW. Thus, five units will be running; with an additional unit in stand-by for redundancy purposes. The annual consumption of these systems amounts to 1,253,260 kWh and 1,254,400 kWh for London and Frankfurt, respectively. The pPUE (or partial PUE, which represents only the mechanical cooling segment of the annual PUE figure) that has been observed in these data centers is 1.4, contributing to an overall PUE of 1.6.

1. First Solution: Technology Upgrade

In order to provide a solution with increased efficiency, the first recommended enhancement to the installed conditioning units would involve AC fans being upgraded to EC (variable speed) fans, and the original refrigerant substituted with the R410A refrigerant. This would immediately lead to an energy saving of 5% (60,000 kWh per year) and would largely be attributed to the variation in consumption levels of the AC versus EC fan technology.

Essentially, the owners of both the London and Frankfurt data centers, can thus choose to replace the existing units with those possessing the same technology and incurring the same annual running costs. An alternative, and more efficient, solution would involve implementing the latest fan and compressor technologies available. The latter option reduces annual running costs, providing a minimized pay-back time due to highly efficient technological components. Table 1 shows the economic and energetic figures when comparing the abovesaid solutions for the Frankfurt data center.

Solutions Available for Frankfurt Data Center	Capital Cost	Energy Cost [€/year]	Savings [€/year]	Pay Back Time [years]	TCO in 2 years [€/kW]
AC fan Air Cooled	100%	125,266			1,146
EC Fan Air Cooled	110%	119,274	5,992	1.49	1,136

Table 1. Economic and energetic comparison of AC vs EC fan solutions for Frankfurt Data Centers.

As shown in table 1, the most efficient solution is that of the “EC Fan Air Cooled” alternative. This solution offers further CO_2 emission reductions within the entire data center, saving 5% of energy for cooling; depending upon the national power grid fuel mix.

If the data center manager decides to continue with the standard solution, they should nevertheless consider compensating for the extra CO_2 impact. The manager could, for example, draw on a renewable power source, such as solar panels, to make up for the lost energy. In such a scenario, to produce the same amount of energy, the data center would need roughly 280 m^2 of solar panels (more than the equivalent of one tennis court which is 261 m^2).

2. Second Solution: Indirect Freecooling

A second proposal, to further enhance the currently installed systems in Frankfurt and London, is to use indirect freecooling units, where the water coil is connected to an external dry cooler.
This system allows for further increases in energy savings by using the outside air temperatures in cooler seasons in order to cool the internal air through the water that has previously undergone the freecooling process.
This technology guarantees energy savings and ensures system availability. Here, savings would amount to 28% of the annual energy consumption registered both in the Frankfurt and London data centers. Below is a figure which illustrates this:

Solutions Available for Frankfurt Data Center	Capital Cost	Energy Cost [€/year]	Savings [€/year]	Pay Back Time [years]	TCO in 2 years [€/kW]
AC fan Air Cooled	100%	125,266			1,146
EC Fan Air Cooled	110%	119,274	5,992	1.49	1,136
EC Fan Freecooling	145%	89,656	35,610	1.18	1,048

Table 2. Economic and energetic comparison of different cooling solutions for Frankfurt and London Data Centers.

Repeating the comparison between the energy saved and the amount of alternative energy which would be required to produce the same amount of saved kWhs - in this case - the customer would need the equivalent of six tennis courts of solar panels.

3. Third Solution: Direct Freecooling

Despite the use of direct freecooling becoming increasingly common in data center applications, its use is still limited when compared to other solutions, such as shelters or cabins, mainly due to humidity control.
Direct freecooling is not only limited by external temperatures but, in particular, by humidity levels. Dry air can absorb varying quantities of vapor depending on its temperature. At a given temperature, there is a maximum quantity of vapor grams per kilogram which can be absorbed by air. As the amount of vapor increases, however, it cannot be absorbed by air any longer, causing a liquid (i.e. water) to form. Given specific external ambient temperature conditions, air will have a defined temperature and humidity level. This is defined as 'absolute humidity'. When comparing the 'absolute humidity' with the maximum level of absorption the air can hold at a certain temperature, the 'relative humidity' is obtained. From a physics point of view, 'relative humidity' is represented by the ratio of the partial pressure of water vapor in an air/water mixture, compared to the saturated vapor pressure of water at a prescribed temperature.

For example, at 18°C the maximum level of humidity is 12.89 g/kg. However, at 18°C, with 50% of the absolute humidity, it becomes 6.38 g/kg.
The higher the air temperature, the greater amount of humidity is absorbed.
These rules are widely applied in physics using the psychrometric chart that presents the different temperature and humidity conditions at sea level pressure.
This physics theory can also be applied to the fresh air freecooling operation. During the European winter season, the air is colder, thus the maximum humidity can be extremely low.
For example, at 5°C the maximum level of humidity is already below the ASHRAE recommended limit[1] and, as a matter of comparison, corresponds to the same absolute humidity of 24°C, at 28%

1 AHSRAE: 2011 Thermal Guidelines for Data Processing Environments

absolute humidity.
Under such conditions, extremely dry air enters the data center, thus requiring the use of a humidifier (a high energy consumption component) to compensate.

Similarly, during European wet seasons, such as spring or autumn, the risk is the opposite as air entering the data center requires dehumidification. With external temperature at 15 °C, and 100% RH with elements of fog, there would be an absolute humidity level of 80%; where relative humidity would sit at 24 °C. Efficient freecooling softwares allow the customer to choose whether to use freecooling operation or not, based on external weather conditions and energy consumption levels.

The savings surrounding direct freecooling operation are closely linked to data center humidity range limits. For a standard control of +/-10% of the relative humidity based on the standard set point of 24°C and relative humidity of 50%, savings only make up 12% of the annual consumption. Details are described in the table below.

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EC Fan Freecooling	145%	89,656	35,610	1.18	1,048
EC Fan Economizer	127%	109,732	15,534	1.61	1,126

Table 3. Economic and energetic comparison of different cooling solutions for Frankfurt Data Center.

In order to reap real benefits from the direct freecooling application, it is recommended that the customer extends the humidity control limits to those defined by ASHRAE as the recommended working zone specifications[2].

Classes (a)	**Equipment Enviromental Specifications**							
	Product Operations (b) (c)					**Product Power Off** (c) (d)		
	Dry Bulb Temperature (°C) (e) (g)	**Humidity Range, non Condensing (h) (i)**	**Maximum Dew Point (°C)**	**Maximum Elevation (m)**	**Maximum Rate of Change (°C/hr) (f)**	**Dry Bulb Temperature (°C)**	**Relative Humidity (%)**	**Maximum Dew Point (°C)**
Recommended (Applies to all A classes; individual data centers can choose to expand this range based upon the analysis described in this document)								
A1 to A4	18 to 27	5.5° C DP to 60% RH and 15° C DP						
Allowable								
A1	15 to 35	20% to 80% RH	17	3050	5/20	5 to 45	8 to 80	27
A2	15 to 35	20% to 80% RH	21	3050	5/20	5 to 45	8 to 80	27
A3	5 to 40	-12°C DP & 8% RH to 85% RH	24	3050	5/20	5 to 45	8 to 85	27
A4	5 to 45	-12°C DP & 8% RH to 90% RH	24	3050	5/20	5 to 45	8 to 90	27
B	5 to 35	8 RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29
C	5 to 40	8 RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29

Table 4. AHSRAE: 2011 Thermal Guidelines for Data Processing Environments.

2 AHSRAE: 2011 Thermal Guidelines for Data Processing Environments

With these working zone extensions, the total savings can arrive at a staggering 33% (41,774 €/year) for the Frankfurt-based data center. For London, on the other hand, which is characterized by a more "friendly" climate as far as direct freecooling applications are concerned, savings can reach up to 47%. Details surrounding these savings are shown below in Table 5.

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EC Fan Economizer	127%	109,732	15,534	1.61	1,126
EC Fan Extreme Economizer	127%	83,492	41,774	0.60	951

Table 5. Economic and energetic comparison of different cooling solutions for Frankfurt Data Center.

This solution has specifically been developed for data center applications that use external air only when temperature and humidity conditions are deemed suitable for the specific installation.

4. Fourth Solution: Variable Cooling Capacity and Latest Technologies

In order to further enhance energy savings and maintain a distinction between internal and external environments, the optimal solution is the alternative which uses an efficient modulating cooling technology.

The most efficient technology that can thus be implemented is the 'digital scroll compressor' with an EC fan and Electronic Expansion Valve[3].

The use of superior cooling technology reduces the data centers' cooling system energy consumption (for both the Frankfurt and London data centers) by almost half, making the return on investment visible in only a few months time. Details on superior cooling technology savings are illustrated below.

Solutions Available for Frankfurt Data Center	Capital Cost	Energy Cost [€/year]	Savings [€/year]	Pay Back Time [years]	TCO in 2 years [€/kW]
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EC Fan Extreme Economizer	127%	83,492	41,774	0.60	951
Digital Air Cooled	128%	66,710	58,556	0.45	843

Table 6. Economic and energetic comparison of different cooling solutions for Frankfurt Data Center.

Repeating the previous calculation in terms of solar panels, the equivalent of 10 tennis courts would be required to produce the same level of energy savings.

3 For more details on the savings resulting from a Digital Scroll see white paper: Liebert® HPM Digital Offers More Requires Less - Liebert® HPM: using the latest industry technologies to reduce energy consumption of your data center by 50%.

The energy saved also leads to reductions in CO_2 emissions of varying levels depending upon the fuel mix taken from the national power grid. On average, to produce the same amount of energy in Europe, 267,000 kg CO_2/year would be produced. To further clarify this concept, the amount of CO_2 emitted by European cars can be used as an example. The mean number of kilometers travelled per year, per person in Europe is 12,000 km and the emissions of a small car equal around 119 g/km. Using the most efficient units, equipped with superior cooling technologies, to cool a 300 kW data center would save the same amount of CO_2 as stopping 188 city cars in the European Union from circulating.

5. Fifth Solution: Reducing Energy Consumption and Optimizing the Installation Investment

In order to dramatically reduce energy consumption and thus truly optimize on installation investment, the data center manager must choose the solution that adjusts the cooling capacity to the servers' specific needs.

This solution includes the separation of the hot and cold areas using cold or hot aisle containment. This allows the cooling units to operate at higher air temperatures, therefore increasing both capacity and efficiency.

Such a solution is designed to include the latest cooling unit (i.e. compressor modulating technology with digital scroll, EC fan and Electronic Expansion Valve) with the best data center application controls and optimized distribution of temperature and air.

The ideal solution consists of a precise control of temperature, humidity, and air flow rate at the server level to ensure the exact availability of airflow needed by the server to guarantee its maximum lifetime and the highest reliability.

This solution is known as SmartAisle™ control for cold aisle containment, which includes the most superior market technologies, such as the digital air cooled modulating compressor, the EC Fan and the Electronic Expansion Valve all controlled in the most efficient way.

The overall result is a reduction in power consumption of more than 60%, again independently of the European reference site, with savings of up to 793,000 kWh (please see Table 7 for details).

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EC Fan Extreme Economizer	127%	83,492	41,774	0.60	951
Digital Air Cooled	128%	66,710	58,556	0.45	843
SmartAisle™ + Digital Air Cooled	154%	45,944	79,322	0.63	785

Table 7. Economic and energetic comparison of different cooling solutions for Frankfurt Data Center.

Producing the same amount of energy with solar panels would require a surface area equivalent to 3,800 m^2 (10% larger than the Colosseum). A similar amount of electricity as the one produced in Europe would lead to the emission of 372,710 kg of CO_2 and would produce the same savings as the ones obtained by stopping 261 city cars in Europe from circulating.

Conclusion

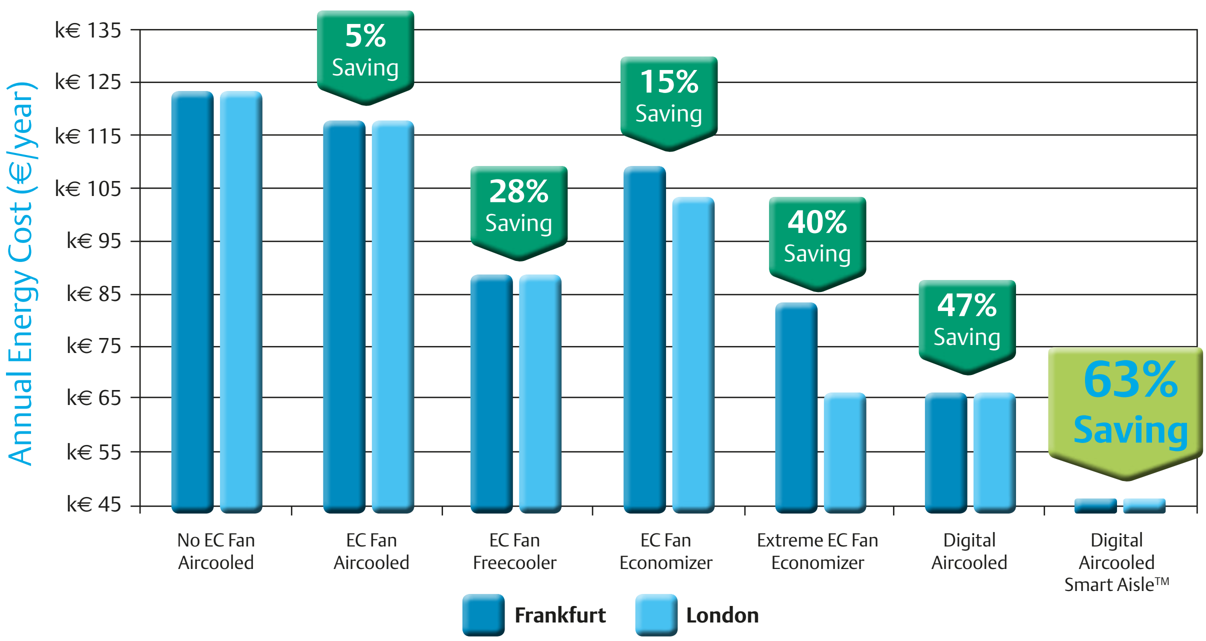
Cooling a data center can be achieved in numerous ways. Methods can range from traditional technologies to increasingly efficient means of addressing the same cooling needs by using the latest industry-leading technologies.

The SmartAisle™ cold aisle containment control logic solution, together with the most efficient technologies developed for a modulated cooling unit (Digital Scroll, Electronic Expansion Valve and EC Fan), allow for a cost saving of more than 60%. Furthermore, this solution provides a return on investment in only a few months. This is clearly shown in the graph below demonstrating the amount of savings earned by the Frankfurt and London data centers.

SmartAisle™, in fact, allows the maximization of energy savings and avoids any possible issues that might emerge from similar solutions where the external environment is in direct contact with the internal data room.

The achievable energy savings also lead to significant environmental sustainability initiatives with a reduction in CO_2 emissions by approximately 370,000 kg/year.

The traditional approach, claiming that Direct Expansion cooling solutions are high-energy consuming, has thus been proven inaccurate. The results of the analysis demonstrate that even city-center based data centers that are not equipped with chilled-water cooling methods are able to achieve a pPUE of 1.15; which is consistently lower compared to the initial pPUE of 1.4 observed in traditional cooling solutions.



Graph 1. Comparison between energy savings obtained using different cooling solutions

APPENDIX

Calculation Assumptions:

- Energy Cost 0.1 €/kWh
- 300 kW Data Center; Set point 22°C +/- 1°C; RH 50% +/- 10%.
- Annual energy consumption has been calculated with Emerson Network Power's calculating program utilizing the annual temperature profile of Frankfurt and London.
- CO_2/kWh for Europe – 0.59 kg CO_2/kWh - Reference: IEA (International Agency of Energy)
- Solar Panel Production: Southern Europe, kWh/year 4650 with 22 m^2 of solar panels

Bibliography

http://www.iea.org/

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