AEX: Lower Data Center Peak Loads, Faster Interconnection, quicker build out.

Rebound Technologies

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SUMMARY: NEW TECHNOLOGY MEETS EXPLOSIVE DATACENTER GROWTH
AEX™ is a new breakthrough ice banking product set to disrupt cooling across the industrial and commercial sectors. AEX uses a self-healing active surface chemistry to achieve a 5X improvement in cost/capacity, a 10X improvement in heat transfer, and a 2X improvement in efficiency. **This step change improvement in cost and performance unlocks thermal energy storage systems with a footprint, cost, and capacity specifically well-suited for the datacenter market.**

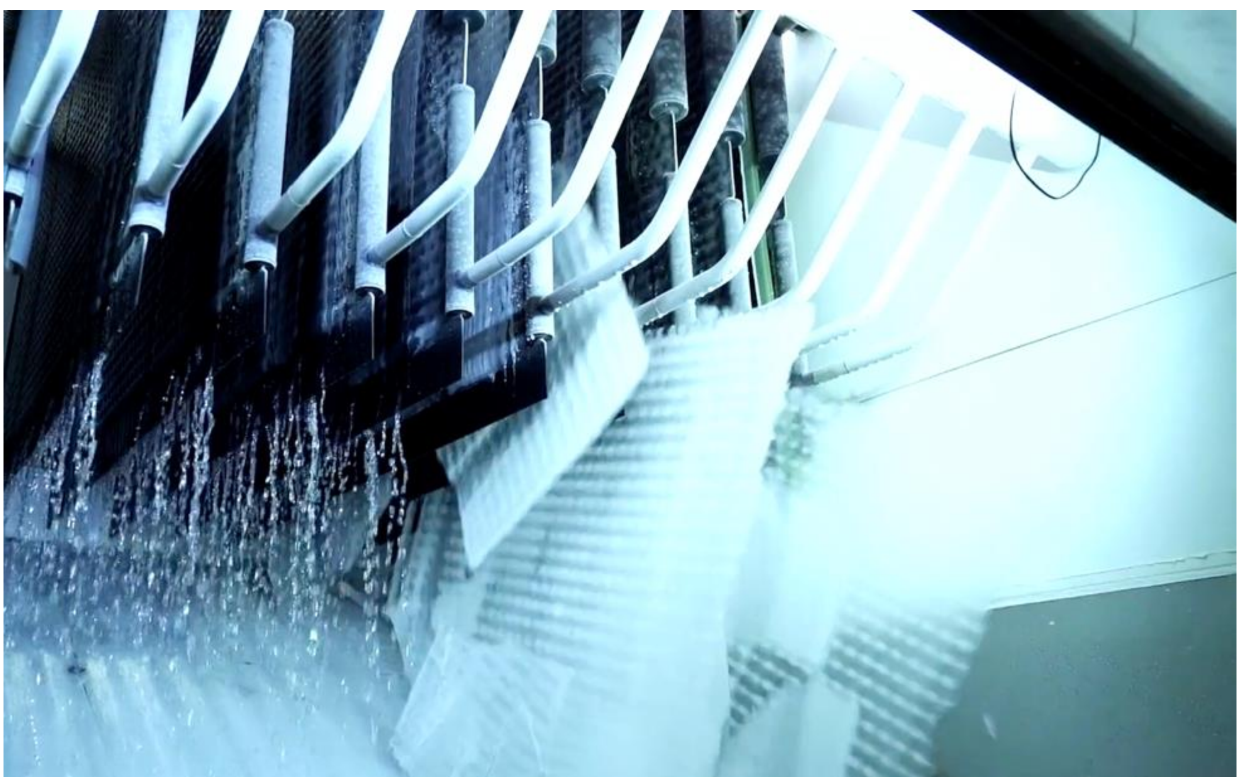

Figure 1: AEX during its harvest phase. The ice maker is significantly more productive than the current state of the art.

With the explosive growth in AI tools and their use, the datacenter market is seeing unprecedented growth forecasts. These forecasts have driven the highest electrical load growth in the past 50 years and have pushed the grid and the utilities that run it to the breaking point. Importantly, the issue is not one of capacity but of peak demand. Utilities have more than enough generation to provide the energy (kWh) for datacenter growth, but the system is constrained by the ability of the grid to deliver instantaneous peak demand power (kW) during the hottest hours of the year[1]. Since the grid runs at only about 40% utilization[2] (kWh generated / potential kWh if generators ran at 100%) there is no shortage of energy, but during the hottest hours of the year air conditioning loads dramatically increase demand while lower performance of thermal generation assets decrease supply. To date the only solution has been to overbuild generation but there is a better way: demand flexibility. **If new datacenter loads can shed just 0.25% of annual load, the current grid can tolerate nearly 100GW of additional datacenter load[1].**

The roll out of the AEX product cannot be more opportune timing: its low cost and small footprint make it an ideal thermal energy storage technology for datacenter peak demand reduction.

CASE STUDY: RAPID GRID INTERCONNECT FOR NEW DATACENTERS

When looking for sites for new datacenters, availability of demand is a key roadblock: new datacenters require significant electrical interconnect, and while utilities are more than capable of providing the energy throughout the year, they cannot guarantee the peak demand capacity that the datacenter will require. Of the many value adds of the AEX system at a datacenter[3], this is by far the most valuable.

In the datacenter industry, Power Utilization Effectiveness (PUE) is the most commonly used metric of energy efficiency. While useful, this metric is particularly bad at capturing the power of load flexibility. This is because, in a demand-constrained situation, the key metric is the power required by the facility during the critical peak window, which is often as short as 15 minutes. So, while a facility might have a very low PUE for 20 hours of the day and only turn on their chillers during the hottest 4 hours of the day, those 4 hours set the peak demand, and the utility will not allow the datacenter to connect to the grid at all. To this end, it is more valuable to look at metrics that take peak system behavior into account:

1. **Peak PUE:** the PUE of a datacenter during the periods of the year when the grid is most stressed.
2. **Total curtailable load:** the amount of datacenter load that can be curtailed without affecting IT power.

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[1] Rethinking Load Growth: https://nicholasinstitute.duke.edu/sites/default/files/publications/rethinking-load-growth.pdf

[2] Electricity Explained: https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php

[3] Other values include: reduced energy costs, demand response revenue, higher cooling system reliability and uptime, emergency shutdown cooling in a power failure, uninterruptable cooling supply, and onsite generation augmentation.

While modern data centers have achieved a very low average annual PUE just above 1, they have done so predominantly through the optimization of free cooling. Figure 2 shows the chiller power consumption of a 200MW datacenter in eastern Texas. This datacenter achieves an annual average PUE of 1.1 through the use of significant free cooling during hours when the ambient temperature is low. While this industry-leading value is impressive, it is misleading because the instantaneous PUE (also shown in Figure 2) is greater than 1.25 during the hours when ambient temperatures are high and free cooling is not available. These hours coincide with the highest peak demand periods and the lowest power availability from the utility. In other words, the low facility PUE only reduces demand when the utility has plenty of available power and offers little relief when the grid is overwhelmed and power is scarce.

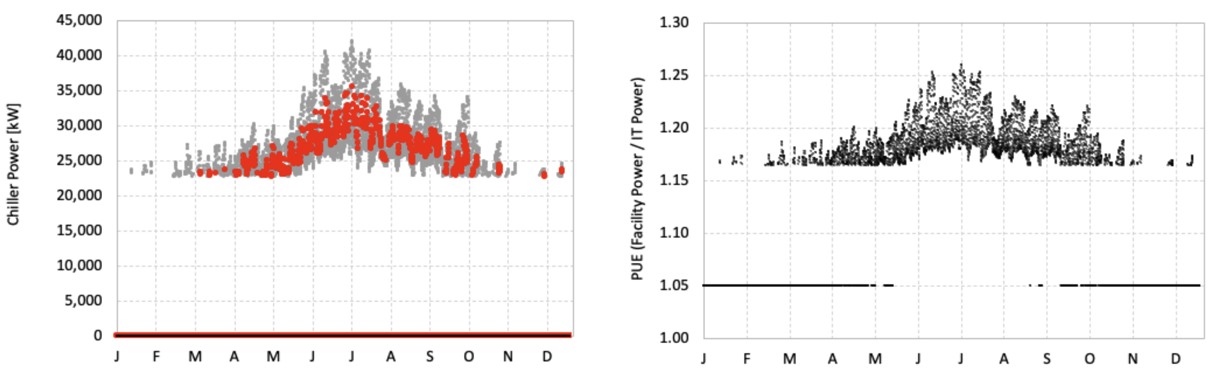


Figure 2: Chiller power and PUE for a 200MW datacenter in eastern Texas with an annual PUE of <1.1

AEX addresses this shortcoming by directly addressing peak PUE and creating curtailable data center load. In this same 200MW example, installing a 4-hour 200MW$_{thermal}$ AEX array allows the facility to reduce peak demand for up to four hours by curtailing compressor loads. These AEX units increase electrical demand during off-peak hours, then curtail datacenter power consumption during peak hours by effectively acting like a free-cooling module. They provide 100% of the cooling for the datacenter as their ice charge is depleted. This drops Peak PUE from

1.25 to less than 1.05 and creates a 36MW curtailable load with no effect on IT performance. Figure 3 shows an hour-by-hour usage for such a AEX array.

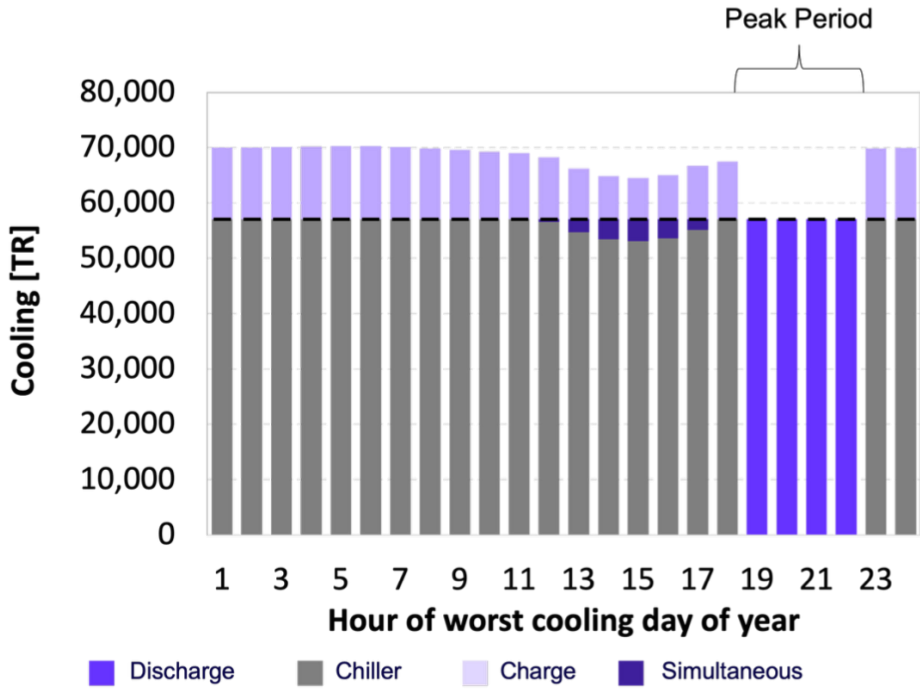


Figure 3: Hourly AEX behavior at a 200MW datacenter in eastern Texas. Note: During simultaneous discharge, ice generation is used to assist chillers in cooling the facility to minimize overall system capex. Additionally, annual modeling includes significant free cooling as shown in Figure 2, but during this "worst day" 24-hour period, no free cooling was available due to elevated ambient temperatures.

SIMPLE INTEGRATION, SMALLEST FOOTPRINT

Outside of the issue surrounding peak PUE vs annual average PUE, footprint is often a hurdle to the implementation of thermal energy storage at a data center. This is largely because most thermal energy storage projects in the past have used chilled water storage. AEX, like all ice-based storage, offers a significantly higher energy density compared to chilled water storage. AEX's novel architecture unlocks cost parity with chilled water storage, making it a lower-cost, lower-footprint solution. Figure 4 shows how impactful this higher energy density can be with an array of AEX units taking up only slightly more space than gas turbines while requiring no additional site permitting or licensing. Furthermore, the AEX array integrates directly into the facility's chilled water and has nearly instantaneous response time to facility needs.

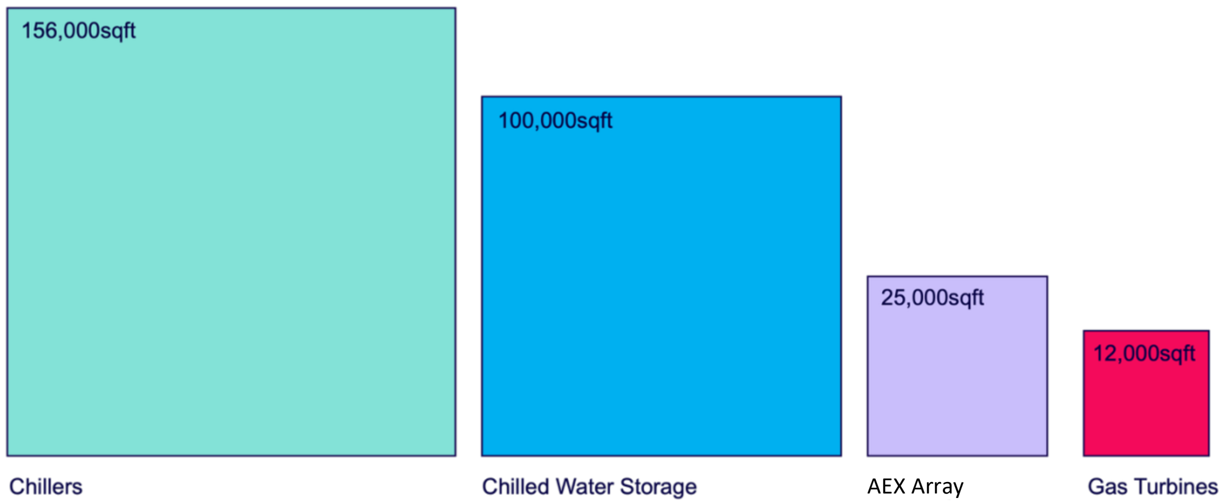


Figure 4: relative footprints associated with a 200MW datacenter in eastern Texas. Gas turbine footprint is based on packaged Solar Turbine Titan 130 modules capable of 36MW of peak discharge without ambient derate[4].

THE LOWEST COST PEAK POWER

This curtailable load is both an asset to the datacenter and to the utility. To the datacenter, it presents an additional revenue stream and allows for significantly faster grid interconnection in locations that inflexible datacenters will not be able to deploy. From the utility perspective, it is effectively peak generation and allows them to increase their generation asset utilization while minimizing overbuilding of new power plants. In this context, the capex of the AEX array can be taken into account to calculate a capex that can be compared with alternative forms of new peak generation. Table 2 shows a comparison between the capex of traditional peak power like natural gas turbines, and a AEX array. The dramatically lower upfront capex makes AEX a faster and cheaper way to provide additional capacity during peak hours.

Table 1: breakdown of peak power supplied by AEX array compared to peak power supplied by combined cycle or simple cycle gas turbines.

	CX SOLUTION
Current cost of peak power[5]	>$2000/kW
Peak PUE	<1.05
Curtailed Load	Up to 36MW
Energy Savings	$1.5MM/yr
AEX Array Tank cost	$6MM
AEX Array Ice maker cost	$35MM

[4] Solar turbine modular power plants: https://s7d2.scene7.com/is/content/Caterpillar/AEX0550267
[5] New York Times: Why a Plane-Size Machine Could Foil a Race to Build Gas Power Plants: https://www.nytimes.com/2025/04/08/business/energy-environment/gas-turbines-power-plants.html

AEX Array Cost	$41MM
Cost of AEX peak power	**$938/kW** **(half the cost)**

SUMMARY

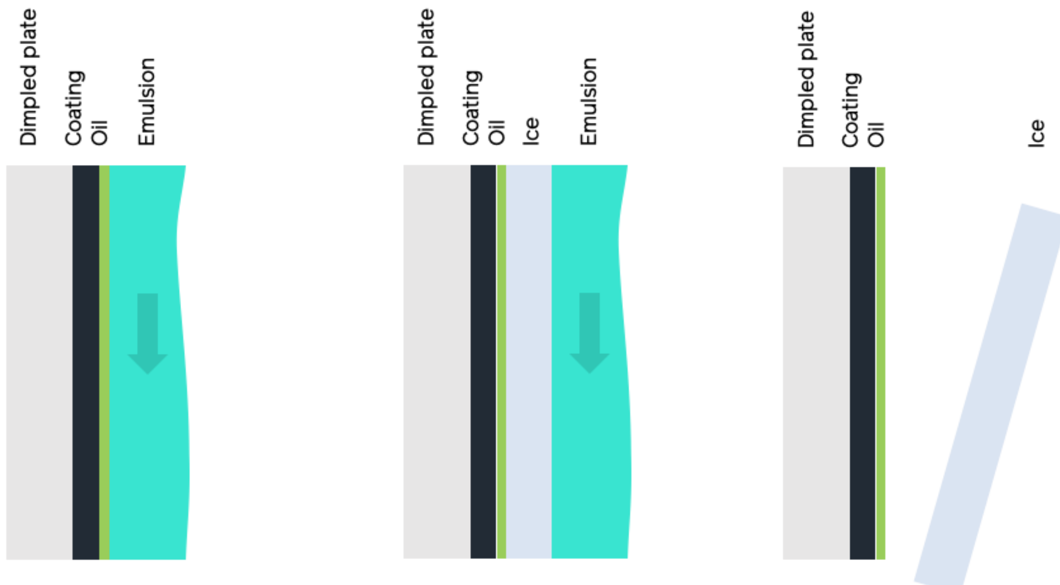
AEX represents a dramatic change in the cost and value of thermal energy storage, but it requires us to rethink datacenter performance. While hyperscalers have been minimizing annual PUE over the past 20 years, the electrical grid has undergone dramatic changes that no longer reward around-the-clock efficiency, but instead require precision flexibility. As datacenter growth has exploded, installers are finding they have nowhere to interconnect. AEX flips this problem on its head. Instead of being an impossible-to-integrate grid burden, data centers become the most flexible loads on the grid. **AEX is the pivotal keystone technology that unlocks a systematic approach, where data centers become cash-positive grid assets that stabilize the grid, reduce renewable energy curtailment, and can be sited anywhere with instant grid connection.**

APPENDIX
AEX PRODUCT BACKGROUND: ICE MAKER PHYSICS

All ice makers, regardless of design, function under a fundamental constraint: as ice grows on any surface it inherently inhibits heat transfer through that surface. This constraint drives the cost, efficiency, and reliability of all modern ice makers. Despite a great need for energy storage and the significant advantages ice storage enjoys, these tradeoffs have not yet been effectively optimized. This is evident in the universal failure or commercial stagnation in the market development of ice-based energy storage efforts[6,7,8,9].

AEX PRODUCT BACKGROUND: REBOUND'S APPROACH

Rebound has developed a novel approach to ice making that charts a new course through these constraints to realize a machine capable of producing higher quality ice at 5X lower costs than traditional approaches. Importantly, this ice maker uses 100% off the shelf process equipment and can be produced at scale without massive investment in new product development or new manufacturing processes.



Step 1: Coating

An oil-water emulsion flows over a coated dimpled plate. The oleophilic coating draws oil out of the emulsion to form a self-healing submicron oil layer on the plate.

Step 2: Growth

Ice begins to grow on the plate trapping the oil between the ice and plate. Pure ice, free of oil, continues to form out of the emulsion.

Step 3: Harvest

The flow of emulsion is curtailed while refrigerant continues to cool the dimpled plate. The temperature drops, subcooling the ice and creating a thermal expansion driven strain between the ice and plate causing the ice to fall off.

Figure 5: the growth-harvest cycle of Rebound's ice maker

[6] Ice energy files for bankruptcy: https://bit.ly/47XjfAV
[7] BAC has moved away from their ice storage product: https://bit.ly/3v1UxAY
[8] CALMAC sells to Trane after 70 years of tepid growth: https://bit.ly/3TtWDUm
[9] Axiom Exergy Fails to commercialize ice storage and pivots to software only: https://bit.ly/3Ntkf7W

Fundamentally, AEX is a plate ice maker which goes through a typical growth harvest cycle: ice grows on the cold plate then is harvested when it reaches a desired thickness. However, unlike a traditional plate ice maker, AEX harvests using subcooling instead of heating, which leads it to harvest significantly faster without any loses even when ice is grown in thin sheets. This is accomplished by paring a chemically matched plate coating and an oil dopant in the water that creates an ideal surface chemistry for ice making. Figure 5 shows the basic process.

By controlling surface chemistry with a thin liquid film (1um thickness) over a solid coating, a robust self-healing layer is created that dramatically improves the overall ice maker performance. This configuration leads to several key benefits of AEX over the state of the art:

1. Thinner ice can be grown and harvested without loss.
2. Subcooled 100% solid ice is produced.
3. Harvest is rapid, leading to a 90% reduction is wasted time.
4. Plate temperatures are (relatively) high, leading to higher efficiency.
5. No mechanical harvesting techniques are required, the only moving part that is used is a mag-drive water pump.
6. Off-the-shelf dimpled plates mean the ice maker is infinitely scalable today.

The system is ideal for large energy storage applications because it is highly scalable. Like traditional plate ice makers that sit over a large water/ice tank, the plates can be arranged above an emulsion tank where the movement of the water by a centrifugal pump creates the emulsion required for the plates. In this configuration a single tank of water can be slowly converted to ice to store cooling for HVAC applications, turbine inlet cooling, or other industrial processes that require intermittent high levels of cooling. This system has one moving part, a mag-drive centrifugal water pump.

Rebound has built multiple full-scale units, generated millions of pounds of ice, and stored that ice for days at a time. This body of work has demonstrated several key performance and reliability features of this technology for use in thermal storage markets:

1. 100% dry subcooled ice production at -5°C and -10°C refrigerant temperature
2. Self-healing active coating with infinite life
3. Greater than 12 hours of continuous operation without defrost or plate heating of any kind
4. Rapid ice harvesting of <1min without ice loss
5. Ice storage in a simple fiberglass tank without re-solidification or “iceberging” for 1-5 days
6. Powder coating robustness through thermal cycles, incidental mechanical contact, and >10k ice harvests.

Table 1 shows the significant improvement AEX represents over the state of the art. Of note, all these systems use nearly identical off-the-shelf components and manufacturing techniques. The only additional step required to manufacture an AEX is the powder coating of the plates prior to the system assembly. This step is accomplished by a mature coating process performed by many coaters across North America and adds <5% to the cost of the ice maker.

Table 2: Comparison of Rebound's ice maker with a traditional thermally harvested plate and ice-on-coil ice maker

	Typical Ice-On-Coil System	Typical Plate Ice Maker	AEX
Harvest method	direct flow	hot gas	subcooling
Ice Lost in harvest	0%	10-20%	0%
Growth time [min]	multi-hour	>15	6
Harvest time [min]	multi-hour	5	1
Ice Thickness [in]	>6in	>1/2"	<1/4"
Suction temp [°C/°F]	-30°C (-22°F)	-18°C (0°F)	-7°C (20°F)
Overall heat transfer [kW/m^2-K]	0.04	0.2	0.5
Levelized Capex [$/(lb/day)]	$50	$20	$5