NORTEK DATA CENTER COOLING

Finding Sustainable Solutions

to Data Center Power and Water Use

AT A GLANCE

- How to protect data centers from peak pPUE and WUE without using expensive TCO oversized equipment designs.
- Using liquid cooling equipment with the lowest PUE and WUE can protect against natural resource depletion.
- As data center hall design temperatures rise, indirect evaporative liquid cooling technology rise in popularity.

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The data center industry is changing at a rapid rate propagated by emerging trends toward artificial intelligence (AI), gaming, autonomous automobiles, the Internet of Things (IoT), 3D graphics and other technologies that generate high rack heat densities.

These changes are bringing power and water sustainability to the forefront as data centers scramble to find cooling technologies to offset the unprecedented rise in computing loads.

Consequently, this rush to sustainability is driven by several factors:

- The data center industry wants to avoid potential expansion restrictions imposed by government agencies that might consider facility power and water usage excessive;
- The planet's finite power and water supplies are also driving data center operators to the most innovative and effective cooling technologies with the industry's lowest power usage effectiveness (PUE) and water usage effectiveness (WUE) See Illustration A (on page 2);
- The need to find the most sustainable balance between power and water utilization given a particular site's local resource constraints.

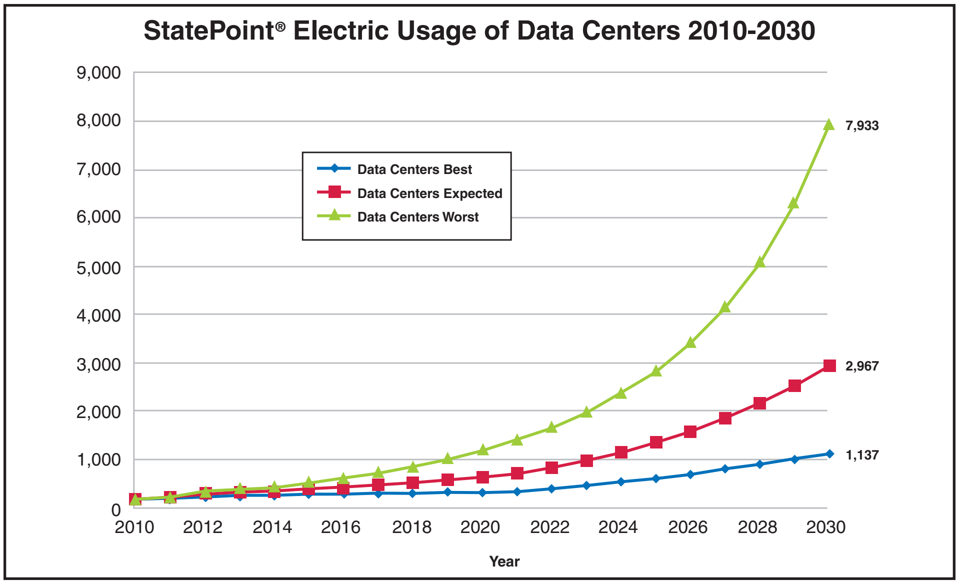


Illustration A: Electricity usage of data centers could potentially reach 7,933-TWh by year 2030, which demonstrates the need for facility owners to employ sustainability measures now. (Source: researchgate.net.)

Trending Operating Parameters for Greater Sustainability

A majority of today's data center chilled water cooling systems still rely on proven, but old-school, chiller and cooling tower equipment that are comparably less efficient and sustainable than today's newly-emerging technologies. Fifteen years ago that technology was state-of-the-art because data halls were commonly kept between 20° to 25°C (68° To 77°F). Furthermore, operators weren't as concerned with efficiency and sustainability as they are today. That technology can still handle today's exponential growth in server rack heat density, but it comes with wasteful power and water consumption.

Consequently, today's data center operators are moving toward several trending operating parameters for greater sustainability:

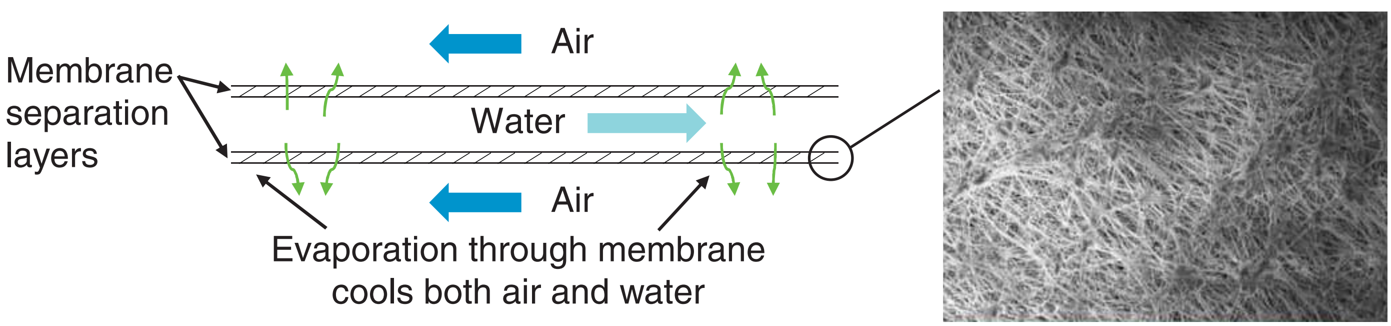
- Allowances of data hall temperature excursions during extreme ambient conditions. Typically, there are very few hours during server operating life in which this would be required; therefore, it would have a negligible impact on server reliability. But the allowance of a couple of degrees higher supply air temperature (SAT) during extreme conditions greatly reduces the need for power- and water-intensive, chiller-based cooling and allows a broader application of free cooling technologies;
- Maintaining higher data hall temperatures, which expands the potential for free cooling, as opposed to chiller-based cooling;
- Using equipment available today that can seamlessly switch its primary resource between water and power utilization, depending on which is more plentiful and readily accessible at a given time;
- Heat recovery, water reclamation and renewable energy are technologies being incorporated into data center cooling[1].

The Path to Sustainability: the StatePoint® Liquid Cooling System

Nortek Data Center Cooling has developed a new free cooling solution called the StatePoint Liquid Cooling system[2]. StatePoint is a chilled water alternative to old-school cooling methodologies, such as water-cooled or air-cooled chillers, fluid coolers and even conventional direct evaporative cooling. Instead of wetted media, direct spray and other traditional evaporative cooling methods that often consume large amounts of water, this patented indirect evaporative cooling method uses a liquid-to-air membrane exchanger strategy that has never before been commercialized in the HVAC industry.

The Path to Sustainability: the StatePoint® Liquid Cooling System continued

Illustration 1: The StatePoint Liquid Cooling system is one of the world's most sustainable data center cooling technologies. (Source: Nortek Data Center Cooling)



Multiple patents awarded or pending

Illustration 2: The StatePoint Membrane Exchanger (SPEX) helps the StatePoint reach unprecedented sustainability. (Photo credit: Nortek Data Center Cooling.)

Consequently, the entire StatePoint cooling system is capable of 1.05 to 1.06 pPUE in 100% free cooling applications. If fan coil wall energy is subtracted, the StatePoint's pPUE alone can drop between an unprecedented 1.025 and 1.03, depending on the climate, operating conditions and equipment. Annualized WUE (L/kWh) can be less than 0.1, depending on the climate.

StatePoint has surpassed its early goals since development began in 2015. Initial efforts were aimed at reducing annual water and power consumption by 20 to 30-percent over the industry's most prevalent method of traditional chiller/cooling tower systems. However, depending on the climate and the technology type it is compared with, StatePoint has the potential for annual water and power reductions of up to 90-percent and 60-percent, respectively.

What Makes StatePoint® So Sustainable?

From a power perspective, reducing and, in some cases, eliminating energy-intensive century-old vapor compression or compressor-based methodology from the chilled water process is responsible for a majority of StatePoint's power cost savings. This also contributes to refrigerant reduction, which is an environmental stewardship goal of the data center industry. Refrigerant reduction solves a host of sustainability challenges, such as the global warming potential (GWP) of refrigerant leakage, maintenance liabilities, governmental regulations, general cost of ownership, and of course, energy costs. Trim chiller cooling can be added to StatePoint designs if hot, humid days challenge chilled water temperature capabilities. However, the trim chillers are supplemental for extreme peak conditions only, thus they're significantly downsized compared to 100-percent chiller operations. They typically operate only a small portion of the year.

From a water perspective, StatePoint's membrane exchanger (See Illustration 3) also solves many problems for the industry. It eliminates the direct contact of water with the air, which usually pollutes the water with dust, pollen and other contaminants that can cause fouling, sludge and accelerated microbial growth. Older indirect and direct evaporative technologies, where water is excessively contaminated by air contact, typically need maintenance-intensive and costly water treatment equipment. This fouled water must be kept isolated in a condenser water circuit or to the cooler sump, which requires frequent cleaning of scale and sludge buildup. The StatePoint membrane exchanger maintains a high level of water cleanliness, which allows the evaporative cooled water to be used directly in the primary chilled water circuit. This improves efficiency and cuts maintenance costs.

The separation of air and water also prevents the air from picking up droplets and aerosol carryover from the water side, which leads to increased water consumption in conventional cooling tower designs and the biohazard potential of Legionella.

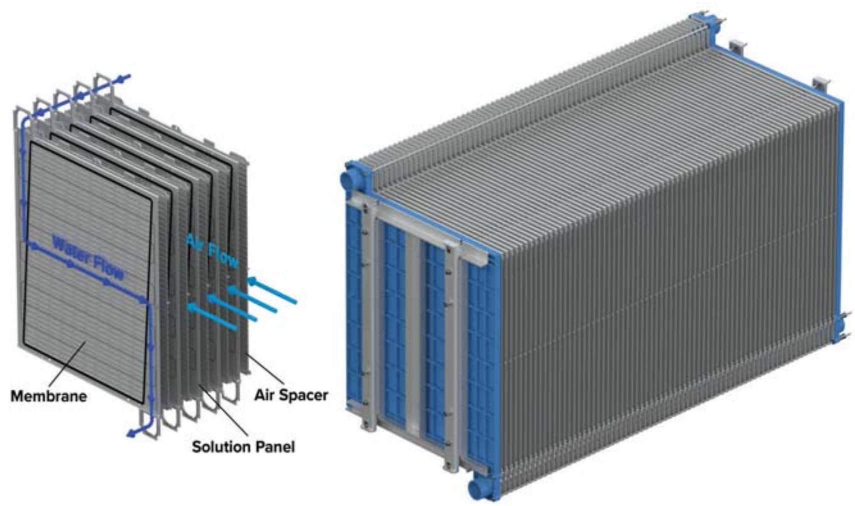


Illustration 3: The Statepoint Liquid Cooling system uses patented microporous membranes to separate water from air during thermal exchanges. The left image is an enlargement of one section of the StatePoint Membrane Exchanger (SPEX) on the right. (Source: Nortek Data Center Cooling)

Case Study of a Frankfurt, Germany Data Center

One StatePoint application case study is a 20MW colocation data center in Frankfurt, Germany, that uses 12 StatePoint units at N+2 redundancy. Illustration 4 details the relationship between SAT and cooling system efficiency. The facility's design engineers used modeling data from three types of cooling technologies: 1) a hybrid fluid cooler system; 2) an open cooling tower system; and 3) a StatePoint system. All of these systems used trim chillers for peak conditions. As the SAT is allowed to climb from 23 to 29°C (73 to 84°F), both the pPUE and WUE achieve significantly more efficient levels.

Case Study of a Frankfurt, Germany Data Center continued

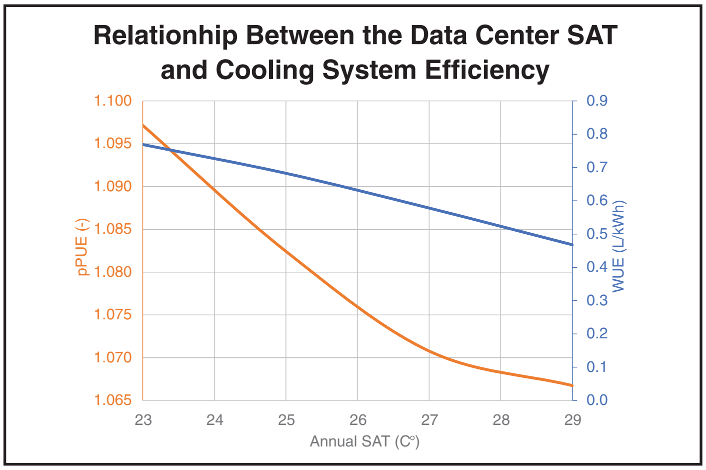


Illustration 4: The Frankfurt, Germany case study demonstrates higher supply air temperature (SAT) can result in impressive cooling system efficiency. (Source: Nortek Data Center Cooling)

Designing for Daily Operation, Not Extremes

Oversizing cooling equipment to guarantee it can handle an extreme peak weather condition that might happen only once in 20 or 50 years is wasteful in everyday efficiency and upfront capital costs. Cooling system operating costs could be substantially reduced simply by sizing the equipment for more typical annual extremes and operating loads while using a methodology that can flexibly handle a temperature/humidity excursion for brief periods.

Furthermore, designing for extreme conditions also creates unnecessary capital costs for oversized cooling equipment, excess trim chiller capacity, and enlarged power and water infrastructure.

The solution to these challenges is a system that is sized correctly and operates for efficient routine cooling but is also capable of maintaining cooling capacity during extreme climate conditions at moderately elevated operating temperatures. It is possible to allow server temperatures to rise on a short-term basis, such as during peak climate conditions, with negligible impact on reliability. Server life stress reliability models can be used to define allowable excursion temperatures and durations while maintaining target reliability levels. Allowable excursions of only a few degrees and for a small number of hours during the server lifespan can have a large impact on the cooling system design as shown in Illustration 5.

Cutting cooling equipment power usage also allows more data center power reallocation for IT equipment load increases. This enhances the data center's value and capacity.

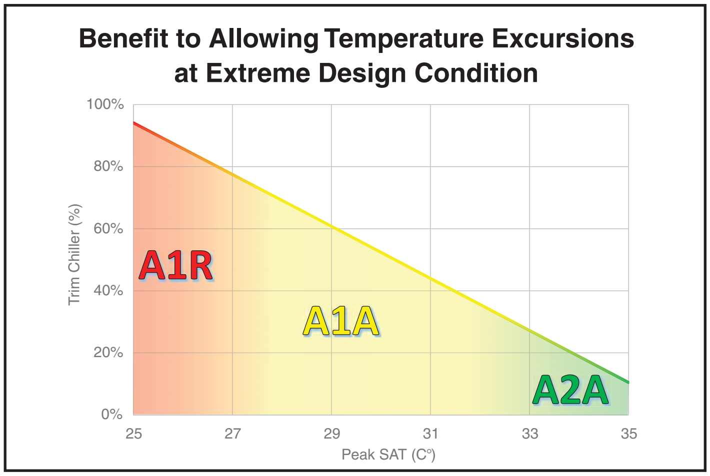


Illustration 5: There's a benefit to allowing temperature excursions at extreme design condition. The Frankfurt, Germany case study demonstrates the peak design condition is based on ASHRAE N50 dry bulb of 39.1°C (102°F) coincident with N20 wet-bulb 23.9°C (73°F), which is extremely unlikely to occur. If the data center allowed SAT in ASHRAE A1 allowable or A2 allowable at this extreme condition, they could greatly reduce the amount of trim chiller required, among other pieces of support equipment. (Source: Nortek Data Center Cooling)

Pinpointing Temperature Control for Operational Efficiency

Many data center operators don't fully understand the perpetually changing server/temperature relationship. In other words, they're unsure of the highest temperatures servers can endure without affecting lifecycle spans. Consequently, data center managers wastefully operate data halls at lower temperatures than needed to ensure reliability.

The main barrier is getting the server design engineers to share server temperature versus reliability models to enable cooling equipment optimization.

Typically, cooling system designers receive a strict, conservative continuous operating temperature limit based on those statistics. Consequently, they overdesign the cooling system based on worst-case conditions to offset risk.

StatePoint®'s cutting-edge control system can operate in concert with data center building management systems (BMS) to provide precise operating temperature control and optimal cooling system efficiency while maintaining required IT equipment reliability and life spans.

Higher SAT temperatures could equate to more server wear-and-tear. However, today's trend is toward planned shorter equipment lifecycles due to anticipated technology obsolescence. Server lifecycles were longer a decade ago. Now, they're approaching three to five years as facility operators opt for more powerful and efficient equipment that enters the market every year[3]. Therefore, the higher and more efficient SAT temperatures that are possible with StatePoint typically won't affect the lifecycle of equipment pre-planned with expected quick turnovers.

Accommodating the Trend Toward Higher Temperatures

Ten years ago, data halls were commonly kept at 20 to 25°C (68 to 77°F), but today 32°C (89.6˚F) and higher is the emerging trend. However, higher temperatures are more acceptable today due to improved server design and better data hall hot aisle/cold aisle containment designs.

ASHRAE has established data center temperature classes: Recommended at 18 to 27˚C (64.4 to 80.6˚F), A1 at 15 to 32˚C (59 to 89.6˚F), A2 at 10 to 35˚C (50 to 95˚F), A3 at 5 to 40˚C (41 to 104˚F), and A4 at 5 to 45˚C (41 to 113˚F). Depending on how the economization is implemented in the data center environmental control system, StatePoint can control cold aisle air temperature excursions to within 32°C (90°F) (ASHRAE Class A2 allowable) in most climate regions around the world.

Running at a higher temperature strengthens the case for non-compressor-based chilled water systems such as StatePoint because outdoor conditions can many times be sufficient or at least supplement an evaporative-type cooling mode.

However, outdoor conditions are perpetually fluctuating and aren't always conducive to one type of evaporative cooling. Therefore, another unique feature of the StatePoint system is the multiple operating modes that allow it to react to constantly fluctuating climate conditions. The StatePoint has three fundamental modes: 1) Economizer Mode; 2) Adiabatic Mode; 3) Evaporative Cooling Mode; in addition to several transitional and optional modes. The StatePoint system automatically operates under the most optimally efficient mode in response to the inherent real-time outdoor temperature and humidity levels. Consequently, the StatePoint system can operate in several ways:

1) operate 100-percent with just the dry coil;
2) or partially use the membrane exchanger for pre-cooling that still covers the facility's full IT load with a limited amount of water consumption;
3) or use the dry coil and the membrane exchanger together to share the facility's load. In a hot, humid climate, the StatePoint system may be combined with a trim chiller, for extremely hot and humid days.

All of these modes can be executed within minutes of temperature/humidity fluctuations or power/water availability changes.

StatePoint's ability to switch modes to accommodate a site's water and power availability fluctuations is unprecedented cooling system flexibility. For example, if water sources become rationed during local droughts, the StatePoint system can switch to a reduced water consumption mode, but still remain within the realm of its inherent power and water-conserving design.

Likewise, when the priority is to reduce electrical power consumption, StatePoint can switch to a more power-conserving mode and use additional water for cooling, if available (See Illustration 6).

Accommodating the Trend Toward Higher Temperatures

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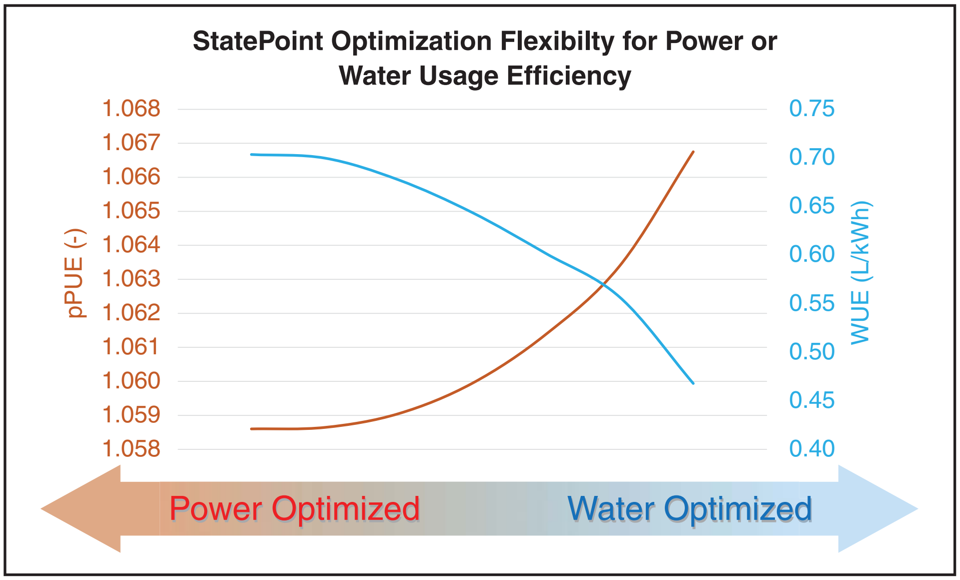


Illustration 6: (Source: Nortek Data Center Cooling)

Solving Temperature Swings

Direct evaporative cooling systems introduce outdoor air directly into the data center hall that can commonly produce temperature swings of up to a 11°C (20°F) variance, resulting in unstable conditions. Furthermore, the relative humidity can fluctuate by up to 70-percent or more. Outdoor air also typically contains pollution, vehicle emissions and other contaminants. This is a difficult challenge for data centers because the combination of fluctuating conditions and environmental pollutants is detrimental to server reliability. The presence of certain types of environmental contaminants, such as airborne salts in marine climates or smoke in regions with frequent wildfires, typically precludes the use of direct evaporative cooling altogether.

StatePoint®'s indirect evaporative technology offers a more stable and protected operating environment for servers, because it's not dependent on direct outdoor air. An indirect evaporative cooling system separates outdoor and indoor airflows. There's only a chilled water loop between them to execute the heat exchange process of vaporization through the StatePoint's patented membrane exchanger. The indirect cooling layout, in addition to the thermal mass of the chilled water loop, results in precision control capabilities that can maintain tight indoor temperature/humidity tolerances throughout the year with fluctuations of less than ± 1°C (1.8°F), which far surpasses a direct evaporative cooling system's temperature/humidity control capabilities.

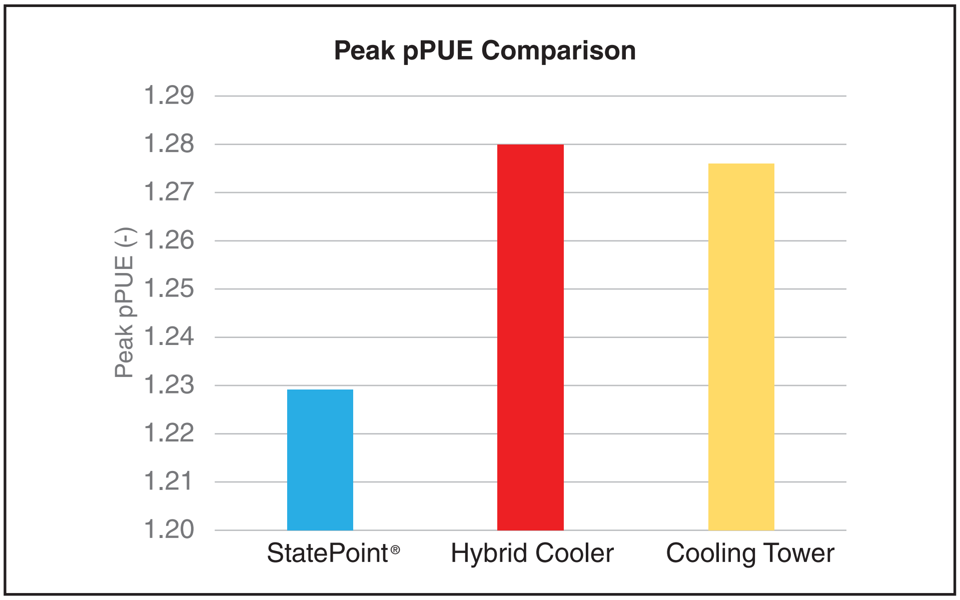
Peak pPUE Comparison

The StatePoint also outperforms conventional liquid cooling equipment during a facility's peak electrical power consumption. This peak pPUE worst-case design scenario includes several factors: 1) full heat mode when all the servers are running at 100-percent load; 2) an ambient temperature/humidity period reaching the ASHRAE 50-year extreme weather conditions; 3) one or two of the StatePoint cooling units are offline for maintenance or repair. The remaining liquid cooling units online must have the ability to cool and hold the data center's temperature to its specified supply air temperature.

In the Frankfurt example, a hybrid or a cooling tower system wouldn't perform as efficiently in power consumption compared to the StatePoint, which was accompanied with approximately 70-percent trim chillers. The StatePoint ran at a 1.23 peak pPUE, while the hybrid cooler and chiller/cooling tower systems ran at 1.28 and 1.275 pPUE, respectively, in order to provide ASHRAE recommended SAT (See Illustration 7).

Requiring 18-percent less power supplied to the cooling system, allows more power for the IT portion of the facility. For every 1,000kW of computer power, an additional 275 - 280kW of electrical power must be provided for the hybrid or cooling tower liquid cooling systems, whereas the StatePoint system only requires 230kW. The additional electrical power raises costs of supply from the grid, equipment installation expense and more infrastructure, such as backup generators and building footprint space to accommodate them.

Peak pPUE Comparison continued



Ilustration 7: Using a Frankfurt colocation as an example, the 1.23 pPUE is the amount of power engineers would need to provide during peak pPUE extreme, versus the higher pPUE of other cooling technologies. The StatePoint® boasts an 18% reduction (Source: Nortek Data Center Cooling)

Peak Water Consumption

Like peak electrical power, data center designers must account for peak water consumption in their cooling equipment designs. The peak instantaneous make-up water flow rate is determined at the extreme design condition, or in some cases an alternate operating scenario that results in the highest evaporation rates. This rate is determined through system modeling during the equipment selection process.

Engineers can save considerable costs because the StatePoint system requires nearly half the flow rates of competing technologies, as shown in (Illustration 8). Using the Frankfurt colocation as an example again, StatePoint's total peak hourly water consumption would be 41- and 6-percent less than a hybrid cooler and a cooling tower system, respectively, during peak conditions.

Consequently, capital expenses are greatly reduced for piping diameters, pump sizes, local utility price and capacity negotiations, and other costs.

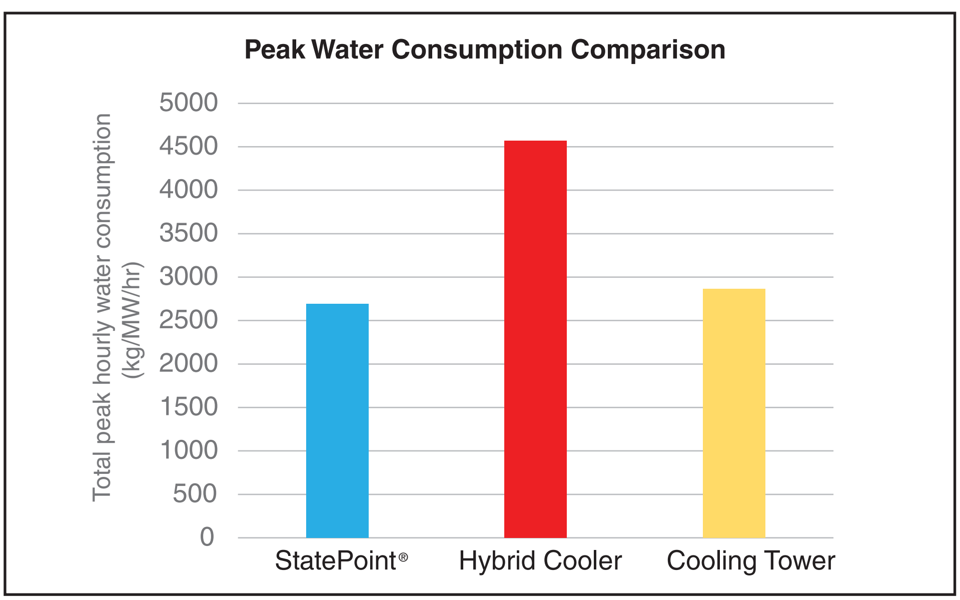


Illustration 8. (Source: Nortek Data Center Cooling)

Reducing Capital Costs and Acreage with Less Water Storage

Many data center sites don't have a reliable water source; therefore, site build-outs must include water storage tanks that are costly in capital investment and consume valuable site acreage when not positioned underground.

StatePoint® can offset this project design liability. Water tank sizing can be based on modeled StatePoint system water consumption. Projected water usage is predicted by calculating StatePoint's worst-case 24-hour water consumption scenario (based on annual climate weather data) with the facility operating at 100-percent load. These predictive calculations can reduce tank sizes by up to 30 percent, based on recent projects such as the Frankfurt application (See Illustration 9).

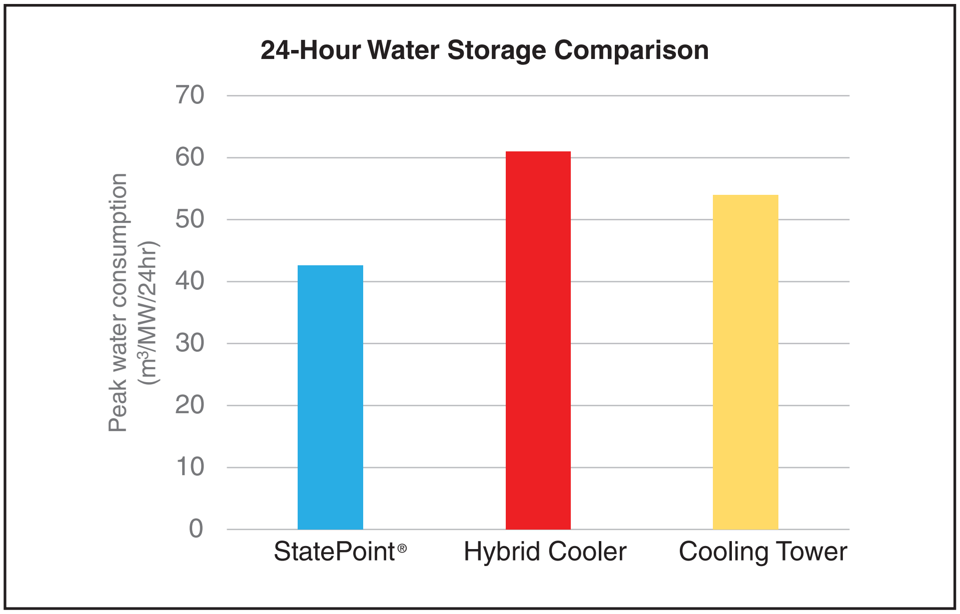


Illustration 9: (Source: Nortek Data Center Cooling)

Incorporating Recovery, Reclamation and Renewables:

StatePoint can provide additional sustainability measures via heat recovery, water reclamation/recycling and renewable energy.

Besides unprecedented efficiency, StatePoint's inherent built-in hydronic loop design easily interfaces with waste heat recovery (See Illustration 10). The rejection of heat from data centers, some of which have more than 1 million square footage of space, can be recovered and reused. Consequently, the data center industry has become a prime target of district energy providers. Instead of exhausting the heat into the atmosphere, server waste heat can be recovered through a heat pump and rejected into a district energy infrastructure. In return, the data center can be paid or receive credits to apply toward its future energy use[4].

Warm 40°C (104°F) data hall return water travels through a heat recovery exchanger and can be rejected into district energy loops for other data center or neighboring building heating applications. There are more than 940 district energy systems currently available in North American cities, communities, campuses, military bases, airports and healthcare complexes[5]. The district energy concept is also popular internationally, especially in the European Union, which actively promotes and encourages it with incentives.

Sending data center waste heat to a district energy system also adds more efficiency to the indirect evaporative cooling system, because heat is rejected externally, which unloads the cooling system and further reduces power and water consumption.

Besides low WUE, another StatePoint advantage is the ability to use reclaimed wastewater, which helps save fresh water for potable applications. For example, data centers in Ashburn, Va. and a Google facility in Atlanta are just two sites currently using reclaimed or recycled wastewater[6].

Microsoft has been even more ambitious. They helped retool the city water treatment infrastructure in Quincy, Wash., to provide recycled water for data center use.

Finally, the StatePoint cooling system is also ideal for wind, solar and other renewable energy technologies. StatePoint's operating electrical power consumption is very low, because it operates with just pumps, fans and controls instead of air or water-cooled chillers that depend on energy-intensive compressors to operate.

Incorporating Recovery, Reclamation and Renewables:

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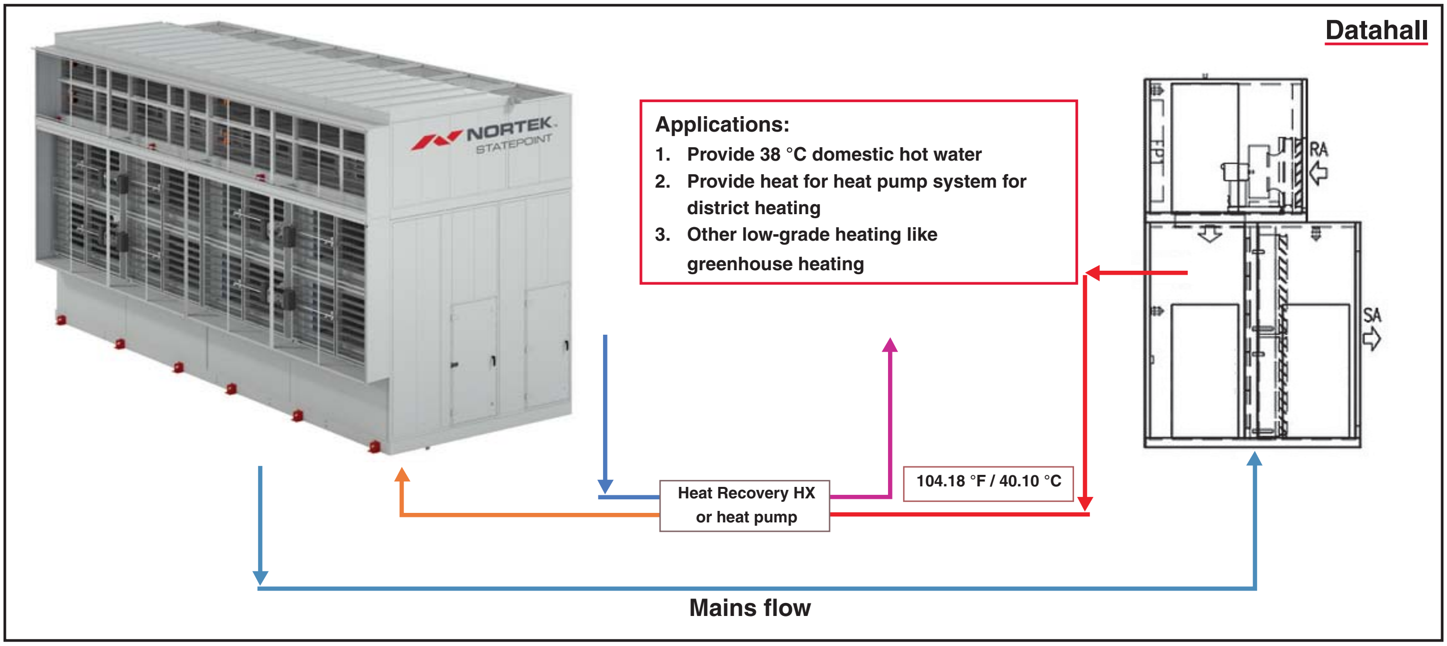
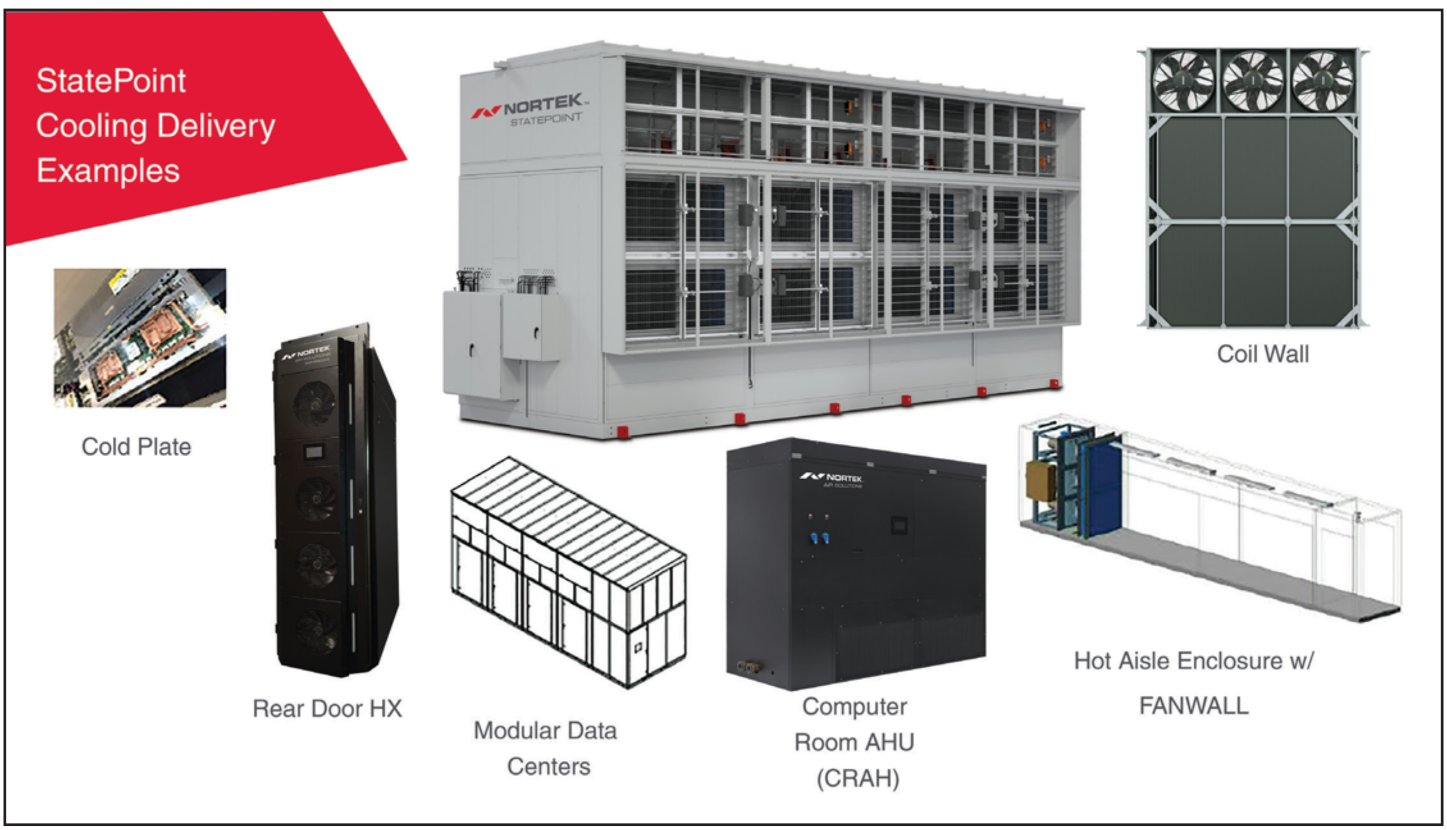


Illustration 10: The design of the StatePoint system makes it a perfect candidate for waste heat recovery to district energy loops or other infrastructures. (Source: Nortek Data Center Cooling)



Incorporating Recovery, Reclamation and Renewables:
continued

New technology such as the StatePoint® indirect evaporative cooling system using membrane exchangers is a breakthrough in sustainability and can be the foundation for a data center's environmental goals. It provides an ideal solution for hyperscale and colocation data center operators that want to be good stewards of the planet's finite resources when they execute plans for new construction and retrofits.

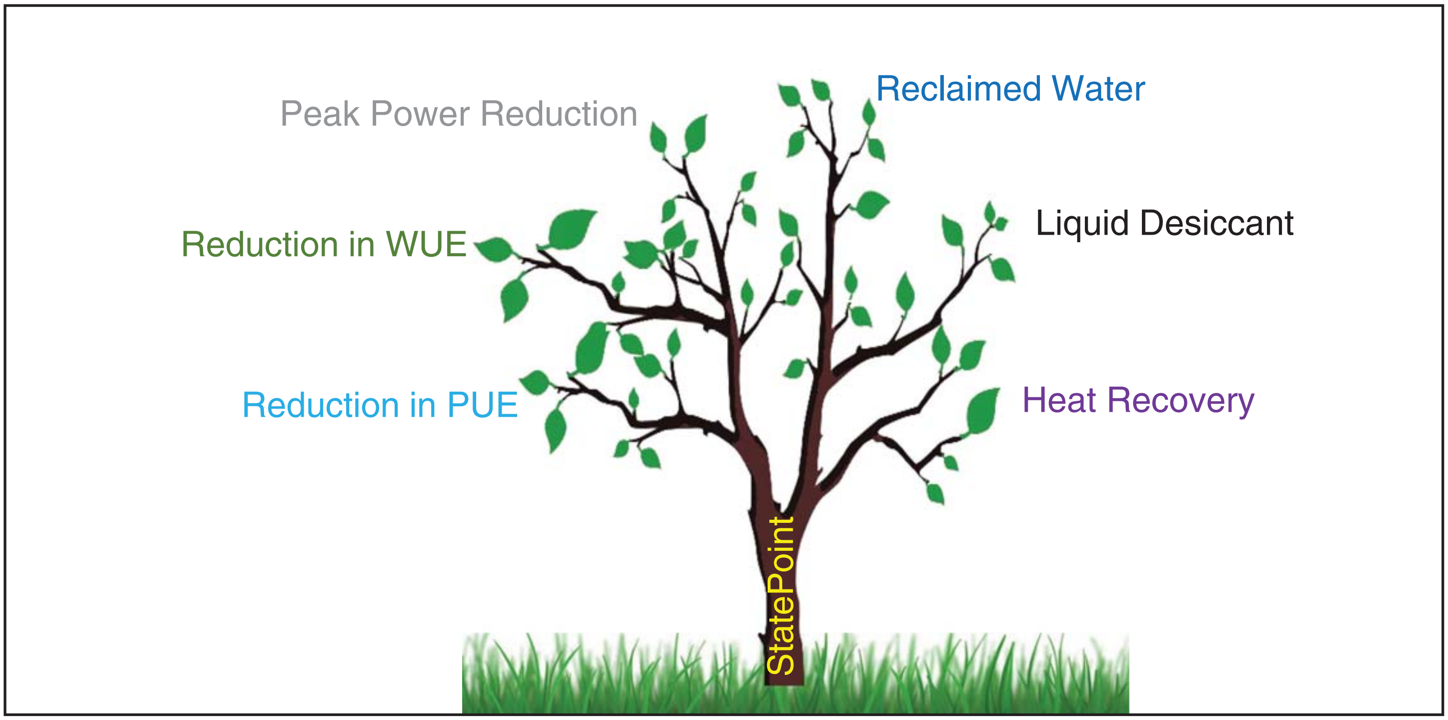


Illustration 12: Data center sustainability requires a multitude of philosophies and methodologies.

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BIO: Pooya Navid has been a mechanical engineer at Nortek Data Center Cooling since 2019. He has an MSc in mechanical engineering from the University of Saskatchewan. He holds a second MSc degree in mechanical engineering with a specialization in energy systems. Since his B.Sc thesis in HVAC systems design in 2008, he has been an active HVAC society member with over 10 years of work experience in the energy sector. His academic and industrial background allows him to understand thermal problems in buildings and offer effective solutions.

References

1) https://datacenterfrontier.com/sustainability-practices-data-center-energy/
2) https://www.contractingbusiness.com/commercial-hvac/press-release/20870526/nortek-air-solutions-selected-for-facebooks-singapore-data-center
3) https://www.proserveit.com/blog/what-is-the-hardware-lifecycle
4) https://datacenterfrontier.com/waste-heat-utilization-data-center-industry/
5) https://www.districtenergy.org/resources/resources/system-maps
6) https://www.datacenterknowledge.com/archives/2013/09/09/ragingwire-ashburn-hooking-up-to-reclaimed-water-loop