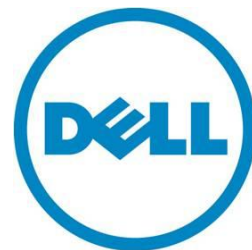

Dell's Next Generation Servers: Pushing the Limits of Data Center Cooling Cost Savings

This white paper explains how Dell's next generation of servers were developed to support fresh air cooling and overall data center level energy savings

Dell

Enterprise Reliability Engineering

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Executive summary

Cooling costs account for a significant portion of the energy consumption of a typical data center. Several hyper-scale data centers have demonstrated significant reductions in operational and capital expenses by building chiller-less data centers that rely entirely on the use of outside air for data center cooling. However, these data centers have been built mainly in northern climates that don't experience excursions to hot temperatures or high humidity levels. Several major world-wide standards and regulatory bodies, such as the Institute for Energy of the Joint Research Centre of the European Commission or the American Society for Heating Refrigeration and Air Conditioning Engineers (ASHRAE), are now recommending and even requiring economization capability for new data centers.

Dell conducted an analysis of climate data from across the United States, Europe, and Asia and found that, for the widespread deployment of highly economized and even chiller-less data centers, IT equipment is needed that can withstand short term excursions of up to 45°C. However, most commercially available IT equipment is rated at a maximum inlet temperature of only 35°C.

What if there was a way for data center operators to leverage fresh air cooling, realize the cost reductions of the hyper-scale data centers, and accomplish this in their locale instead of a specially selected northern climate? Dell's next generation servers are fresh air capable with a peak excursion temperature rating of 45°C. Dell's server line-up includes a broad portfolio of richly featured 1U, 2U, 4U, tower and blade servers. And, Dell offers fresh air capable storage, networking, and power products to round out a complete chiller-less data center. Regardless of whether you are considering a chiller-less data center, one that is highly economized, or whether you are looking for data center hardware with additional environmental capability and ride-through time in the event of an HVAC failure, Dell's servers are ready to meet your needs.

Contents

Introduction	3
Economization	4
Analysis of world-wide climate data	5
Matching equipment design to climate data	6
Estimating cooling cost savings from economization	8
Next generation servers and energy savings with more features	11
IT equipment reliability	13
Conclusion	14

Introduction

In public announcements over the last several years, Yahoo¹, Google² and other companies have demonstrated that construction and operation of a chiller-less data center with free cooling or fresh air cooling (economization) capability is not only feasible but very cost effective and very green for the environment. According to Joe Kava, Director of Data Centers at Google, the single “biggest opportunity for efficiency is through free cooling—greater than all other areas combined”³.

These large and technically savvy companies have set a new standard for cost effective and environmentally friendly computing. Chiller-less economization avoids the initial capital expense of having to install chiller equipment and, by using outside air to cool the data center, it avoids the operational expense of running chillers. These capital expense and operational expense reductions were accomplished through a very specialized approach that included unique facility designs, such as the Yahoo “computing coop”, and by locating these data centers in northern climate zones that were especially conducive to chiller-less economization, such as Washington and northern New York.

Now that a number of hyper-scale data center operators have proven there is only a minimal impact to the reliability of the IT equipment, the construction of chiller-less facilities and the use of economization are becoming much more widespread. For example, the European Union recommends the use of economization as part of their European Union Code of Conduct for Data Centres best practices⁴. Even here in the United States, ASHRAE has revised its 90.1 standard on building energy efficiency to require economization capability for new data centers in most of the United States⁵.

With typical IT equipment rated at a maximum air inlet temperature of 35°C, most world-wide locales can still economize for a majority of hours in a year, assuming they are willing to run their data center hotter for short periods. However, in order to realize the additional cost savings of building a chiller-less facility, a 35°C maximum inlet temperature rating doesn’t comprehend the extremes of most climate zones in industrialized parts of the world such as Europe, the United States and Asia.

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¹ “Yahoo Computing Coop: Shape of Things to Come?” Data Center Knowledge, April 26, 2010. <http://www.datacenterknowledge.com/archives/2010/04/26/yahoo-computing-coop-the-shape-of-things-to-come/>

² “Google’s Chiller-Less Data Center”, Data Center Knowledge, July 15, 2009. <http://www.datacenterknowledge.com/archives/2009/07/15/googles-chiller-less-data-center/>

³ “The Big Picture: How Google eliminates its impact on climate change” by Joe Kava, Sr., Director of Data Centers for Google, December 1, 2011.

⁴ European Union Code of Conduct for Data Centres”, http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_data_centers.htm

⁵ ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings

What if there was a way for you and your data center to realize proportionally similar capital expense and operational expense savings to those of Yahoo and Google? And, what if you had the flexibility to build and locate a chiller-less data center almost anywhere, not just in a few selected northern locales?

Dell conducted extensive research on world-wide climate zones to understand climate extremes and develop a set of IT equipment environmental design specifications that will allow our IT equipment to operate in a chiller-less data center in more than 90% of the United States, Europe and Asia. In addition, Dell has conducted a three-year long fresh air cooling research project to evaluate the reliability of IT equipment under these conditions⁶. Dell already offers an ecosystem of fresh air capable IT equipment including servers, storage, networking and power. Now, Dell is poised to launch our next generation servers, all of which will be fresh air capable (rated to 45°C instead of the 35°C, which is typical of most IT equipment). Our next generation fresh air server portfolio is richly featured and includes 1U, 2U, 4U, towers, and even blades, all of which have extended environmental capability for chiller-less data center economization up to 45°C.

Economization

Economization involves using the outside climate conditions to cool the data center to save money on energy and cooling costs instead of using mechanical cooling means such as air conditioning. There are two primary forms of economization: air-side and water-side. Air-side economization brings outside air directly into the data center as the primary source of cool air, whereas water-side economization uses an air-to-water heat exchanger and then brings cooled water into the data center where a second heat exchange takes place that uses the water to cool the data center air.

Both approaches to economization have pros and cons. The main advantage of water-side economization is the ability to maintain more constant humidity levels in the data center. Because the heat transfer medium is water contained inside a closed recirculating loop, water-side economization doesn't bring any humidity into or out of the data center. The disadvantages of water-side economization are that it requires a larger capital investment to install and some efficiency is lost in the multiple heat exchange steps it requires. For this reason, water-side economization tends to be employed in slightly cooler climates.

The primary advantage of air-side economization is its simplicity. An air-side economized data center uses an outside air inlet with an economizer fan that draws outside air directly into the data center. This outside air enters a mixing chamber that is also connected to the data center hot air exhaust. On cold days when the outdoor temperature is too low, hot air is re-used and mixed with the incoming air to raise its temperature to some minimum value such as 20°C (68°F).

⁶ Dell Fresh Air Cooling Research, <http://en.community.dell.com/techcenter/power-cooling/w/wiki/fresh-air-cooling.aspx>

Other than the use of an economizer fan and a mixing chamber, air-side economization uses the existing fans and plenums in the data center. Thus the capital cost of installing air-side economization is low.

The primary disadvantage of air-side economization is that it doesn't afford humidity control. Supplemental humidity control systems can use a significant amount of energy and can offset the advantages of air-side economization. However, if your climate doesn't have humidity extremes that go beyond the rating of your IT equipment, air-side economization offers more hours of economization and more cooling cost savings than water-side.

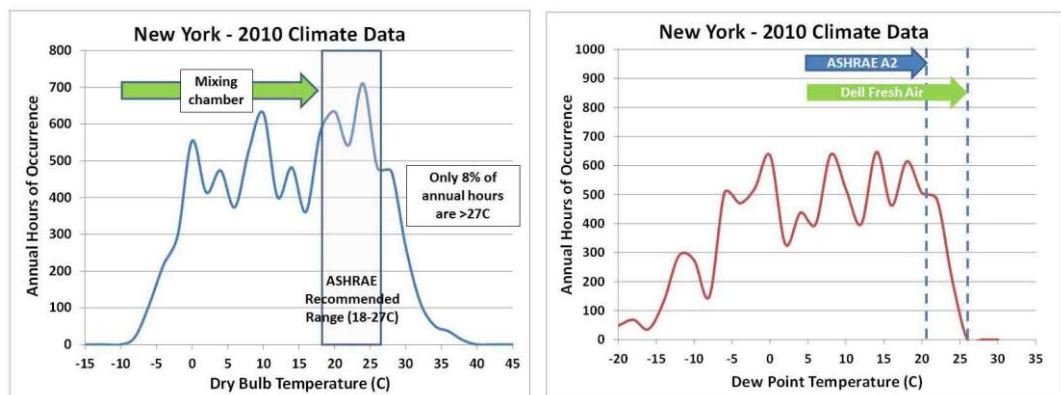
Analysis of world-wide climate data

Whether you choose to use air-side or water-side economization, the number of hours of economization and the potential cooling cost savings from economization are dependent on a combination of a) the climate of the area where your data center is located, and b) the capability of your equipment to meet those climatic conditions.

There are parts of the world where chiller-less data centers are already being deployed—locations where the climate is cold enough to economize 100% of the hours in a year, even with typical industry standard equipment specifications that restrict operation to a maximum temperature of 35°C. However, these climate zones are very limited (northern most Europe and a few places in the northern United States) and they don't include most of the industrialized world such as central Europe, most of the United States, and much of Asia.

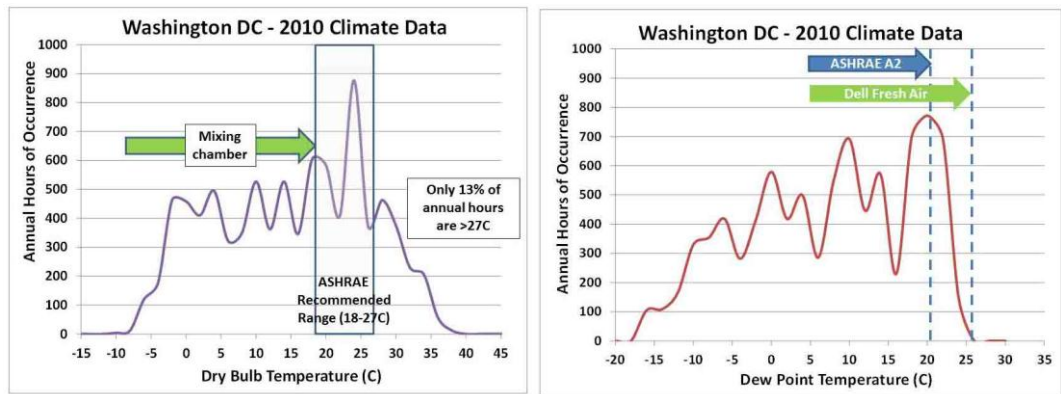
Some of the locations where current equipment capability limits chiller-less data center deployment might surprise you—New York City for example (see Figure 1). In order to build a chiller-less (100% economization) data center in New York City, at least a 38°C maximum operating temperature is needed for less than 50 hours a year. Because New York City is located on the coast, it is a fairly humid climate and requires equipment with a relatively high dew point of approximately 25°C, but only for about 100 hours a year, which is less than a week (1 week = 168 hours).

Figure 1. New York climate data



Next consider a warm and humid region that is not very conducive to fresh air cooling—the southeastern United States. One of the fastest growing data center hubs in this region is Washington DC and its nearby suburbs. Even in the warm and humid climate of Washington DC, a data center spends 87% of its annual operating hours within the ASHRAE recommended range of 18-27°C as shown in Figure 2. Because of Washington DC’s proximity to large bodies of water, a 25°C maximum dew point is required in order to build a chiller-less data center facility. The climate data plots for other warm and humid world-wide locales, such as Tokyo Japan, Taipei Taiwan, and Shanghai China are fairly similar to those of Washington DC.

Figure 2. Washington DC climate data



There is a common thread between the climate data of New York, Washington DC, Tokyo Japan, Taipei Taiwan, and Shanghai China—the extended temperature and dew point ranges that would make these locations candidates for chiller-less data centers (economization for 100% of the hours in a year) are required for no more than a couple of weeks a year. In other words, the climate data shows all that is needed to build chiller-less facilities in these regions is the ability to tolerate extended temperature and humidity levels for short periods and for a very limited number of hours per year.

Matching equipment design to climate data

A summary of environmental ranges, including the ASHRAE⁷ recommended ranges Class A1, A2, A3, A4, and the Dell Fresh Air class is shown in Table 1. Note that ASHRAE Class A2 is fairly typical of the environmental specifications of most currently available IT equipment. A graphical representation of the Dell Fresh Air class environmental range is given in Figure 3.

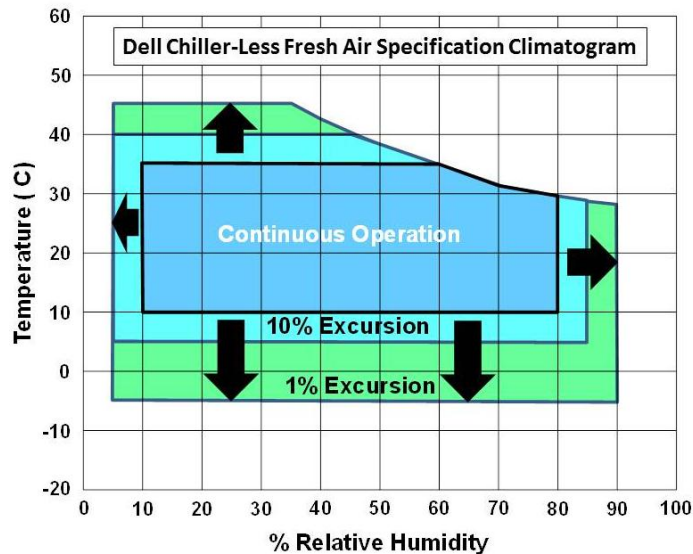
⁷ ASHRAE TC9.9, “2011 Thermal Guidelines for Data Processing Environments - Expanded Data Center Classes and Usage Guidance”, <http://tc99.ashraetcs.org/documents/ASHRAE%20Whitepaper%20-%202011%20Thermal%20Guidelines%20for%20Data%20Processing%20Environments.pdf>

Table 1. Summary of environmental ranges

Specification	Dry bulb temp range (°C)	Relative humidity range (%RH)	Dew point limits (°C)
ASHRAE recommended range (Classes A1 - A4)	18 to 27°C	Up to 60%RH	5.5°C minimum to 15°C maximum
ASHRAE Class A1	15 to 32°C	20% to 80%RH	17°C maximum
ASHRAE Class A2	10 to 35°C	20% to 80%RH	21°C maximum
ASHARE Class A3	5 to 40°C	8% to 85%RH	-12°C minimum to 24°C maximum
ASHRAE Class A4	5 to 45°C	8% to 90%RH	-12°C minimum to 24°C maximum
Dell Fresh Air	-5 to 45°C*	5% to 95%RH*	26°C maximum

*Dell fresh air assumes a limited number of annual operating hours at the extreme ranges of these conditions. See Figure 3 for more detail.

Figure 3. Dell chiller-less fresh air specification climatogram



When you compare the equipment classes shown in Table 1 to the climate data in Figures 1 and 2, it becomes apparent that typical IT equipment specification ranges are not wide enough to construct chiller-less data centers in most of the world’s industrialized regions. Also, most economization systems are not 100% efficient and they add 1.5-5°C to the temperature of the outside air. This occurs because the data center fans do work on the air and cause a small amount of heating and, for water-side economization, multiple heat exchange steps cause heat transfer efficiency losses.

The net result of an excursion-based specification, such as the Dell fresh air specification, is a significantly different IT equipment development paradigm—one that meets the full temperature and dew point range of the climate data, but does so with little or no additional cost.

For example, a 37°C maximum air temperature, as shown for Washington DC, becomes a 38.5-42°C equipment inlet air temperature inside the data center. A maximum operating temperature limit in this range would only be met by an ASHRAE Class A3 (40°C) or A4 (45°C) rating. However, the climate data shows a need for a 25°C maximum dew point rating whereas Classes A3 and A4 have a maximum rating of only 24°C. The Dell fresh air specifications shown in Figure 3 meet both the maximum temperature and dew point ratings needed for chiller-less data centers, even in a majority of warm and humid regions world-wide.

ASHRAE and most traditional data center equipment specifications assume continuous 7x24x365 operation to the full extent of the stated temperature range. The Dell fresh air specification is different—it is defined around short-term, time-limited excursions to those extreme limits. The net result of an excursion based specification, such as the Dell fresh air specification, is a significantly different IT equipment development paradigm—one that meets the full temperature and dew point range of the climate data but does so with little or no additional cost.

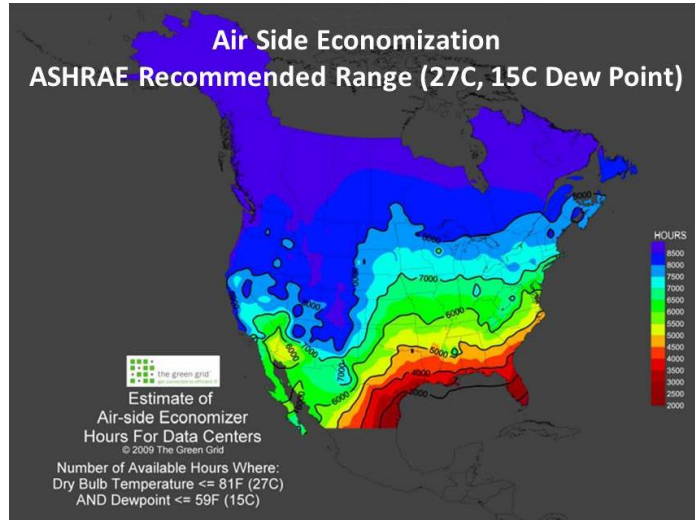
Estimating cooling cost savings from economization

The Green Grid⁸ has developed a free cooling tool that takes climate data and an assumed set of IT equipment operating conditions, and provides an estimate of the total number of annual hours of economization available to a data center. Figure 4 and Figure 5 show maps of North America with two sets of assumptions:

- Figure 4 assumes a traditional data center that economizes only within the narrow limits of the ASHRAE recommended range (18-27°C with a 21°C maximum dew point)
- Figure 5 shows the extent of economization that is possible with Dell fresh air capable products (45°C with a 26°C maximum dew point)

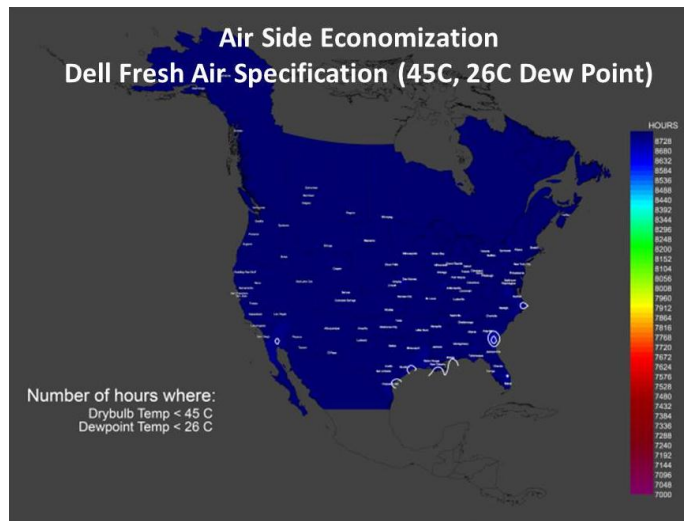
⁸ The Green Grid Free Cooling Tool, <http://www.thegreengrid.org/Global/Content/Tools/NAmericanFreeCoolingTool>

Figure 4. Air-side economization of North America (27°C with 15°C dew point)



Note on Figure 4: The geography suitable for a chiller-less fresh air cooled data center (economization for 100% of the hours in a year) corresponds to the dark blue region in Alaska and northernmost Canada. The remaining regions below the dark blue region would all require a chiller plant, air conditioning system, or other supplemental cooling capability.

Figure 5. Dell fresh air specification for North America (45°C with 26°C dew point)

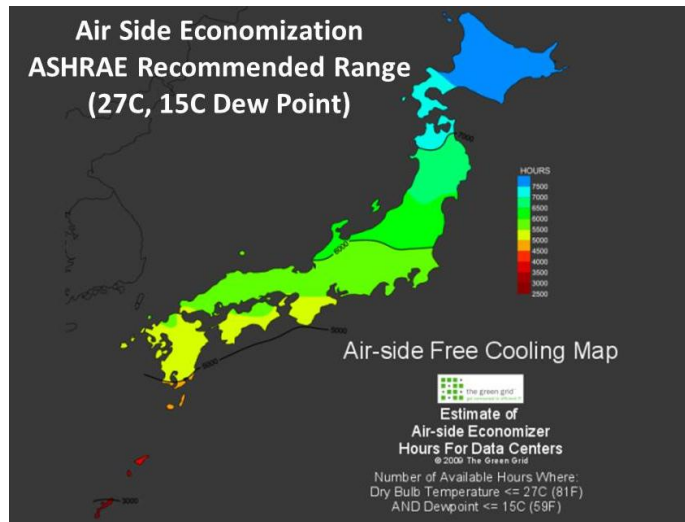


Note on Figure 5: With the Dell fresh air capable IT equipment specifications of 45°C and a 26°C maximum dew point, the dark blue region corresponding to economization for 100% of the hours in a year (chiller-less fresh air cooling) envelopes almost the entire North American continent.

The change in the number of hours of available economization between the ASHRAE recommended range (or even ASHRAE Class A2) and the Dell fresh air limits is dramatic. In fact, with Dell fresh air capable hardware, nearly all of North America is a candidate location for chiller-less (8,760 hours per year of economization) data centers as is nearly all of Europe.

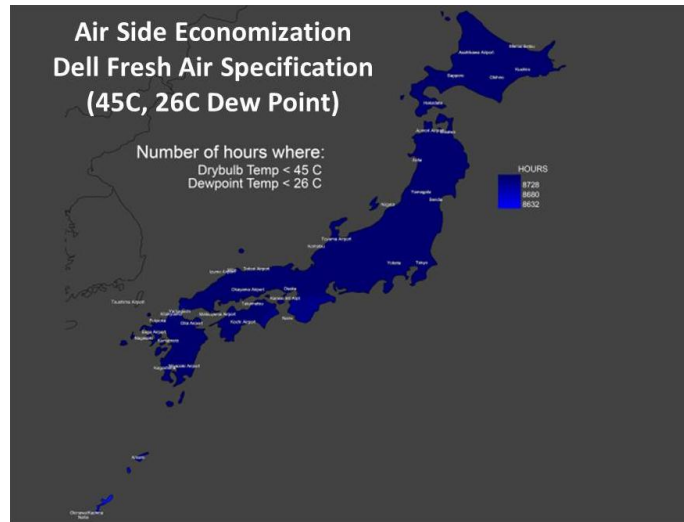
Maps for Japan show similar results as seen in Figure 6 and 7. With IT equipment rated at the Dell fresh air limits, nearly all of the Japanese islands could be candidates for chiller-less data centers, or at least data centers that make extensive use of economization as would the majority of Asia. Currently, partially economized data centers are deployed only on the northernmost island of Hokkaido.

Figure 6. Air-side free cooling map of Japan (27°C with a 15°C dew point)



Note on Figure 6: Under the assumed conditions of 27°C maximum dry bulb temperature and a maximum dew point of 15°C, none of the islands of Japan are suitable for chiller-less fresh air cooling. Any data center built under these temperature assumptions would have to bear the capital cost of installing a chiller, air conditioner or some kind of cooling plant.

**Figure 7. Dell fresh air specification for Japan
(45°C with a 26°C dew point)**



Note on Figure 7: With Dell fresh air rated IT equipment, a chiller-less data center could be built almost anywhere in Japan. The darkest shade of blue corresponds to economization for 100% of the hours in a year.

With Dell fresh air rated IT equipment, a data center can realize \$100-\$275k per year of operational savings per megawatt of IT, and eliminate chiller and related capital expenditures of approximately \$3M per megawatt of IT.

With Dell fresh air rated IT equipment, a data center can realize \$100-\$275k/year of operational savings per megawatt (MW) of IT and eliminate chiller and related capital expenditures of approximately \$3 million per MW of IT⁹ (savings assumes \$0.07 per KW/hour and/or \$.20 per KW/hour). In addition, the fact that Dell products can tolerate higher temperatures also means a data center provisioned with Dell fresh air rated IT equipment will be less likely to experience a failure that might cause a service interruption during a facility cooling outage.

Next generation servers and energy savings with more features

As part of our ongoing commitment to providing energy saving fresh air solutions, Dell's next generation fresh air servers are even more richly featured and provisioned than our last generation. Table 2 shows a comparison between a typical 2U, 2S fully provisioned previous generation and next generation fresh air capable Dell™ PowerEdge™ servers. The differences are significant—the next generation server has 130W processor capability versus 95W for the previous generation, as well as six more DIMM slots and considerably more hard drive slots.

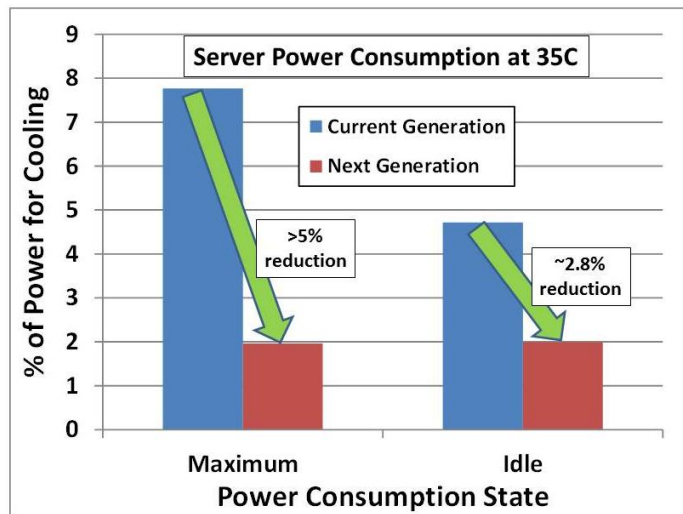
⁹ Global Ad # G11001403

Table 2. Comparison of fresh air capable PowerEdge servers

Component	Previous Generation (R710)	Next Generation (R720)
Form factor, # of sockets	2U, 2S	2U, 2S
Processor	2 x 95W Intel® Xeon® processor 5500 and 5600 series	2 x 130W Intel Xeon processor E5-2600 product family
DIMMs	18 x 4GB DDR3	24 x 4GB DDR3
Hard disk drives	6 SAS 3.5" or 8 SAS 2.5"	16 SAS 2.5" or XX 3.5"
Power supply	2 x 870W	2 x 1100W

In addition to an enhanced provisioning, Dell’s next generation servers have been behaviorally developed for fresh air cooling and short-term high temperature operation to consume even less cooling power than the preceding generation. Figure 8 shows a cooling efficiency comparison between the previous and next generation servers from Table 2. The results show a drop of more than 5% in power to cool at maximum load as well as significant improvements in idle cooling efficiency for the R710 versus the R720 as configured in Table 2.

Figure 8. Server power consumption at 35°C



Dell servers have also been engineered with a number of innovative new power savings and power management features, some of which include:

- Power supply right-sizing for higher efficiency as well as some EPA ENERGY STAR® Platinum rated PSUs
- User programmable power capping modes allow you to cap power based on the rack power, the cost of power based on time of day, and many other algorithms
- System profile feature allows you to optimize for performance, performance per watt, or overall system temperature
- Server-level power management with iDRAC7 Enterprise gives you control of power at the server, rack, row or room level

Our next generation servers are inherently energy efficient and give you a wide range of programmable features. These features help you tailor the way your IT equipment consumes energy to your usage environment whether it is a chiller-less facility, partially economized, or a traditional air-conditioned data center.

IT equipment reliability

One of the most frequently asked questions about economization is “what is the impact of economization and raising the facility air temperature on the reliability of the IT equipment in my data center?” A common misconception is that the use of economization means high (greater than 35°C) sustained 7x24x365 data center operating temperatures and dramatically higher equipment failure rates. A review of the climate data, even from some relatively warm locales, shows this is not the case—most world-wide regions spend 80-90% of their operational hours within the ASHRAE recommended range of 18-27°C (with the use of a mixing chamber during winter months to bring the cold air up to a minimum temp in the 15-20°C range), and excursions beyond the traditional industry maximum temperature of 35°C are limited to no more than about 10 days a year.

In 2008 Intel ran an air-side economization study at their Rio Rancho, New Mexico facility¹⁰ which showed fairly comparable IT equipment failure rates between two identical portions of their data center: one being air-side economized and the other non-economized. Dell has independently confirmed the Intel result with our own fresh air cooling research program⁵. And, in a recent white paper published by the ASHRAE TC9.9 committee⁶, ASHRAE did a number of analyses that showed the reliability impact of economization for most moderate climate zones was negligible and, even for warm climate zones, the impact was small. In summary, there is a growing body of data and data center practice that concerns over higher failure rates are unfounded and that the energy savings from economization and even chiller-less facility operation are well worth pursuing.

¹⁰ “Servers Do Fine With Outside Air”, Data Center Knowledge, September 18, 2008. <http://www.datacenterknowledge.com/archives/2008/09/18/intel-servers-do-fine-with-outside-air/>

Conclusion

Chiller-less fresh air cooling can deliver cooling cost savings of as much as \$275k/year of operational savings per MW of IT and eliminate chiller and related capital costs of almost \$3 million per MW of IT. Now that the deployment of economization and chiller-less facilities have been proven by a number of hyper-scale data centers, they are rapidly becoming a mainstream cooling cost reduction tool for all data centers whether they are hyper-scale, containerized, medium or even small footprint. However, an analysis of world-wide climate data indicates 45°C is needed to tolerate extremes for chiller-less facility operation in many common climate zones, whereas most commercially available IT equipment is only rated at 35°C.

Dell's next generation servers were developed with a 45°C excursion capability to meet these climate extremes and enable the construction of chiller-less data centers in most climate zones of the industrialized world including Asia, the United States and Europe. Dell's next generation fresh air capable servers are richly featured and are available in 1U, 2U, 4U, tower and blade form factors. The cooling cost savings formerly reserved only for hyper-scale data centers are now available to you and your data center. And, with Dell next generation servers, you are no longer restricted to locating your data center in a cold northern climate. The fresh air cooling capability of Dell next generation servers is just one of the ways Dell gives you the power to do more.

Author bio

Jon Fitch, PhD, is a Principal Reliability Engineer working on fresh air cooling research and the reliability impact of fresh air and related means of reducing customer data center power and cooling costs. Jon has more than 20 years of industry experience in the field of reliability. In addition he is an active member of the ASHRAE TC9.9 committee on mission critical facilities. Jon has 25 US Patents issued and more than 45 publications in various fields.

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