Extend the Life of Your Data Center

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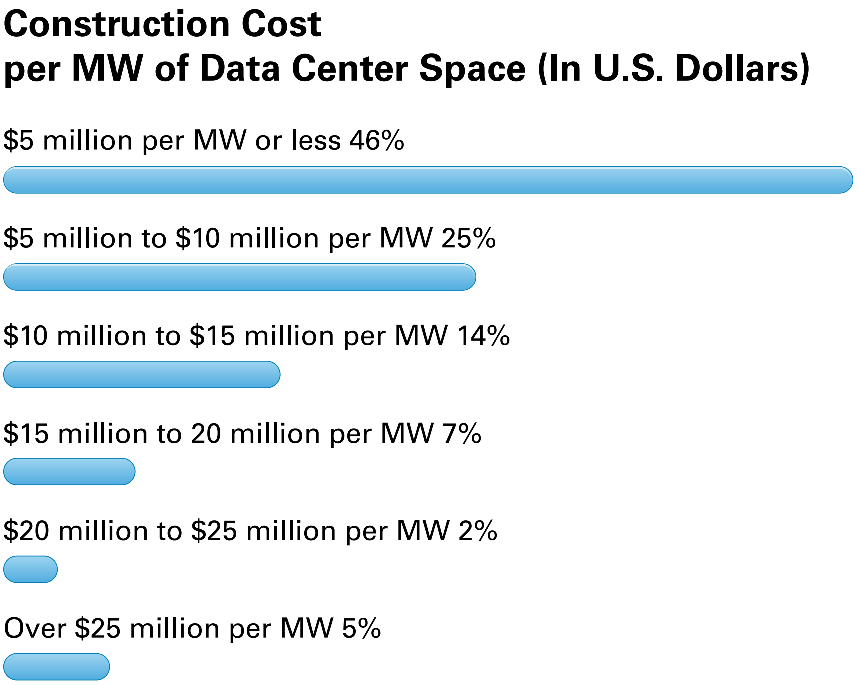
What do you do when you are managing one of the 30% to 50% of data centers which are going to run out of power and/or cooling within the next year?[1,2] Build a new data center? According to the latest Uptime Institute data center survey, summarized in Chart 1 below, that price tag may not be in this year's budget.[3] It may not be possible to avoid spending $5-$25 million or more on that new data center, but it is very possible to delay that expenditure, and such a delay might not have strictly cash flow and capital management implications. Buying time may be necessary just to accommodate the lead time to bring on a new facility. Fortunately, implementing an effective airflow containment architecture in the data center can often add enough life to an existing data center to buy that extra time to bring on new space intelligently and in some cases, even remove the need for new construction.



Source: Uptime Institute

Chart 1: Data Center Construction Costs from Uptime Institute Data Center Survey

According to the latest findings from the Upsite Technologies, in audits of forty-five data centers, the data centers averaged 3.9 times the amount of cooling capacity than the associated IT load.[4] Despite improvements in airflow management to reduce bypass airflow, that surplus cooling capacity had increased from a factor of 2.6 in a previous study conducted 10 years earlier[5] by the Uptime Institute. The difference between capacity and required demand described by these numerical terms, has been defined by Upsite Technologies as the Cooling Capacity Factor (CCF). A CCF of 1, includes a 10% surplus of supply to demand to accommodate lights and building loads. Furthermore, despite this excess cooling capacity, there were still hot spots. For facilities representative of this research sample, there are definitely opportunities for extending the life of the data center.

Planning an extension to the life of a data center that appears to be out of cooling and power is not merely a matter of eliminating hot spots and recapturing stranded capacity to supply a static environment. After all, when data center managers are forecasting hitting a capacity wall, they are envisioning some continued growth to support the business' mission critical activities. This growth is a combination of increased traffic, incremental applications, and technology refreshes. However, all these stimuli for growth do not necessarily translate directly to a linear growth in IT power and cooling load. For example, there is the story of a particular state IT agency who built a hyper-efficient new data center with the idea of eventually bringing all the different, dispersed state agency and department data centers into one consolidated data center. They built the data center for a 10-15 year life, based on the cumulative growth history trends of all the separate data centers. Besides the state-of-the-art energy efficient mechanical plant of the new consolidated data center, they also had an initiative to improve the efficiency of IT. The two main thrusts of the IT efficiency initiative were to begin a program of virtualization to increase server utilization levels and enable the energy management features of all the servers located in the new, consolidated space. It took a couple of years to convince some of the different state agencies of the efficacy of the planned move, but eventually they got everyone moved and supportive of the IT management philosophy. Much to their surprise, when all the dust had settled, the data center was less than one third full, utilizing around half of the installed mechanical infrastructure, resulting in cancellation of plans to complete the mechanical and electrical build-out. Bottom line, there are competing factors here – transaction and application growth (more work) balanced by virtualization and utilization improvements (less machines to do the work).

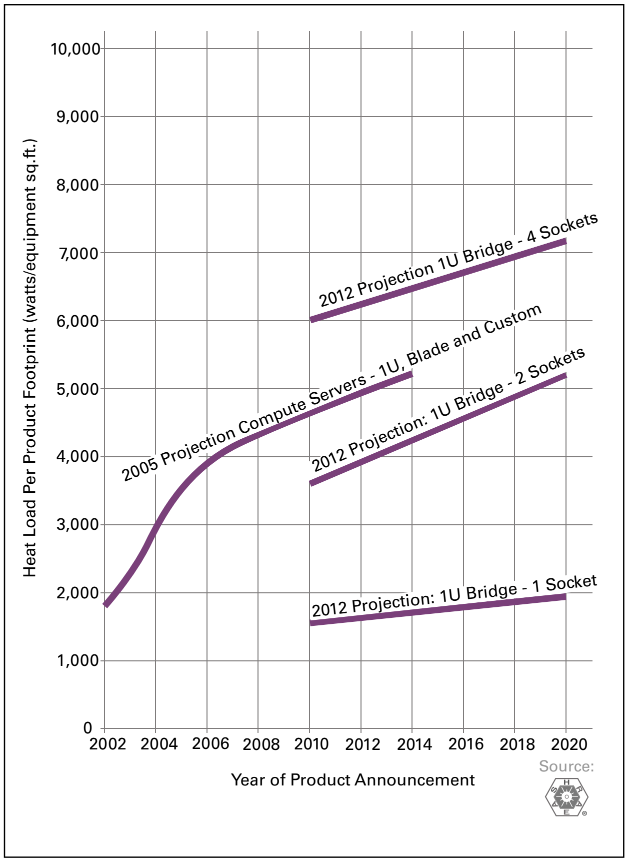


Chart 2: 1U Server Power Trends[6]

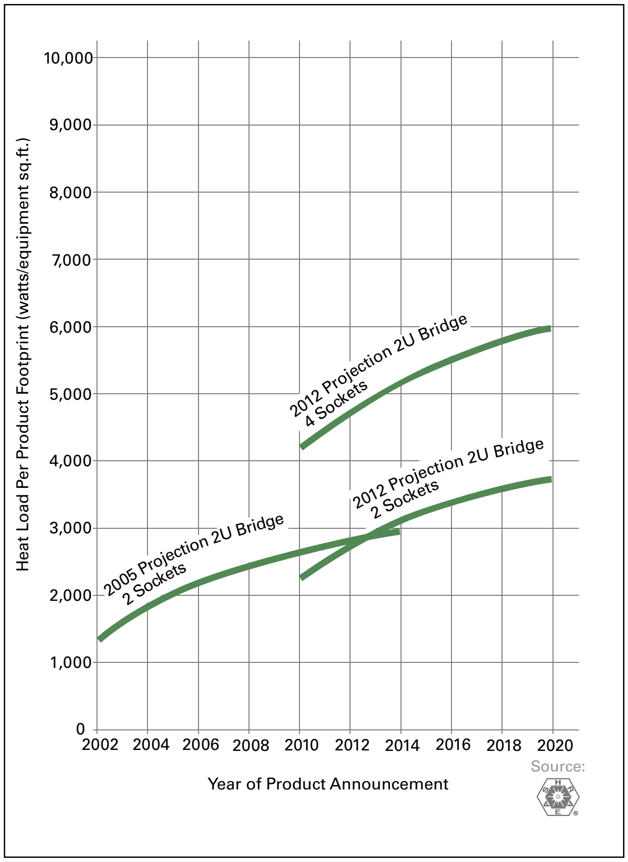


Chart 3: 2U Server Power Trends[6]

The unpredictable relationship between those competing motives makes forecasting a demand curve adventurous, if not downright plagued with guaranteed uncertainty. Nevertheless, just to drive a stake in the ground, we will use the server density estimated growth curves from the ASHRAE power trends handbook (Chart 2 and 3).

The average density growth curves for the low lines and high lines from the 2012 estimates for 1U servers and 2U servers combined comes out to a compound annual growth rate of 8.1%. A similar averaging of 7U, 9U and 10U blades produces a 6.1% CAGR. Because a migration from “pizza box servers” to blade servers does not typically result in a 1:1 power density conversion, we will just use the higher 8.1% density CAGR for this analysis. Furthermore, the ASHRAE power trend curves are typically not straight linear slopes, so a consolidated CAGR might not accurately represent the total data center industry trend. However, since all data centers would be entering these trend lines at different points than the indicated dates for product release, and since many sites may, in fact, be at a density point pre-dating the current trends analysis, the CAGR approach seems as reasonable as any other approach and obviously simpler to quantify in chart form.

Before providing some estimates for how long the life of a data center may be prolonged with effective airflow management, we might as well take a shot at defining “effective” airflow management. In general terms, effective airflow management means minimal server inlet temperature variation. More specifically, Figure 1 shows temperature data collection for a well-designed and properly installed highly effective hot aisle containment configuration with 1.7% leakage with 0.007” H_2O (1.74 Pa) column pressure outside the containment aisle and -0.004” H_2O (-0.996 Pa) inside the containment, from data collected from testing in a data center test lab. To add some context for these test conditions, CPI’s standard containment system is rated at <5% leakage at 0.15” H_2O (37.36 Pa), while there is a competitive containment system available rated at <3% leakage at 0.001” H_2O (0.249 Pa). Normalizing these two specifications to each other, the CPI containment would be 0.7% leakage at 0.001” H_2O (0.249 Pa), while the competitive cabinet would be >21% leakage at 0.15” H_2O (37.36 Pa).

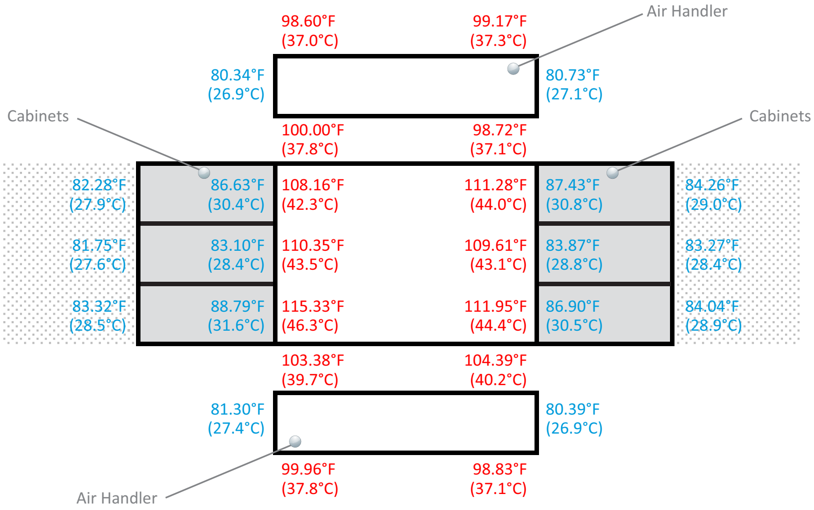


Figure 1: Temperature Variations @ 1.7% Containment Leakage (Highly Effective)

The rectangles at the top and bottom of Figure 1 are 10 ton air handlers – the blue numbers being the average supply temperature over the duration of the test and the red numbers representing average return in-take temperatures. In the shaded areas, the blue numbers represent the average temperatures coming through perforated floor tiles. The two rows of rectangles represent six cabinets organized in the hot aisle containment. The blue numbers represent the average server inlet temperatures taken at the bottom, middle and top of the front of the cabinet and the associated red numbers represent the server exhaust temperatures, also taken at three different vertical points. The critical message of this test report is that with carefully executed containment, there is less than 1 °F (0.6 °C) total variation from the floor supply over the full vertical face of the server cabinets. Those temperature variations and the total supply: return ΔP of 0.011” H_2O (2.73 Pa) mean that supply air volume does not need to be set above server demand and supply temperature only needs to be 1 °F (0.6 °C) below the maximum desired server inlet temperature. Both of those results translate into significant energy savings and extension of data center life without having to add additional power or cooling capacity.

With the proper solution, you can obtain excellent performance, low leakage and good pressure using a containment system, and it is worth the extra effort.

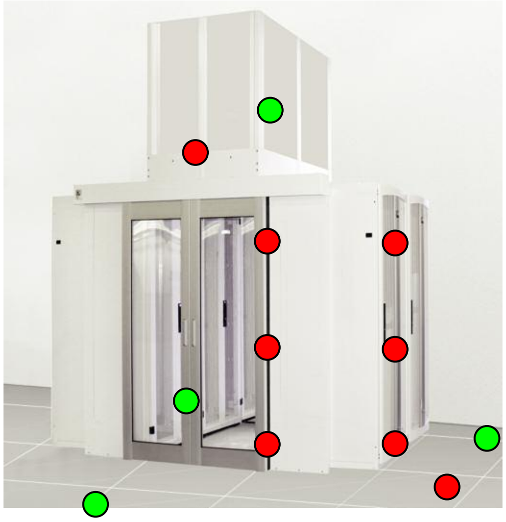


Figure 2: Representative Photograph of Hot Aisle Containment Test Installation

Figure 2 provides a point of reference for the above discussion. This is a representative photo of the test containment set up described in Figure 1. In the test site, there were six cabinets and air handlers located on each end of the contained row opposite the sliding doors. The red dots indicate approximate locations for a set of temperature sensors, and the green dots indicate approximate locations for pressure sensors. The three red dots vertically arrayed in front and in the rear of each cabinet capture inlet and exhaust temperatures. Additionally, floor tile sensors and return plenum sensors were placed in front of the cabinets (cold aisles) and above the air handlers to capture bounding conditions against which leakage can be calculated. Pressure was measured in the room, under the floor, within the containment aisle and in the return plenum.

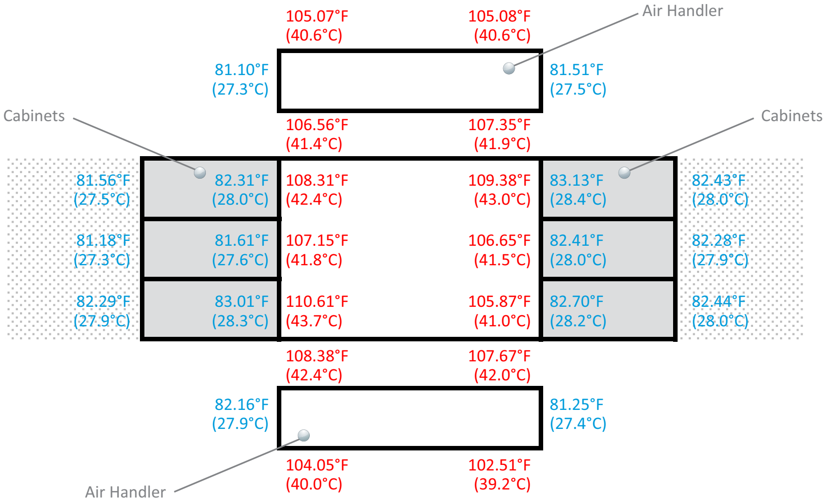


Figure 3: Temperature Variations @ 9.4% Containment Leakage (Sub-optimum)

In contrast, at only 9.4% containment leakage as shown in Figure 3, average server inlet temperatures range up to 7-8 ˚F (3.9-4.4 ˚C) above supply temperature. There are two results from this wider temperature variation and neither is good. First, temperatures likely exceed maximum requirements. Secondly, because of the high temperatures, either higher air volume (more fan energy), lower temperatures (more chiller energy) or both will be required to compensate for the less than optimum containment.

Constrained Only By Available Cooling Capacity

Extra Years	Load kW	CCF	Demand Airflow CFM (CMH)	Supply Airflow CFM (CMH)	Rack Density (kW)	Quantity Racks
	1000	3.9	172700 (293419.1)	673530 (1144334.6)	5	200
1	1081	1	186689 (317186.1)	673530 (1144334.6)	5.4	200
2	1169	1	201810 (342878.2)	673530 (1144334.6)	5.8	200
3	1263	1	218157 (370651.3)	673530 (1144334.6)	6.3	200
4	1366	1	235828 (400674)	673530 (1144334.6)	6.8	200
5	1476	1	254930 (433128.6)	673530 (1144334.6)	7.4	200
6	1596	1	275579 (468212.1)	673530 (1144334.6)	8.0	200
7	1725	1	297901 (506137.2)	673530 (1144334.6)	8.6	200
8	1865	1	322031 (547134.4)	673530 (1144334.6)	9.3	200
9	2016	1	348116 (591452.2)	673530 (1144334.6)	10.1	200
10	2179	1	376313 (639359.9)	673530 (1144334.6)	10.9	200
11	2355	1	406794 (691148)	673530 (1144334.6)	11.8	200
12	2546	1	439745 (747131)	673530 (1144334.6)	12.7	200
13	2753	1	475364 (807648.6)	673530 (1144334.6)	13.8	200
14	2975	1	513869 (873068.2)	673530 (1144334.6)	14.9	200
15	3217	1	555492 (943786.7)	673530 (1144334.6)	16.1	200
16	3477	1	600487 (1020233.4)	673530 (1144334.6)	17.4	200
17	**3759**	**1**	**649126 (1102872.3)**	**673530 (1144334.6)**	**18.8**	**200**

Table 1: Extra Years of Data Center Life With Effective Containment (Cooling Capacity Constrained)
(3.9 CCF assumes no containment and 1.0 CCF assumes highly effective containment)

So, what is the impact of making the extra effort to create a highly effective containment solution? The impact of very effective containment can be seen by the effect of reducing the CCF from an average 3.9 to 1, thereby potentially adding many additional years of data center life without expanding mechanical capacity. For a 1MW IT load, as demonstrated in Table 1, where cooling is constrained but power is not, that very effective containment will add an extra seventeen years of life to the data center.

Constrained Only By Available Cooling Capacity

Extra Years	Load kW	CCF	Demand Airflow CFM (CMH)	Supply Airflow CFM (CMH)	Rack Density (kW)	Quantity Racks
	1000	2.6	172700 (293419.1)	449020 (762889.8)	5	200
1	1081	1	186689 (317186.1)	449020 (762889.8)	5.4	200
2	1169	1	201810 (342878.2)	449020 (762889.8)	5.8	200
3	1263	1	218157 (370651.3)	449020 (762889.8)	6.3	200
4	1366	1	235828 (400674)	449020 (762889.8)	6.8	200
5	1476	1	254930 (433128.6)	449020 (762889.8)	7.4	200
6	1596	1	275579 (468212.1)	449020 (762889.8)	8.0	200
7	1725	1	297901 (506137.2)	449020 (762889.8)	8.6	200
8	1865	1	322031 (547134.4)	449020 (762889.8)	9.3	200
9	2016	1	348116 (591452.2)	449020 (762889.8)	10.1	200
10	2179	1	376313 (639359.9)	449020 (762889.8)	10.9	200
11	2355	1	406794 (691148)	449020 (762889.8)	11.8	200
12	**2546**	**1**	**439745 (747131)**	**449020 (762889.8)**	**12.7**	**200**

Table 2: Extra Years of Data Center Life With Effective Containment (2.6 CCF)
(2.6 CCF assumes no containment and 1.0 CCF assumes highly effective containment)

Extra Years	Load kW	CCF	Demand Airflow CFM (CMH)	Supply Airflow CFM (CMH)	Rack Density (kW)	Quantity Racks
	1000	1.75	172700 (293419.1)	302225 (513483.5)	5	200
1	1081	1	186689 (317186.1)	302225 (513483.5)	5.4	200
2	1169	1	201810 (342878.2)	302225 (513483.5)	5.8	200
3	1263	1	218157 (370651.3)	302225 (513483.5)	6.3	200
4	1366	1	235828 (400674)	302225 (513483.5)	6.8	200
5	1476	1	254930 (433128.6)	302225 (513483.5)	7.4	200
6	1596	1	275579 (468212.1)	302225 (513483.5)	8.0	200
7	**1725**	**1**	**297901 (506137.2)**	**302225 (513483.5)**	**8.6**	**200**

Table 3: Extra Years of Data Center Life With Effective Containment (1.75 CCF)
(1.75 CCF assumes no containment and 1.0 CCF assumes highly effective containment)

If excess cooling capacity is only 2.6, as found in the Uptime Institute audit of participating data centers ten years ago, containment will stretch the data center's life twelve years, as shown in Table 2. If that excess capacity is only 1.75, then containment produces an extra seven years of data center life before investing in additional mechanical infrastructure (Table 3).

While it is conceivable that a data center could be cooling constrained but not power constrained, it is much more likely to find a facility power constrained. Even with a power constrained data center, the CRAH fan energy savings resulting from eliminating the need for producing excess supply can regain power capacity that can be applied to IT load. Table 4 and Table 5 show three extra years of data center life with containment for spaces deemed power constrained with actual 3.9 and 2.6 surplus cooling capacity. Table 6 shows an extra two years of life when only overcoming 1.75X cooling capacity versus actual demand in containment. Table 7 shows how an extra year might be squeezed out from a migration from pizza box servers to blade servers and the resultant higher ΔT's, or CFM:kW ratios. It is worth repeating that these results are exclusive of any impacts from utilizing economization for free cooling hours or any IT improvements, like virtualization or implementing power savings features on servers that may result in even lower loads.

Constrained By Power Availability

Extra Years	Available kW	Load kW	Mech kW	CCF	Demand Airflow CFM (CMH)	Supply Airflow CFM (CMH)	Rack Density (kW)	Quantity Racks
	1350	1000	350	3.9	172700 (293419.1)	673530 (1144334.6)	5	200
1	1350	1081	7.5	1	186689 (317186.1)	186689 (317186.1)	5.4	200
2	1350	1169	9.4	1	201810 (342878.2)	201810 (342878.2)	5.8	200
3	1350	1263	11.9	1	218157 (370651.3)	218157 (370651.3)	6.3	200
	1350	1366	15.0	1	235828 (400674.0)	235828 (400674.0)	6.8	200

Table 4: Extra years of Data Center Life When Power Availability Constrained (3.9 CCF Benchmark)

Extra Years	Available kW	Load kW	Mech kW	CCF	Demand Airflow CFM (CMH)	Supply Airflow CFM (CMH)	Rack Density (kW)	Quantity Racks
	1350	1000	350	2.6	172700 (293419.1)	449020 (762889.8)	5	200
1	1350	1081	25.2	1	186689 (317186.1)	186689 (317186.1)	5.4	200
2	1350	1169	31.8	1	201810 (342878.2)	201810 (342878.2)	5.8	200
3	1350	1263	40.1	1	218157 (370651.3)	218157 (370651.3)	6.3	200
	1350	1366	50.7	1	235828 (400674.0)	235828 (400674.0)	6.8	200

Table 5: Extra years of Data Center Life When Power Availability Constrained (2.6 CCF Benchmark)

Extra Years	Available kW	Load kW	Mech kW	CCF	Demand Airflow CFM (CMH)	Supply Airflow CFM (CMH)	Rack Density (kW)	Quantity Racks
	1350	1000	350	1.75	172700 (293419.1)	302225 (513483.5)	5	200
1	1350	1081	82.5	1	186689 (317186.1)	186689 (317186.1)	5.4	200
2	1350	1169	104.2	1	201810 (342878.2)	201810 (342878.2)	5.8	200
	1350	1263	131.6	1	218157 (370651.3)	218157 (370651.3)	6.3	200
	1350	1366	166.3	1	235828 (400674.0)	235828 (400674.0)	6.8	200

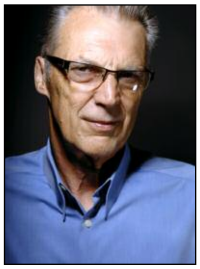
Table 6: Extra years of Data Center Life When Power Availability Constrained (1.75 CCF Benchmark)

Constrained By Power Availability

Extra Years	Available kW	Load kW	Mech kW	CCF	Demand Airflow CFM (CMH)	Supply Airflow CFM (CMH)	Rack Density (kW)	Quantity Racks
	1350	1000	350	1.75	172700 (293419.1)	302225 (513483.5)	5	200
1	1350	1081	82	1	186688.7 (317186.1)	186688.7 (317186.1)	5.4	200
2	1350	1168.5	19	1	115320.277 (195930.4)	115320.277 (195930.4)	5.8	200
3	1350	1263.2	25	1	124661.2194 (211800.7)	124661.2194 (211800.7)	6.3	200
	1350	1365.5	31	1	134758.7782 (228956.6)	134758.7782 (228956.6)	6.8	200

Table 7: Extra years of Data Center Life When Power Availability Constrained (1.75 CCF Benchmark)

Optimum airflow management through effective containment will not guarantee a longer life for all data centers, but it will definitely reduce the total CFM delivery requirements for any data center space. Given the high amount of stranded mechanical capacity in most data centers revealed through the Uptime Institute research, and then again in a more comprehensive CCF audit conducted by Upsite Technologies last year, it is clear that many data centers could definitely expand their life to either delay significant capital expenditures or buy time to institute IT equipment initiatives, such as virtualization and enabling server energy management options that would result in flattening or even reversing power density growth trends. Since the investment in implementing a containment solution is so much less than the alternatives of adding air handlers or other supplemental cooling equipment, considering containment should be part of any data center life extension investigation. This paper features the example of hot aisle containment, but similar results are possible with cold aisle containment or by containing individual cabinets with ducted exhaust. CPI can help you find the right solution and show you how to achieve a highly effective containment solution.



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Ian has over 30 years of mechanical and electro-mechanical product and application development experience, including HVAC controller components, automotive comfort environmental controls, and aerospace environmental controls and, for the past 13 years, he has spear-headed Chatsworth Products' data center thermal management initiatives. He is the working group leader for the rack and cabinet section of BICSI-002-2010, Data Center Design and Implementation Best Practices, and also served on the mechanical working group for that standard. He serves on ASHRAE TC 9.9, has published numerous articles and research papers and has presented at conferences and technical meetings in 12 different countries around the globe. He has bachelor's and master's degrees from California Polytechnic State University.

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