IMMERSION COOLING DENSITY AS A DRIVER OF SAVINGS

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Mario Conti | VP of Engineering Midas Green Technologies: mario@midasgt.com

In the Data Center industry, higher density server racks are becoming increasingly more common due to more powerful chips. About 15 years ago, a typical data center would be built to support 4-5 kW per rack. Data centers built about 10 years ago were built for densities between 8-10kW. [1] Today the majority of Data Centers still report server densities below 10kW, although some newer data centers are able to handle as much as 20 to 25 kW per rack.[2]

Higher densities normally mean higher efficiencies as less space and equipment is necessary to perform the same job. However, the biggest challenge facing higher densities is cooling. At higher densities, air cooling becomes prohibitively expensive and difficult to manage. For some, higher densities are not even possible. This quest for higher densities has done two things. One, it has spurred the development of 48 and 96 core chips that are very hot and two, it has pushed the advent of new cooling technologies involving liquid. For example liquid to the chip, two-phase immersion cooling, and open bath, or Single Phase Liquid Immersion Cooling.

The liquid to the chip solution has gained considerable momentum over the last couple of years. Most of the time, these technologies use water to provide cooling. As water and electronics do not mix, this is not a very good idea as the question is not about whether it will leak but when. In fact, one OEM server manufacturer has gone as far as to install a troth for water flow "IF" there is a leak. Additionally, liquid to the chip solutions require custom servers with intricate and expensive piping that becomes obsolete as the computer technology refreshes. Liquid to the chip does not eliminate the need for air conditioning as cooling is only applied to the processors.

Immersion cooling technologies share the benefit that the servers operate submerged inside a dielectric liquid that is compatible with electronics.
As such, servers only require minimal customization (i.e. fan removal) instead of fancy pipes that need to be discarded with technology refreshes. Immersion cooling eliminates all of the most common failure causes of a data center: no fans, no dust, no humidity, no oxidation, no corrosion, no noise, and no hot zones. Additionally, by removing the fans it is possible to reduce the overall server consumption between 5-15%.

Two-phase immersion cooling liquid has a slightly superior heat dissipation to a single phase coolant. That slightly superior heat dissipation capacity comes at a cost, literally. Not only are two-phase immersion cooling fluids extremely expensive but

[1] See "Raising Data Center Power Density" by Jeff Clark, 10/24/2013. http://www.datacenterjournal.com/raising-data-center-power-density/
[2] See "Uptime Institute Global Data Center Survey 2018" Uptime Institute 2018

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1905 East 6th Street, Suite 150
Austin, Texas 78702
+1.512.518.212

they also need to be airtight, therefore expensive to build. Additionally, as the liquid is constantly being boiled off, performing maintenance on a server is impractical as it requires either turning off the servers or opening the vat while they are running which will cause the loss of large quantities of liquid while maintenance is being performed.[3] Under current technologies, the limiting factor towards higher densities in immersion cooling is server density, not heat dissipation of the liquid. As such, the increased heat dissipation capacity of two-phase liquids offers little to no advantagesto single phase liquids.

Open bath immersion cooling is, therefore, the only solution that allows the same level of maintainability as an air data center but eliminates all of their major problems while allowing densities far above 50kW per rack. Of the open bath immersion cooling technologies available, the Midas XCI system offers the only patented solution that allows a uniform flow of dielectric from the bottom to the top allowing both natural and forced convection to remove the heat from the computer equipment. Additionally, the Midas XCI system comes equipped with up to two fully redundant cooling modules. Modules can be replaced in less than 10 minutes without downtime or tools, making the system concurrently maintainable. For more information about the Midas XCI system, visit www.midasimmersion.com

This paper will analyze the cost savings of using the Midas XCI immersion cooling technology and how this technology can become not a response of higher density but rather an economic driver. This paper will compare the economies of having a 1MW redundant installation, as built for current air standards, as well as different densities Midas XCI installations. The air data center installation assumes an average density per rack of 12kW; for the Midas XCI installations, we will evaluate 25kW, 50kW and 100kW per tank. Density per tank is normally limited by the physical space of the server rather than the power, for simplicity, this analysis will fix maximum power constraints to the 25kW and 50kW cases.

For a complete list of all the assumptions, please refer to the tables at the end of the document. This project will be designed to host 500 high-density servers. These servers are 1U, 2,000W with eight 2A 12V fans. As it is summarized on the table below, the compute power consumption for an air data center using the above parameters issimply the multiplication of 500 serverstimes its 2000W per server consumption.

[3] See “Immersion Cooling of Electronics in DoD Installations” by Coles, H. and Herrlin, M. Lawrence Berkeley National Laboratory, May 2016
[4] See “Uptime Institute Global Data Center Survey 2018” Uptime Institute 2018

For the immersion cooling, it is necessary to consider the removal of the fans. In this case, 192W of fans per server for savings of 96kW or a total compute power consumption of 904kW.

Similarly, when calculating the overhead power consumption for a regular data center, we need to consider the chiller, condenser, air handler and power distribution losses. This outputs a PUE of 1.65 which is consistent with global standards.[4] For an immersion system, we only account for the immersion tank, the condenser, and the power distribution losses. This translates to a PUE of 1.07. Although it might sound incredible, this number is easily justifiable due to the high dissipation capacity of liquids. Indeed, a standard Midas XCI installation is only composed of one small pump per tank, and the pumps and fans of the cooling tower or dry cooler; there is no need for compressors or any other high power components.

This PUE is consistent with measurements of our Austin, Texas facility which has been running with a PUE of 1.06 or less, even during the Texas summer. It is important to note that even though the true PUE of the Midas system as calculated is 1.07 when calculating total savings vs. an air installation it is necessary to compare using the same standards. The PUE vs AIR calculation on the table below illustrates what the PUE of an immersion cooling installation would be if we use the same denominator as for our Air data center calculation. Doing this yields a PUE lower than one. What this translates to, is that for every dollar spent in electricity to the rack in a regular data center, a Midas XCI installation would only require $0.97 after overhead expenses.

$$PUE_{AIR} = \frac{Server\ Power + Overhead}{Server\ Power} = \frac{Compute\ Power + fans + Overhead}{Compute\ Power + fans}$$

$$PUE_{Midas} = \frac{Compute\ Power + Overhead}{Compute\ Power}$$

$$PUE_{Midas\ vs\ Air} = \frac{Compute\ Power + Overhead}{Compute\ Power + fans}$$

		Air DC	Midas 25kW	Midas 50kW	Midas 100kW
Compute Power Consumption	kW	1000	904	904	904
Overhead Power Consumption	kW	650	63	63	63
Total Power Consumption	kW	1650	967	967	967
PUE		1.65	1.07	1.07	1.07
PUE vs AIR		1.65	0.97	0.97	0.97

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An obvious benefit of lower power consumption is lower electricity costs. This analysis assumes a cost of $0.08/kW-h. As seen on the table below, power savings on an immersion cooling installation are 90% in cooling and 41% overall.

		Air DC	Midas 25kW	Midas 50kW	Midas 100kW
Server Consumption	$/month	58,400.00	52,793.60	52,793.60	52,793.60
Overhead Consumption	$/month	37,960.00	3,695.55	3,695.55	3,695.55
Total Consumption	$/month	96,360.00	56,489.15	56,489.15	56,489.15
Total Power Savings	%/month	0%	41%	41%	41%

As the Midas XCI system is designed to match cooling with heat generation, the increased benefits of a denser installation are not as apparent when analyzing power savings alone. These benefits can be seen on other operating expenses such as maintenance and rent but most significantly in the capital expenditures. The table below shows the number of tanks or racks that would be necessary to host a 1MW data center according to the maximum allowed heat dissipation per rack. Accordingly, area requirements are calculated based on the space required per rack/tank as well as aisles and support equipment. The table below illustrates the number of racks/

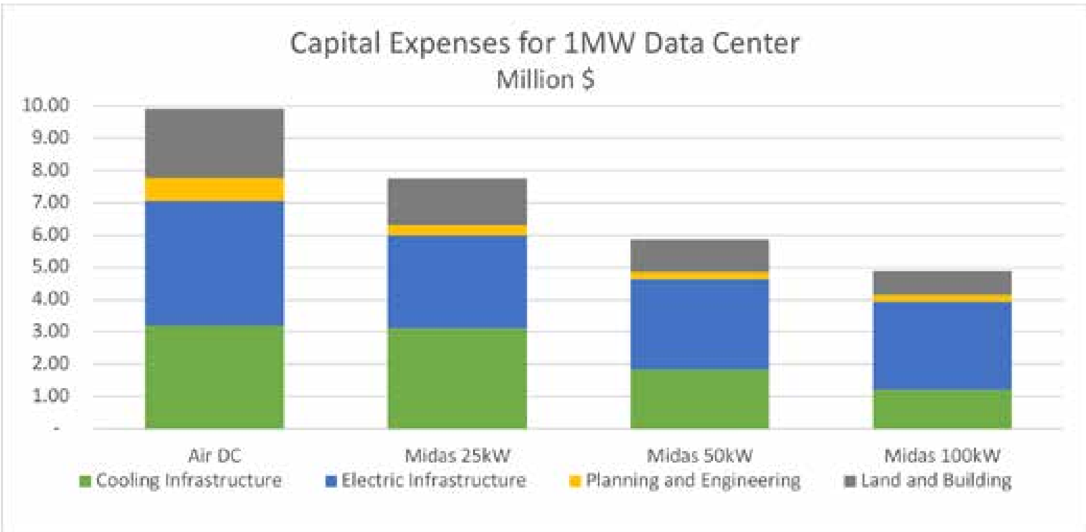
		Air DC	Midas 25kW	Midas 50kW	Midas 100kW
Number of Racks/Tanks	Racks	84	37	19	10
Rack/Tank Density	kW/Rack	11.9	24.4	47.6	90.4
IT Area	Sq Ft	3302	2368	1216	640
Overhead Area	Sq Ft	1320	1193	1193	1193
Total Area	Sq Ft	4622	3561	2409	1833

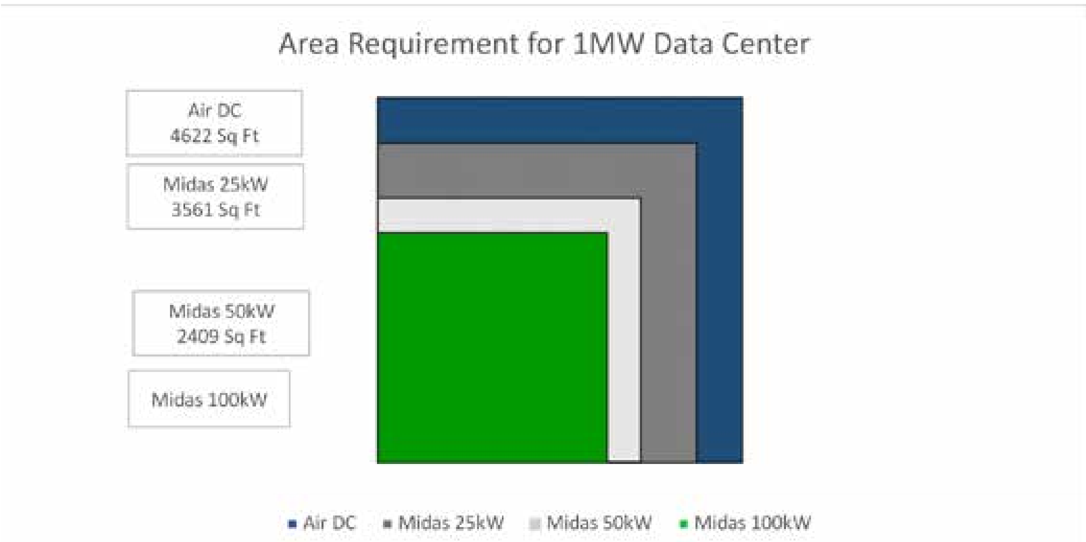
tanks and space that would be necessary for each application.

In a regular data center, racks are one of the cheapest components as most of the budget is spent on the cooling and electrical infrastructure. A Midas XCI system is considerably more expensive than a standard rack but it replaces the need for raised floors, air handlers, chillers, cold/hot aisles and allows to reduce the overall size of the power infrastructure (generators, Transfer Switches, UPS, etc.). Indeed, even for a 25kW per Tank installation, this offset makes the overall capital expenditure less than for a traditional Data Center. By allowing more power per tank, it is possible to reduce the overall number of tanks that are necessary to accomplish the same amount of cooling. Fewer tanks mean less overall infrastructure and smaller capital investment.

		Air DC	Midas 25kW	Midas 50kW	Midas 100kW
Cooling Infrastructure	$	3,190,092	3,103,472	1,843,472	1,213,472
Electric Infrastructure	$	3,880,950	2,897,253	2,789,260	2,735,263
Planning and Engineering	$	707,269	300,099.23	231,700	197,500
Land and Building	$	2,132,903	1,459,329	987,396	751,430
Total CAPEX	$	9,911,214	7,760,153	5,851,827	4,897,664
Savings	%	0%	22%	41%	51%

The estimated capital expenditures for the four cases can be seen on the table below. As immersion cooling technologies replace the need of most of the cooling and containment infrastructure, the benefits of a denser immersion cooling application are more readily apparent than those for an air data center. While a comparable density application would require roughly the same electrical and cooling infrastructure, reducing the number of tanks through consolidation of heat load offers significant





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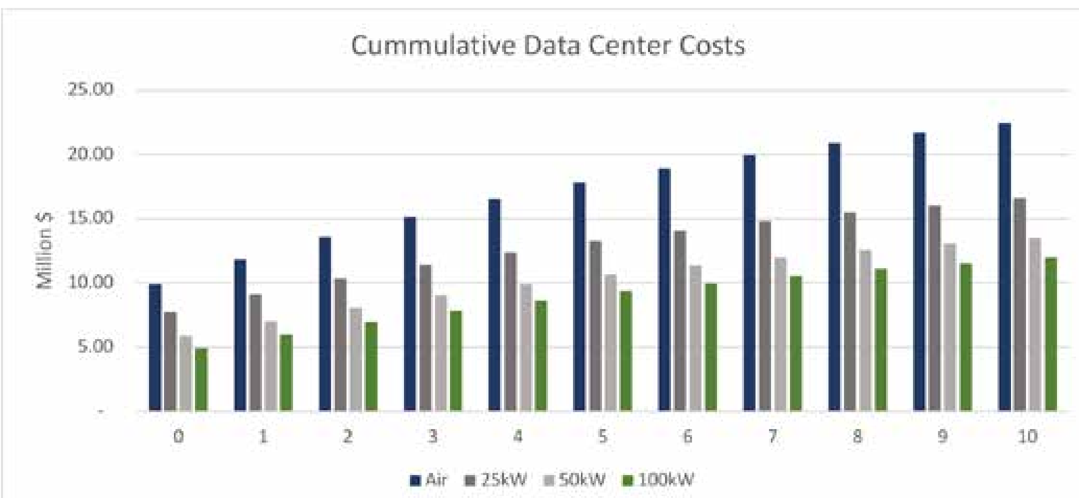
savings visible on the graphics below.

Under most conditions today, immersion cooling is one of those rare investments that do not require a payout period. An immersion cooling installation requires smaller capital investment and incurs less operational expenses. Just as with the invention of the gasoline engine, large improvements require large leaps in technology. In this case, the leap involves replacing the cooling medium from air, which is a terrible heat conductor, to a dielectric liquid that is able to move over 1200 times more heat. An immersion data center allows eliminating the need to keep servers "cool". Instead warm dielectric is able to quickly remove the heat out of the chips and this warm dielectric is able to be cooled using slightly less warm water. A graph showing the cumulative cost of building and operating the data centers (electricity, maintenance, and rent) assuming a 10% discount rate over 10 years is shown below. Ultimately, for greenfield installations, Midas XCI immersion cooling solution allows building the same capacity data center in less area for less investment and a smaller operating



budget.

For existing data centers, most data centers today are running out of space or out of power. Using the model above we can calculate that an existing 1MW compute power air data center uses a total of 1.65MW in at least 4,622 Sq Ft. If retrofitting such a data center to use immersion cooling, the same power feed would allow over 1.5MW of computer equipment and, provided that the density is above 31kW per tank, plenty of additional leftover space. In reality, however, most data centers today would be thrilled to claim a PUE as low as 1.65 and be able to host 1MW of computer equipment in just 4,622 Sq Ft. The benefits of retrofitting even a small fraction of a current data center and condensing some of the denser systems using immersion cooling can be substantial.

ASSUMPIONS

CAPEX ASSUMPTIONS		
Chiller Cost	510.00	$/kW
Condenser System Cost	260.00	$/kW
Air Handler Cost	570.00	$/kW
Ducting Costs	210.00	$/kW
Piping Costs	40.00	$/kW
Raised Floor	40.00	$/Sq Ft
Cost of Rack	1,500.00	$/Rack
Sensors & Controls	150.00	$/kW
UPS Cost	660.00	$/kW
Diesel Generator & Switch Gear Cost	600.00	$/kW
Electrical Infrastructure & Power Distribution	240.00	$/kW
Site Preparation Cost (AIR)	150	$/Sq Ft
Site Preparation Cost (MIDAS)	60	$/Sq Ft
Engineering and Design Services (AIR)	10%	% of Total Cost
Engineering and Design Services (MIDAS)	5%	% of Total Cost
Building Construction Cost	200.00	$/Sq Ft
Land Acquisition Cost	150.00	$/Sq Ft
OPEX INPUTS		
Chiller Overhead	50%	% IT Load
Condenser System Overhead	3.0%	% IT & Cooling
Air Handler Overhead	10%	% of IT Load
Power Distribution Losses	2.0%	% of Total Power
Maintenance Cost	3.0%	% of upfront cost
Rent	2.50	$/Sq FT-month

The listed equipment costs are for simple systems. These were doubled to account for redundancy.

TECHNOLOGY SPECIFICS	Air DC	Midas DC	
Max Rack Density (Power)	12	150	kW/Rack
Max Rack Density (Volume)	42	50	U/Rack
Mechanical PUE (tanks)	NA	1.02	mPUE
Maximum Tank Consumption	NA	3.72	kW/Tank
Rack/Tank Width (left to right)	26.62	94	Inches
Rack/Tank Depth (front to back)	43.3	44	Inches
Cold/Server Aisle Width	72	36	Inches
Hot/Mechanical Aisle Width	48	30	Inches
Between Rack/Tank Aisle	0	6	Inches
Row Width	416	198	Inches
Racks/Row	12	NA	Racks
Overhead Area	0.66	0.66	Sq Ft/kW

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