UPDATED AIR-SIDE FREE COOLING MAPS: THE IMPACT OF ASHRAE 2011 ALLOWABLE RANGES

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Executive Summary

In May 2011, the American Society of Heating, Refrigeration, and Air conditioning Engineers (ASHRAE) published updated guidelines for the "Recommended" and "Allowable" temperature and humidity of data centers. The new specification created two new classifications of data centers and expanded the range of Allowable environmental conditions in order to encourage energy efficiency practices like air-side economization. The Green Grid published Free Cooling maps in 2009 based on the ASHRAE 2008 Recommended ranges for temperature and humidity. Now, with the wider Allowable ranges, new maps showing the expanded potential for free cooling are needed to encourage design teams to incorporate these energy saving techniques.

The class A2 Allowable range, though not changed by the 2011 release, shows that 75 percent of North America could use air side economizers for every hour of a typical year if operators are able to allow temperatures up to 35°C for short periods of time. The same class A2 range allows 97 percent of Europe and 14 percent of Japan to use free cooling all year long. If operators have equipment that can run in the new class A3 Allowable range, that is, up to 40°C for short periods of time, then the maps indicate that in 91 to 99 percent of locations, free air cooling could be used every hour of the year, even in Japan.

The Green Grid survey of data center operators showed that use of economizers will result in saving an average of 20 percent of the money, energy, and carbon for cooling when compared to data center designs without economizers[i]. The expanded ranges should allow greater savings in each data center, and increase the number of data centers that can take advantage of economization.

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I. Introduction

In May 2011, the American Society of Heating, Refrigeration, and Air conditioning Engineers (ASHRAE) published updated guidelines[ii] for the temperature and humidity of data centers. The new specification created two new classifications of data centers and expanded the range of Allowable environmental conditions in order to encourage energy efficiency practices like air-side and water-side economization.

The Green Grid published Free Cooling maps[iii] in 2009 based on the ASHRAE Recommended ranges for temperature and humidity. An example of the maps is shown in Figure 1. The maps are meant to show graphically what the potential for free cooling might be, under ideal conditions, at any location in North America, Europe, and Japan. A data center designer can get a more accurate estimate of the hours available using The Green Grid's free cooling tools, located at http://cooling.thegreengrid.org/. The free cooling tools allow users to specify the IT load, temperature and humidity ranges, and location for their data center, and return the number of hours that can be used for air- and water-side economizers.

If data center operators are willing and able to run in the Allowable ranges for temperature and humidity, including the newly defined class A3 and A4 ranges, there are a significant number of additional hours available to use outside air for cooling IT equipment. The "and able" part of the statement above is determined by manufacturers' specifications of the equipment in the data center and company policy. The expanded ranges are generally based on the specifications of so-called "volume servers," and attempt to address the needs of the majority of these types of equipment[iv]. But corporate IT policies frequently require facilities to be operated at much lower temperatures. If facilities and IT departments work together, significant savings can be achieved. As an example, Deutsche Bank recently announced they had built a production data center in the New York City metro area that achieves nearly 100 percent free cooling through a combination of facilities innovations and being willing to operate IT equipment in expanded environmental ranges.[v]

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The new A3 Allowable range in the 2011 ASHRAE specification states that inlet temperatures up to 40°C are acceptable. The new A4 Allowable range says that IT inlet temperatures can range as high as 45°C. Given the large differences between the Recommended and new Allowable ranges, The Green Grid decided to publish updated air-side economizer maps to visually reflect the increased number of hours that might be available to data center operators.

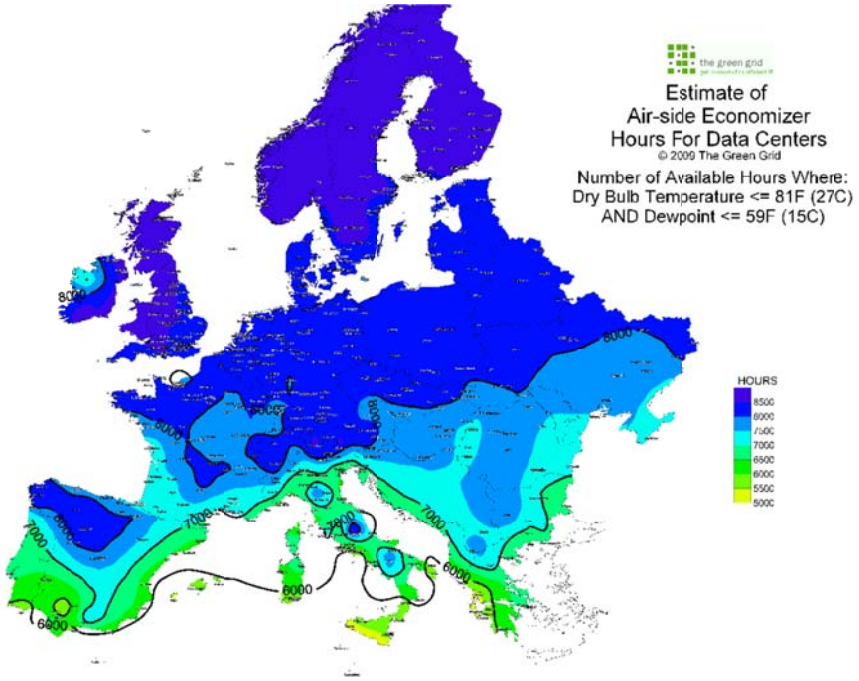

Figure 1 - The Green Grid 2009 European Air-side Free Cooling Map, based on ASHRAE Recommended ranges for temperature and humidity (available online at: http://goo.gl/KBjHn)

II. New ASHRAE Ranges

Table 1 below shows the details of the new ranges[vi]. The data center classes defined by ASHRAE have been renamed from numeric designations to alphanumeric names in the 2011 version of the recommendations. Classes 1, 2, 3, and 4 have become classes A1, A2, B, and C. Two new classes, A3 and A4, have been defined to reflect data center spaces with less strict control over temperature and humidity specification, and wider ranges of environmental conditions. These new classes allow dry bulb temperatures as high as 45°C, and humidity as high as 90% for short periods of time. Data center operators should conduct a careful review of their hardware's environmental specifications before adopting A3 or A4 limits.

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Classes (a)	Equipment Environmental 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 the ASHRAE paper)								
A1 to A4	18 to 27	5.5ºC DP to 60% RH and 15ºC DP						
Allowable								
A1	15 to 32	20% to 80% RH	17	3050	5/20	5 to 45	8 to 80	27
A2	10 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 1. ASHRAE 2011 updated temperature and humidity ranges for data centers (ASHRAE Technical Committee 9.9, 2011)

III. Free Cooling Maps

2009 VERSIONS

The original free cooling maps were published in 2009, and included maps for North America, Europe, and Japan. Two kinds of maps were produced: an air-side economizer map that shows the number of hours available in each location where the temperature and humidity meet or exceed the ASHRAE Recommended ranges, and a water-side map that makes assumptions about the performance of the mechanical systems, especially about the approach temperature of the water economizer system.

Bin data was collected from each region to determine the number of hours where outside conditions meet the required data center conditions. The bin data was collected by WeatherBank, a contractor to The Green Grid. WeatherBank used data from 1999 to 2009 for the North American maps. Ten years worth of data was not available for all locations outside of North America, so the European and Japan maps used the maximum length of time available for those locations, typically 5 to 10 years. In North America, bin data was gathered by zip code, while in Europe and Japan, airport locations were used to collect data.

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The algorithm used to sum the bin data for the air-side economizer map is simple: for each hour where average dry bulb and dew point temperatures are below the ASHRAE recommended maximums, an hour is added to the possible free cooling hours. This assumes that fresh air can be mixed with return air as needed, and that humidity is added to dry air if required. The total number of hours per year are then color-coded and blended to produce the maps. The psychrometric chart in Figure 2 provides a graphical representation of the original free air cooling algorithm.

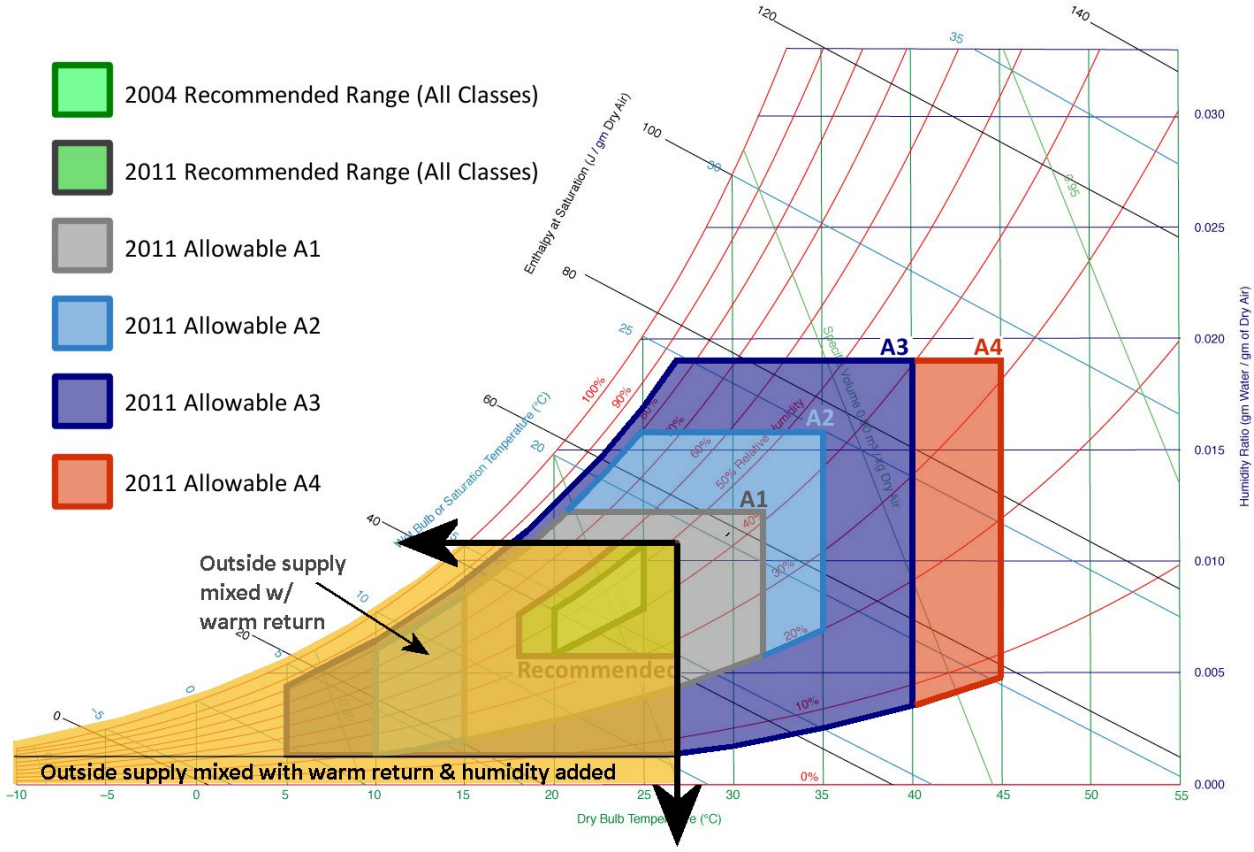

Figure 2 – Graphical representation of the hours summed for the 2009 Green Grid air-side Free Cooling Map, based on ASHRAE Recommended ranges

The original maps show number of hours below the Recommended max dry bulb (27°C) and max dew point (15°C). Since the Recommended temperatures and humidity have not changed, the original maps are still valid for those operators who want to operate within the 2011 Recommended range for all data center classes.

2011 AIR-SIDE ECONOMIZER MAP UPDATES

To make the updated air-side economizer maps, The Green Grid used same weather data but changed the maximum dry bulb and dew point temperatures to the class A2 and A3 Allowable ranges. The map colors were recalculated using the revised number of bin hours. Figure 3 shows graphically how the class A2 maps were calculated.

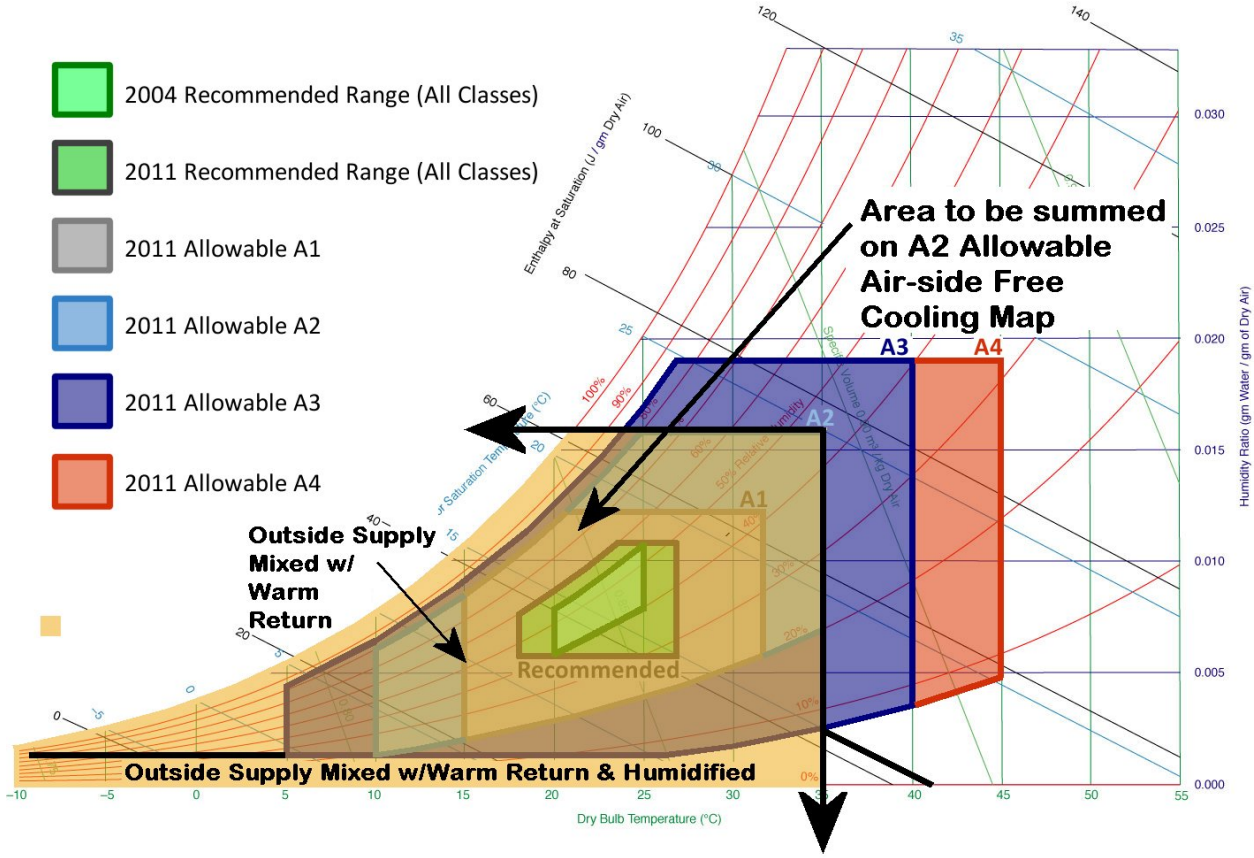

Figure 3 - Graphical representation of the hours summed for the class A2 Allowable air-side Free Cooling Map, based on 2011 ASHRAE ranges

The new Class A2 maps below show that 75 percent of North America is covered by the 8500+ hours per year color. In Europe, the A2 Allowable range results in 99 percent of locations being able to use free cooling all year. The only locations in Europe that cannot use 100 percent free cooling are a small area in northwestern Spain (too hot), a small area in southwestern Ireland (too humid), and as small area in Sicily. In Japan, 14 percent of locations can use free air cooling every hour of the year if data center operators allow temperatures and humidity in the A2 Allowable range.

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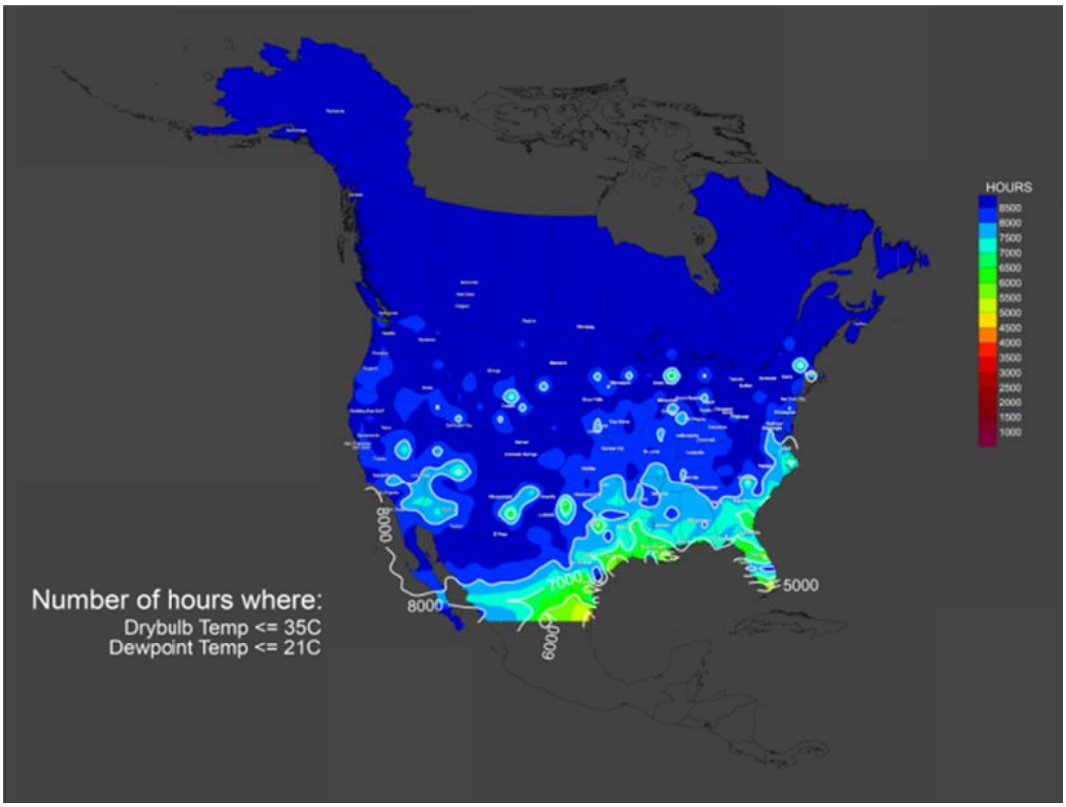

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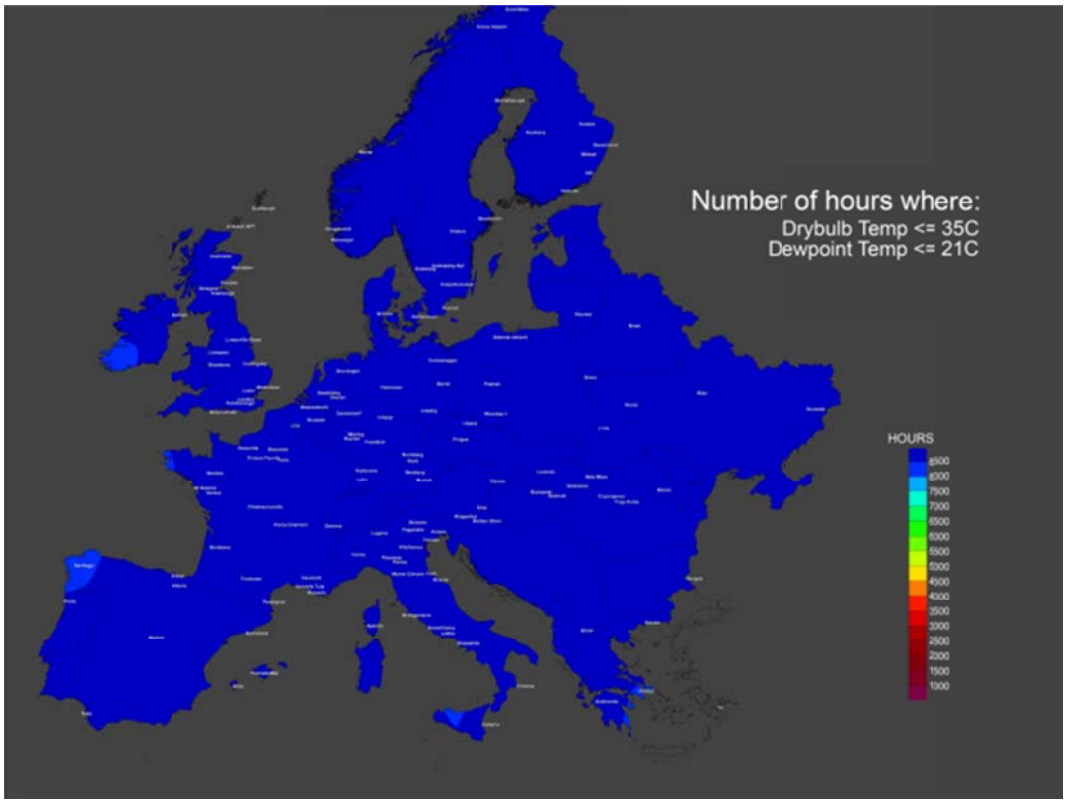

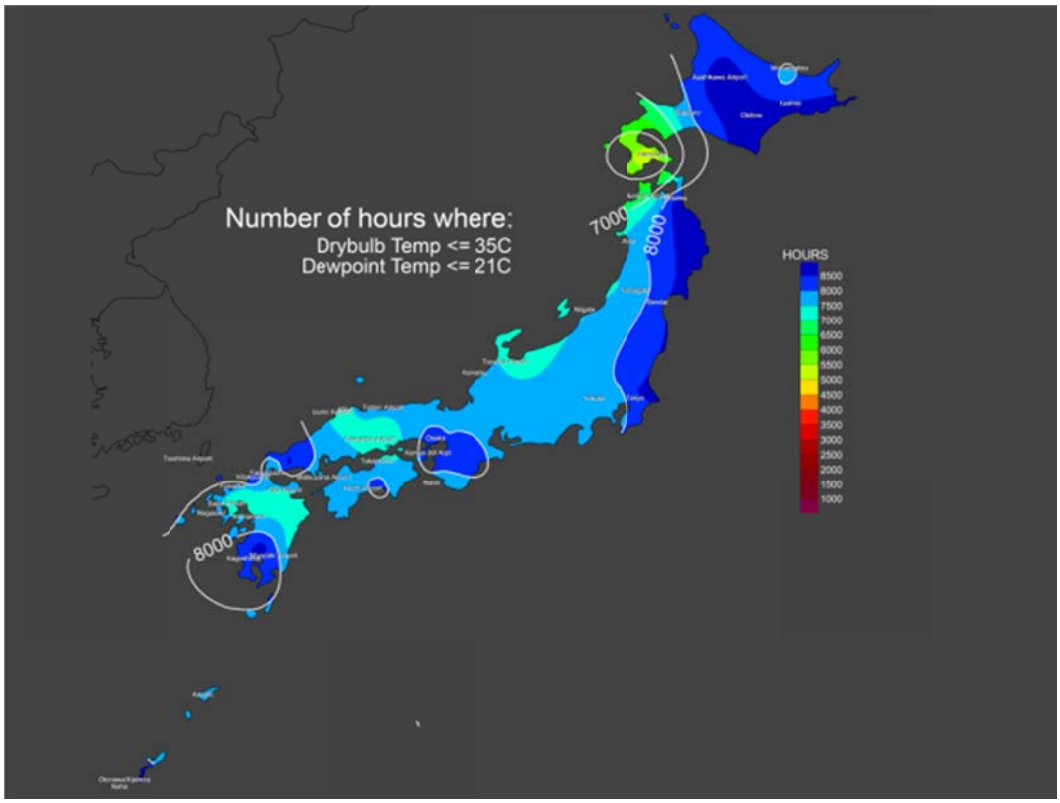

Figure 4 - Class A2 Allowable Free Air Cooling Maps for North America, Europe, and Japan based on ASHRAE 2011 Thermal Guidelines

The A3 maps show even more dramatic results. With 40°C as the highest dry bulb temperature, 97 percent of North America can use free air cooling all year. Similarly, 99 percent of Europe and 91 percent of Japan, including Tokyo, can use free air cooling all year if operators can specify conditions up to the A3 Allowable ranges.

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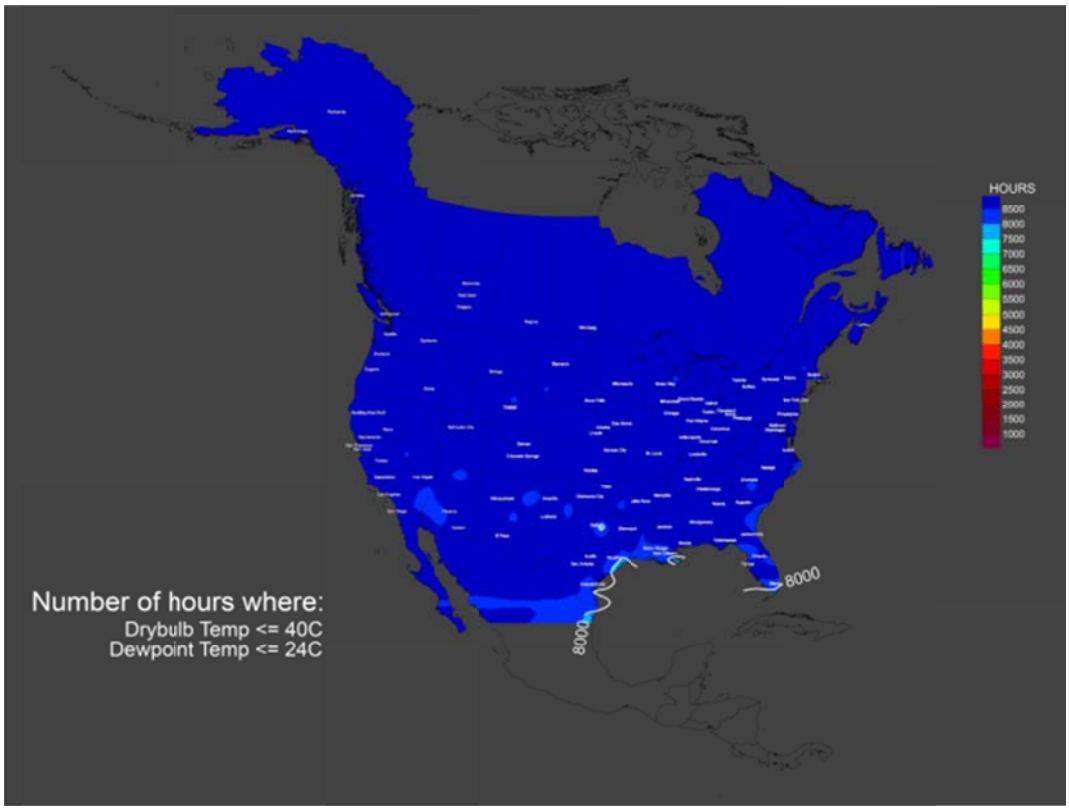

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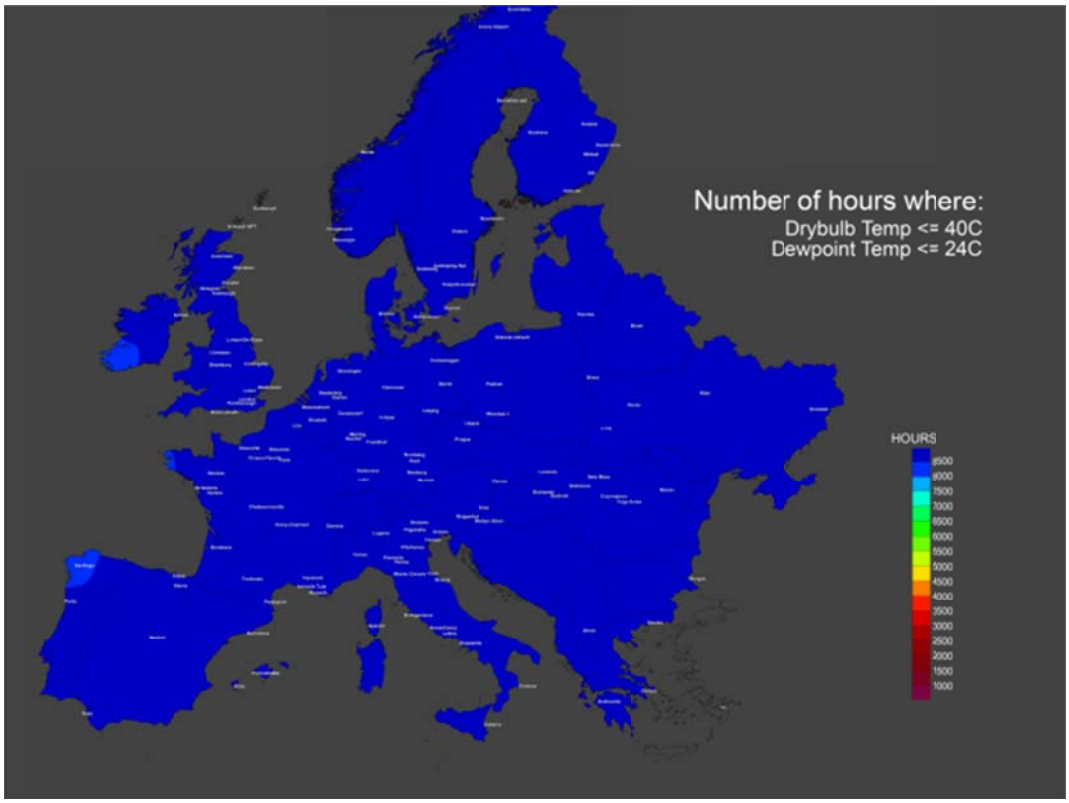

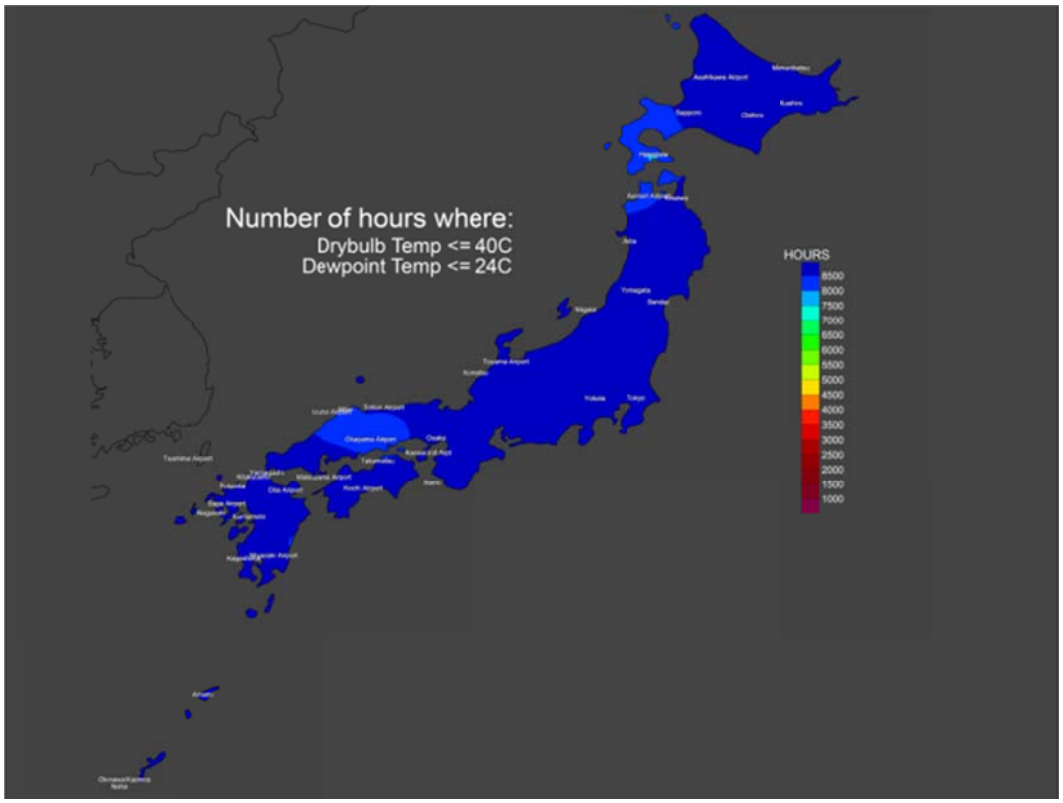

Figure 5 - Class A3 Allowable Free Air Cooling Maps for North America, Europe, and Japan based on ASHRAE 2011 Thermal Guidelines

IV. Conclusion

The maps show the potential for free air cooling if the expanded environmental Allowable ranges are used to govern temperatures and humidity in the data center. Virtually all of North America and Europe, and more than 90 percent of Japan, can operate without mechanical cooling if data center owners can allow occasional incursions into the higher end of the ASHRAE class A2 and A3 ranges.

These maps are constructed to show the maximum potential of free cooling. There are a number of factors that affect the actual hours: weather conditions, operating policies, equipment start times, peak power costs, local regulation on working conditions, and IT equipment installed to name a few. A detailed engineering study should be able to estimate the actual hours of free cooling to be used in a specific data center.

The use of free cooling will result in the cold aisle temperature in the data center being elevated for some hours during the year. However, in most free cooling schemes, the cold aisle temperature fluctuates with

outside temperature, so the maximum temperatures exist for a few hours before the outdoor temperature cools at night and results in cooler temperatures again in the morning. In addition, most free air cooling schemes will operate the cold aisles at low temperatures for some of the year. During winter hours, cold aisles may run as low as 5°C or 10°C, depending on the equipment and operator polices.

The new Allowable ranges have great potential for savings of energy, carbon, water and capital expense. Data centers that take advantage of expanded environmental ranges can be designed without chillers or cooling towers, resulting in lower capital and operating cost, and can be run with higher reliability because there will be fewer components in the design to fail.

The updated maps show 91 to 99 percent of North America, Europe, and Japan can use free cooling throughout the year if class A3 equipment is used and operating policies allow fluctuation of temperatures within the A3 Allowable range.

The new Allowable ranges will also affect water-side economizers by allowing higher condenser water temperatures. Interested readers can use The Green Grid Free Cooling tool to investigate other operating temperatures and humidity ranges, and to estimate the amount of savings that might result from increased water-side economizer use. Data center operators should consult engineering and design personnel, and IT and facilities vendors, in order to be sure they can use the maximum amount of free cooling and maintain required reliability.

V. About The Green Grid

The Green Grid is a non-profit, open industry consortium of end users, policy makers, technology providers, facility architects, and utility companies collaborating to improve the resource efficiency of data centres and business computing ecosystems. With more than 150 member organizations around the world, The Green Grid seeks to unite global industry efforts, create a common set of metrics, and develop technical resources and educational tools to further its goals. Additional information is available at www.thegreengrid.org.

VI. References

[i] The Green Grid. *WP#41-Survey Results: Data Center Economizer Use*. 2011. Web. http://www.thegreengrid.org/en/Global/Content/white-papers/WP41-SurveyResultsDataCenterEconomizerUse

[ii] ASHRAE TC 9.9. *2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance*. 2011. Web. http://goo.gl/Y0H8H .

[iii] The Green Grid. *North American, European*, and *Japan Fresh Air* and *Water Side Cooling Maps*. 2009. Web. http://www.thegreengrid.org/library-and-tools.aspx

[iv] ASHRAE TC 9.9, pg 13.

[v] Neudorfer, Julius. "Deutsche Bank's New Cool Data Center." CTOEdge.com, 04 Apr 2011. Web. http://www.ctoedge.com/content/deutsche-banks-new-cool-data-center

[vi] ASHRAE TC 9.9, Table 1 Reprinted by permission.