NetApp Bangalore Optimizes Data Center Cost Savings Through "Free" Outside Air Cooling

OVERVIEW

Organization & Data Center Background

NetApp, Inc., is a hybrid cloud data services and data management company headquartered in Sunnyvale, California. NetApp has five data centers (Sunnyvale, CA; Durham, NC; Boulder, CO; Amsterdam; and Bangalore). In concentrating on data center design and operation, NetApp has deployed innovative energy-saving measures that make each data center unique as an industry model.

PROJECT INFORMATION

Project Summary

NetApp's Bangalore campus is 15 acres (60,703 sq. meter), the largest outside of the U.S. A single building houses an R&D lab, offices, and a data center. The building is comprised of 11 floors above ground and three underground. The data center occupies 1,200 of the 100,000 total square meters of floor space yet consumes the majority of energy. About 2,500 employees work on the campus, which began operating in 2017. The facility has a contracted demand from the utility of 4,000 kVA. This contract demand will increase as the data center load increases. Currently, the data center operates at 23% of its design IT capacity, i.e., the data center's operational IT load is 0.96 MW versus a 4.26 MW design load.

Project Highlights

- *Utilization of "free" outside air cooling to optimize cooling system (designed for 20% full free cooling and 78% partial free cooling).*
- *When fully cooled by outside air, the data center PUE is lowest (lowest monthly PUE was 1.35), demonstrating the opportunity for significant energy and cost savings in moderate Indian climates.*
- *Independent chiller plant operates at elevated temperatures to cool data center.*
- *Flywheel-based rotary UPS for increased resource efficiency (investment, elimination of batteries, hazardous waste, etc.).*
- *Stacking of air-handling and power distribution units to reduce costs and non- IT losses.*

This data center is one of the first in India to use an outside air economizer for "free" cooling and a Diesel Rotary Uninterrupted Power Supply (DRUPS). Further, the designers stacked the air handling and power delivery systems vertically above the data center for shorter air and power pathways, thus reducing construction cost, space and distribution losses. These innovations make the data center design unique and energy efficient.

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The project’s focus on clean and efficient energy includes an onsite solar photovoltaic (PV) system as well as offsite renewables (wind & mini hydro). The solar PVs (116 kW peak) cover the entire roof area. Offsite green power further reduces the facility’s carbon footprint. Currently, renewable sources supply more than 75% of the facility’s annual electricity, yielding a significant cost benefit.

NetApp doesn’t stop at the data center in their quest for innovative solutions. For example, the building’s lighting is a Power over Ethernet (PoE) system that optimizes energy use and visual comfort. The PoE-based lighting and control system is an emerging technology with few global examples, and it is being showcased in the Bangalore facility.

Table 1 lists the design and operational parameters with regard to IT load, cooling, UPS, total energy use, and PUE for the NetApp-Bangalore data center. Even at partial load, the data center has demonstrated good performance. Figure 1 and 2 depict the NetApp-Bangalore campus and white space (server hall).

Table 1. Design and operational parameters

Facility Characteristics	***Description***	
IT Load	*4.26 MW Design (up to 8 kW/rack)*	*0.96 MW Operational*
Cooling System Specification	*Dedicated cooling system for data center (1 x 500-ton water- cooled chiller) with shared backup (700-ton).*	
UPS Capacity	*4 x 2,000 kVA, scalable to 6 x 2,000 kVA*	
Total Annual Energy Use	*11,953 MWh (Data Center)*	
Annual PUE	*1.30 (Design)*	*1.42 (Operational)*

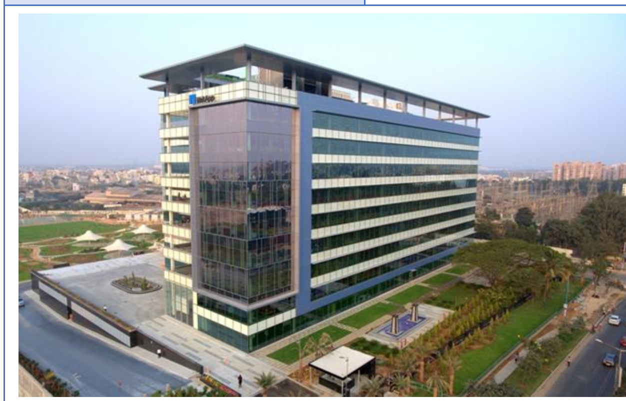

Figure 1. NetApp Bangalore campus, including lab and data center

Figure 2. Data center server floor with air containment system

The data center is designed to accommodate 532 racks, with a maximum rack capacity of 8 kW. The server hall is maintained at 23.5°C.

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The following key energy efficiency technologies were adopted for enhanced performance:

Vertical stack configuration of AHU and power delivery systems

The verical stack configration of the data center helps in reducing the cooling load and increases energy efficiency through shorter air and power delivery paths and also reduces the requirements for ducting, piping, cabling etc.

Flywheel-based rotary UPSs

The flywheel-based energy storage and UPS system coupled with a diesel engine provides higher efficiency than a standard UPS and saves space.

Free air cooling

Outdoor 'free air' is used to cool the data center without the use of chillers. An air-side economizer uses cool ambient air to maintain the required temperature inside the server hall when temperatures are suitable.

Integrated Building Management System (iBMS)

NetApp's integrated Building Management System (iBMS) enables the energy monitoring system to capture real-time performance and optimizes operations for low PUE.

Aisle containment for air management

Automated access-control doors provide security and energy efficiency through cold-aisle containment that elimiates air leakages and prevents mixing of cool with warm air.

DESIGN AND IMPLEMENTATION OF INNOVATIVE MEASURES

Vertical stack configuration of air-handling units (AHU) and power delivery system

NetApp stacked air handling units (AHUs) and power delivery systems vertically, which reduced overall construction cost and enhanced energy efficiency. In a vertical stack configuration, mechanical and electrical system components are installed directly above the data center server hall (as shown in Figure 3), shortening the distribution runs and therefore reducing losses in energy as well as the cost of the infrastructure. The vertical stack construction reduces the length and costs of piping, cables and associated materials, such as insulation, etc.

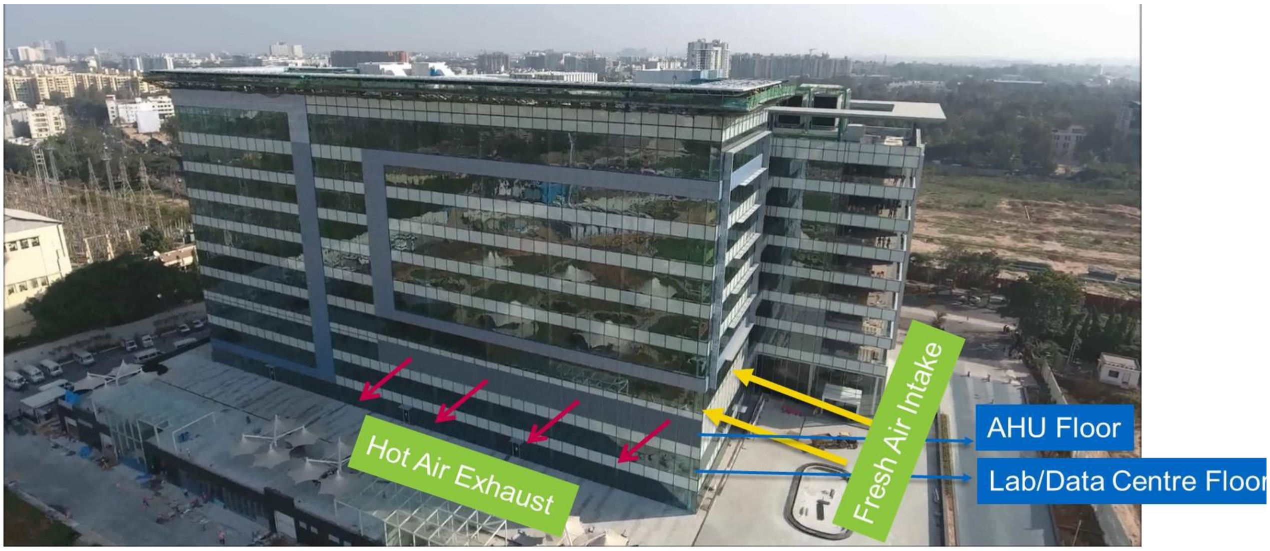


Figure 3. Vertical stack configuration of the data center showing air handling unit and power delivery systems on the floor right above the data center floor

Figure 4 shows the fresh air intake and exhaust in the floor above the server hall. Figure 5 shows airflow vents between the AHU floor and the server hall.

Figure 4. Fresh air intake and exhaust through motorized dampers. Both the intake and exhaust are directly above the server hall.

Figure 5. Air flows through vents next to the air-handling units, providing shorter air cycles and higher efficiency.

Rotary (Flywheel) UPS

The NetApp-Bangalore data center has installed a diesel rotary UPS (DRUPS) with a capacity of 4 x 2,000 kVA (8,000 kVA total). NetApp has found that the rotary UPS or flywheel has less loss (higher efficiency) and other benefits over conventional static UPS systems. The DRUPS utilizes a rotating motor-generator, which conditions the power and provides on-demand storage to protect the critical loads. The most common design is a diesel engine coupled to a rotary UPS in which the motor-generator and short-duration flywheel are mechanically attached. The flywheel eliminates the use of a battery bank, which also saves capital and operating cost. DRUPS systems have other benefits including:

- High efficiency: According to NetApp, the integrated flywheel UPS has an efficiency up to 96.5%.
- No compressor-based cooling: Conventional static UPS battery systems need to be cooled to maintain efficiency. The DRUPS system can operate in an environment of up to 40°C without degradation in performance. This high-temperature capability provides a longer life and lower O&M costs compared to battery storage systems.
- Lower conditioned space requirements: A DRUPS system saves conditioned space normally required for battery banks. This space can be used for other purposes including greater IT capacity.
- Reduced environmental impacts: No worry about replacement, recycling, and disposal of batteries.

Figure 6 shows the rotary UPS installed at NetApp-Bangalore campus.

Figure 6. Rotary UPS systems installed at NetApp-Bangalore data center. The system has a built-in flywheel for energy storage and supply.

Power for the entire campus flows through the NetApp DRUPS system, but the unused power capacity in the data center results in low loading. Efficiency falls off at low loads, so that the DRUPS efficiency for now is about 90%. With increases in the data center load, efficiency of the DRUPS system should increase to the target values.

Further, the UPS is coupled with an IP (integrated parallel, also known as isolated parallel) bus configuration. Each UPS serves a load, and each of these loads is connected to a parallel bus through an inductor (or "choke") that integrates all of the UPS units so they can share the total load. The chokes also isolate the individual load/UPS pairs from each other, which limits potential short circuiting and protects affected loads in case of a failure. Typical data centers with A and B feeds for all server loads have double the required UPS capacity (i.e., N+N UPS capacity) since the A and B feeds are carried upstream to at least the UPS. However, with an IP bus, NetApp can achieve greater reliability and maintain dual sources in the IT equipment with just an N+1 UPS configuration. There will be current flow (and some energy loss) in the chokes whenever the loads are unbalanced, but the ability to reduce the redundancy means the UPS loading is higher and overall efficiency improved. Fewer UPS units also means lower capital expenditure for equipment and space.

Air Cooling

The NetApp-Bangalore data center uses “free” outside air cooling during favorable ambient conditions when the outdoor air temperature is below 23°C and outdoor relative humidity is lower than 80%. The air filtration system consists of two sets of synthetic air filters at the fresh air intake that filter particles below 10 microns. An air-side economizer with proper primary and secondary filtration enables confidence in the use of outdoor air to cool IT hardware. NetApp has experienced no increase in hardware failures since using outside air cooling in India and their other global data centers. The air-side economizer is completely automated and can operate in four modes: 100% free cooling, free cooling with mixing, partial free cooling, or 100% chilled water-based mechanical cooling. The data center was designed to operate in the full free cooling mode about 20% of the time and about 78% of the time with partial free cooling. The remaining 2% of the time was to be entirely cooled by the chiller system with no free cooling. Table 2 shows the modes of operations.

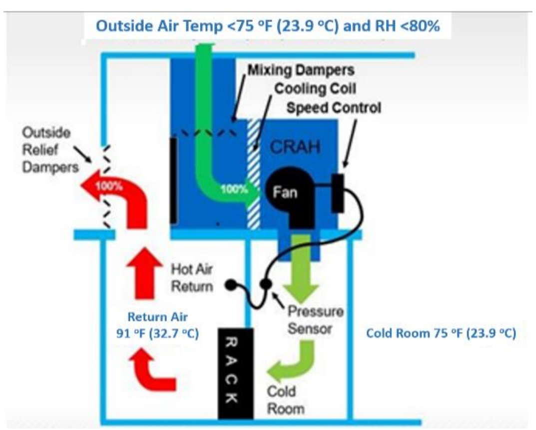
Table 2. Modes of operations: free cooling (with and without mixing), partial free cooling and mechanical cooling

Mode of operation	***Ambient Environmental Conditions***	***Working Principle***
100% free cooling	*< 23.9 °C (75 °F) & RH % < 80*	• *Fresh air damper opens: 100%* • *Return air damper closed 100%* • *100% fresh air intake & return exhaust* • *Chillers: OFF*
Free cooling with mixing mode	*< 23.9 °C (75 °F) & RH % > 80*	• *Fresh air & return air dampers are open partially* • *Return air is mixed with fresh air to achieve RH less than 80%* • *Chiller OFF*
Partial free cooling	*> 23.9 °C (75 °F) & < 32.7 °C (91 °F)*	• *Fresh air damper open and return air damper closed* • *Chillers ON: Partial cooling mode*
Mechanical cooling	*> 32.7 °C (91 °F)*	• *Fresh air damper closed* • *Return air damper completely open* • *100% air being recirculated* • *Chillers ON*

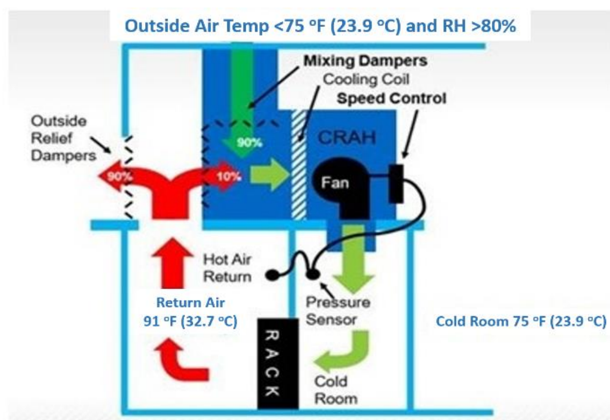
Four Cooling Modes:

1. 100% free cooling: When the ambient air temperature is less than 23.9°C (75°F) and the RH is less than 80%, the fresh air dampers open 100% and the return air dampers close 100%, resulting in 100% fresh air intake and return exhaust. The chillers are off.
2. Free cooling with return air mixing: When the ambient air temperature is less than 23.9°C (75°F) and the RH is more than 80%, the fresh air and return air dampers are partially open. The return air is partially mixed with the fresh air to achieve a RH less than 80% and a supply air temperature less than 23.9°C (75°F). The chillers are off.
3. Partial free cooling: When the ambient air temperature is more than 23.9°C (75°F) and less than 32.7°C (91°F), irrespective of RH, the fresh air dampers are open and the return air dampers are closed. The chiller fed coil cools the air to 23.9°C (75°F) and the system operates at partial free cooling. In this mode, the chiller is providing only part of load (for example, 30%).
4. Mechanical cooling: When the ambient air temperature is more than 32.7°C (91°F), the fresh air dampers are closed and the return air dampers are completely open resulting in 100% of the return air recirculated. The chiller is fully on, providing 100% of the load.

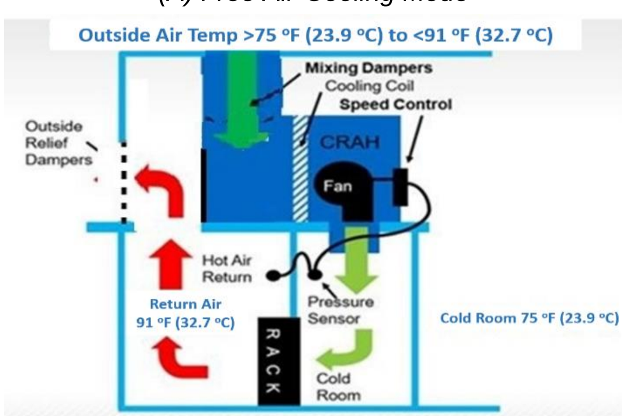
Figure 7 shows the four modes of cooling. When the data center operates on free cooling, its operational PUE is lowest (e.g.,1.35 to 1.38 monthly PUE). The NetApp data center demonstrates opportunities to utilize free air cooling and achieve significant operational cost savings in Indian data centers, at least in moderate climates.



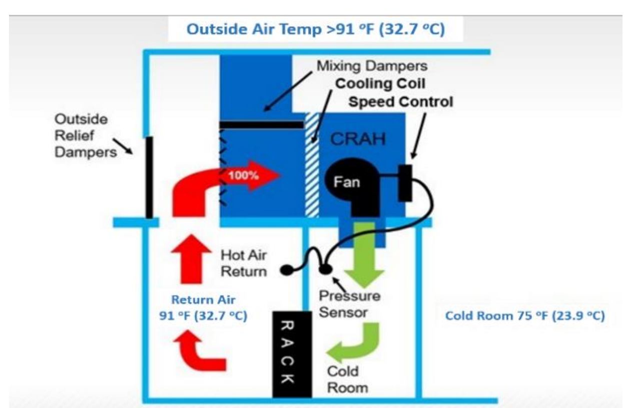
(A) Free Air-Cooling Mode



(B) Free Cooling with Mixing Mode



(C) Partial Free Cooling Mode



(D) Mechanical Cooling Mode

Figure 7. 100% free cooling (A), free cooling with mixing (B), partial free cooling (C) and 100% chiller cooling (D)

Energy performance of the air-side economizer has not met expectation with the hours of free cooling substantially under what was expected. While this can be partially explained by abnormal weather, there may be an opportunity for control optimization and retro-commissioning. Furthermore, Recent-vintage servers can operate within a wide range of temperatures (to more than 35ºC) and humidity (to 90%). Therefore, the NetApp data center may be able to operate at higher temperatures and humidity, which could allow for more hours of full free and partial cooling, more in line with the design targets. This can be done in small steps (e.g., 0.5°C) to ensure no ill effects, and could provide significant benefits.

The NetApp-Bangalore data center takes advantage of another important cooling efficiency opportunity. It is served by a dedicated chiller that operates at 17°C (63°F). At this warm non-condensing temperature, the chiller is much more efficient than typical chillers used to cool and dehumidify offices and other commercial spaces.

Integrated Building Management System (iBMS)

The integrated BMS monitors the building as well as the IT systems. IT equipment power is recorded hourly along with building systems and components. For example, total cooling energy is recorded along with energy for each of the different cooling modes. Equipment efficiency levels are measured, as is the overall PUE. Figure 8 showcases the cloud-based iBMS user interface and overall facility performance.

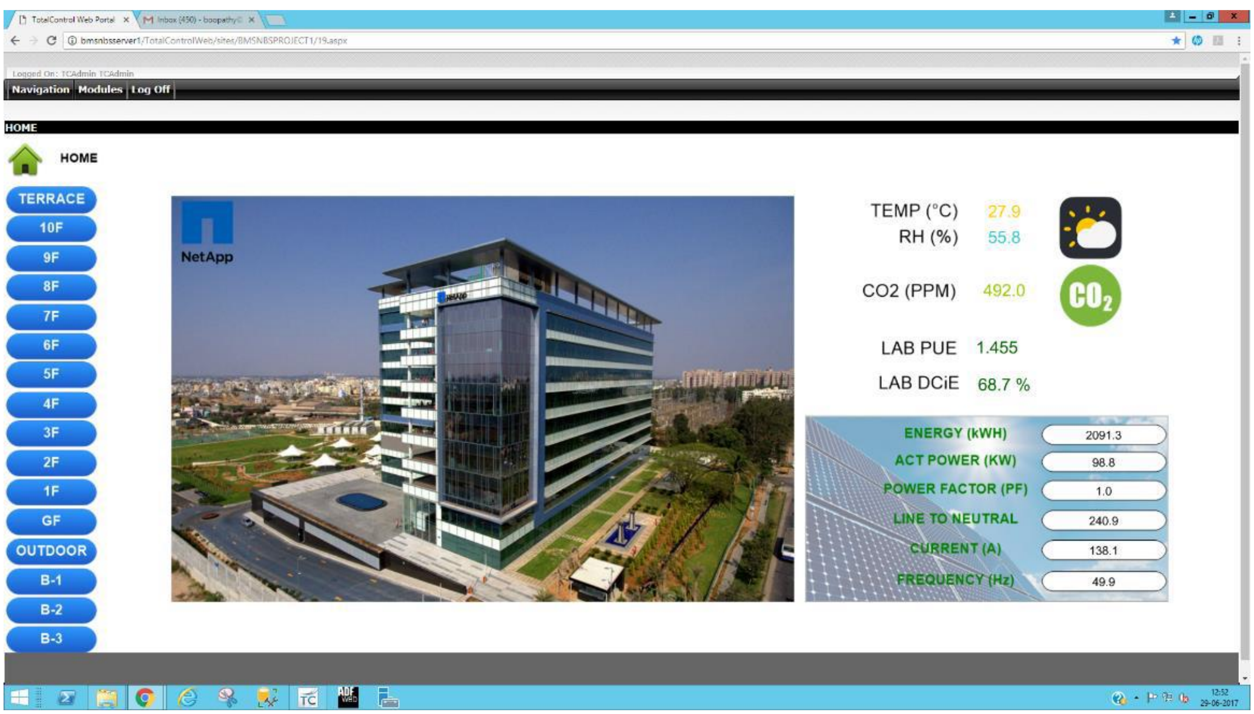


Figure 8. The user interface of the cloud-based iBMS enables the operations team to closely monitor the performance of the data center.

Air Management

The data center features good air management with cold-air containment, judicious use of blanking panels, and a containment system with automated access-control doors at both ends. Airflow is regulated based on the temperature settings. AHUs right above the server hall supply cold air to the “cold” aisles that then passes through the racks, cooling the IT hardware. Air from the hot aisle is exhausted to the outside or returned to the data center via the AHUs based on the mode of operation (100% free air cooling, partial free air cooling, or cooling with the chilled water system only).

PROJECT PERFORMANCE

Project Results & Benefits: Design and Operational Performance

Figure 9 shows the breakdown of the annual energy consumption. The data indicate that less than 30% of the energy is utilized for cooling, UPS, and lighting, yielding an efficient data center with an annual PUE of 1.42.

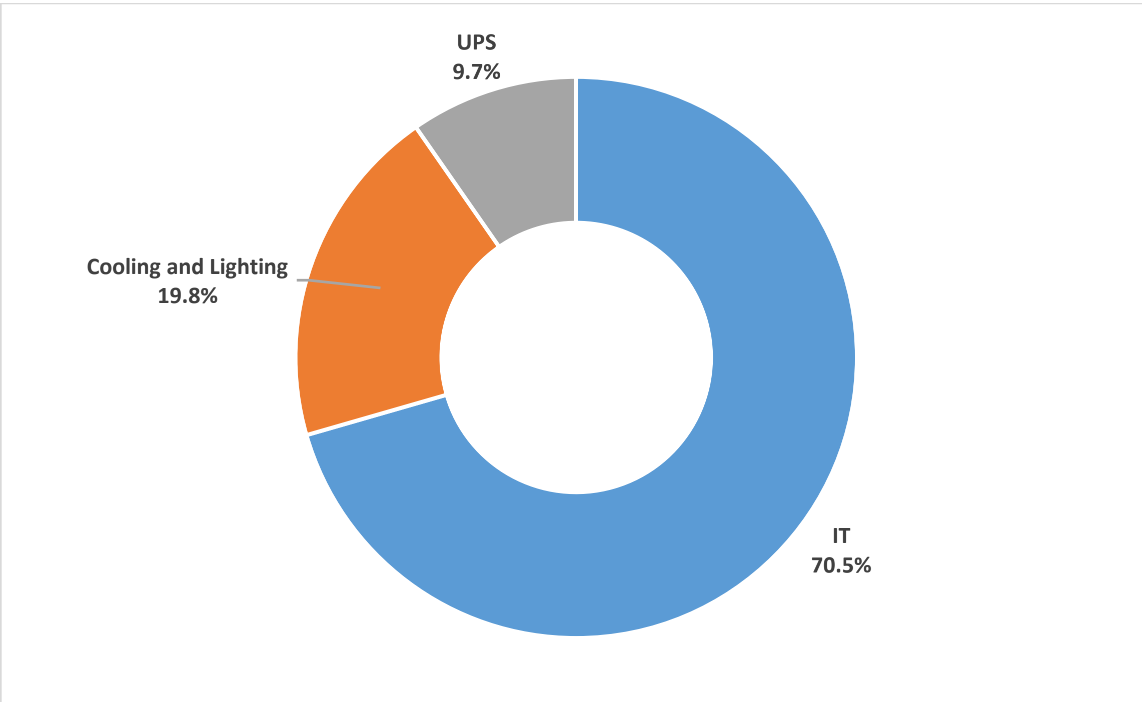


Figure 9. Breakdown of annual energy consumption

In 2020, the total annual facility energy consumption of the data center was 11,953 MWh. Monthly consumption varied by nearly 10%, falling between 1,041 MWh and 898 MWh as shown in Figure 10. The IT load consumes ~70% of the total facility energy whereas cooling, UPS and lighting consume nearly 30%. Since the lighting is PoE-based and highly efficient, its energy use is almost negligible. The data center marked the lowest monthly PUEs when free cooling was used. The annual average PUE was 1.42, varying monthly between 1.35 and 1.47.

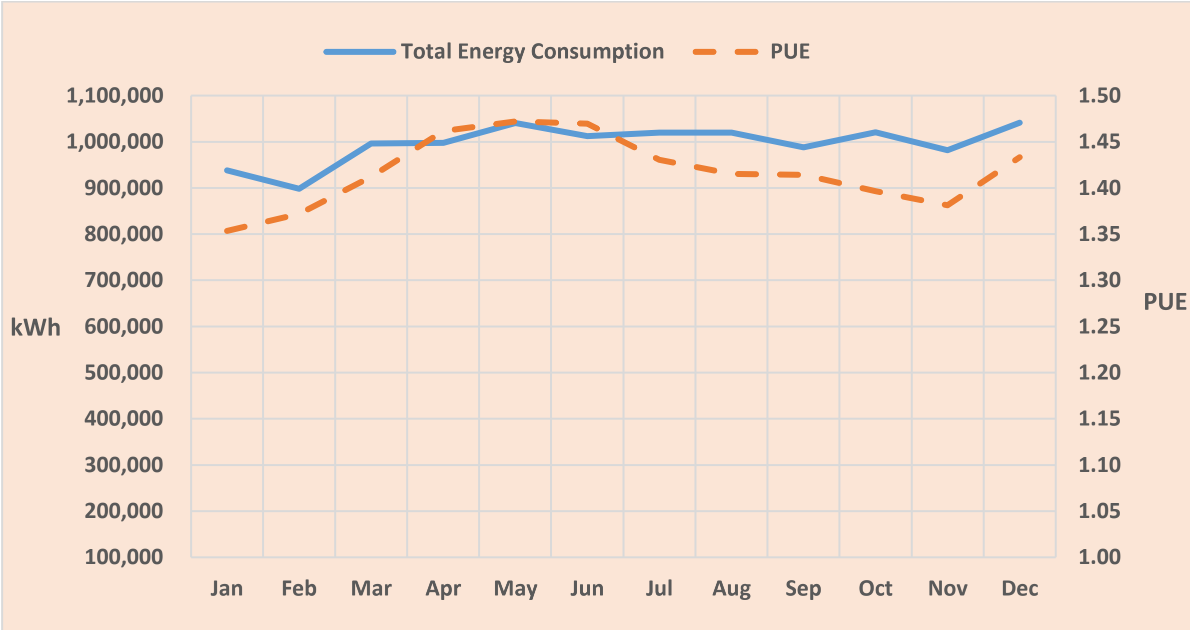


Figure 10. Monthly total energy consumption and PUE in 2020 for the NetApp-Bangalore data center

Comparison to Industry Best Practices

NetApp is a forerunner in adopting innovative technologies globally. Our state-of the-art data center in Bangalore is an excellent demonstration center which showcases optimum usage of technologies like free cooling, PoE lighting and flywheel-based UPS system. It empowered us to achieve the lowest PUE of 1.35 when free cooling is being utilized. The innovative vertical stack configuration and fully integrated BMS have rewarded the project to achieve performance goals.

- Vinod Kulkarni, Facility Manager, NetApp

The Bureau of Energy Efficiency (BEE) promulgated an Energy Conservation Building Code (ECBC), and data centers were included in the 2017 edition. A technical committee of industry experts, led by the Confederation of Indian Industry (CII)-Indian Green Building Council (IGBC) and the Lawrence Berkeley National Laboratory (LBNL), have developed a "User Guide for Implementation of ECBC 2017 in Data Centers" (see references). The user guide provides recommendations on meeting the ECBC (Level I in the guide) and sets out two higher performance levels: Level II (ECBC+) and Level III (SuperECBC). The NetApp data center's performance already meets most of the proposed specifications for Level II and Level III, which sets a very high level of compliance. Figure 11 illustrates how NetApp PUE compares to typical Indian data centers, as well as estimated performances for Levels I, Level II, and Level III. Table 3 shows the performance level achieved by the NetApp data center for each of the guide's sections (room cooling, chiller plant and electrical system).

NETAPP-BANGALORE DATA CENTER

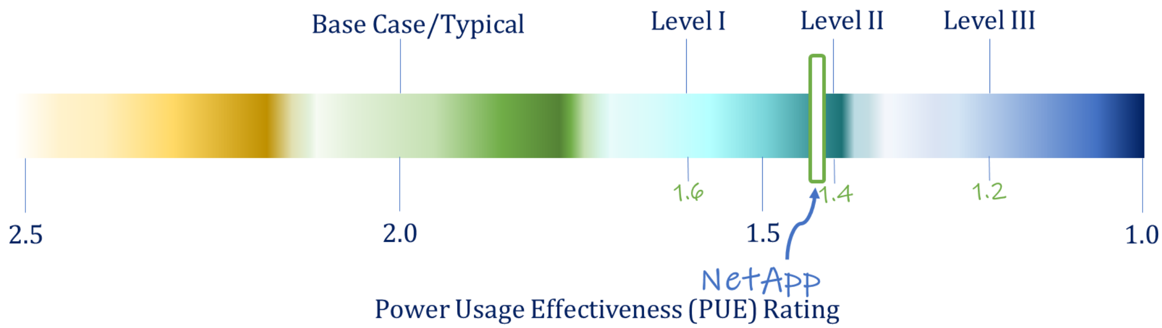


Figure 11. NetApp's Bangalore data center PUE compared to estimated standard and enhanced performance levels

Table 3. NetApp Bangalore's data center performance relative to the ECBC Guide's recommended performance levels for room cooling, chiller plant and electrical system

Data Center Measure Category	*Level I*	*Level II*	*Level III*	*Relevant Measures Meeting or Exceeding Level*
Room Cooling System				
CRAC Efficiency				Not applicable (central air handlers).
Air Management		X		
Environmental Control		X		
Fan Systems			X	
Air-Side Economizing			X	
Chiller Plant				
Chillers			X	
Cooling Towers		X		
Pump Systems			X	
Chiller Plant – Performance Approach			X	
Water -Side Economizing				Project using air-side economizer
Electrical System				
Diesel Generators				Flywheel based technology used
Metering & Monitoring		X		
Uninterruptible Power Supply (UPS)	X			

CONCLUDING REMARKS

NetApp-Bangalore optimizes its data center energy use through multiple techniques. The firm is increasing the load, which will further reduce the PUE. NetApp has a corporate-wide plan to continually improve its facilities' efficiency through improved operation and deployment of innovative technologies. In the case of the Bangalore data center, this has resulted in reducing the PUE from 1.47 in 2019 to 1.42 in 2020, a more than 10% reduction in energy "overhead" (PUE – 1). Key conclusions of the study are:

- Free cooling offers significant operational benefits. An annual PUE of 1.42 and lower monthly PUEs of ~1.35 during free cooling mode show what is achievable in a moderate tropical climate. With proper air filtration, reliability of the IT equipment remains high.

- Free cooling may be further extended with control optimization, retro-commissioning, and increasing the cooling and humidity set points.
- Selection of the UPS technology and configuration are critical for any data center. NetApp reports the rotary UPSs reduced losses in power as well as their total cost of ownership (TCO). It further reduced environmental risks by excluding battery banks. As the data center load increases, so will the UPS efficiency. The lesson for other data centers is to design a scalable system that provides high efficiency across a wide range of loads.
- An integrated BMS further improves operational efficiency and facilitates the identification of new areas for energy savings and system optimization.
- Green power offers operational savings and demonstrates the owner's commitment to responsible and sustainable operations. The NetApp-Bangalore campus offsets 75% of its grid power with low- or zero-carbon sources onsite and offsite.

The NetApp project team is very proactive in decision making and emphasizes continuous performance improvement. The NetApp experience demonstrates their willingness to innovate in multiple systems, to achieve energy, cost and emissions avoidance – lessons that merit attention from other data center owners and operators.

REFERENCES

1. User Guide for Implementing the ECBC In Data Centers: Complying with the Energy Conservation Building Code (2017) and Higher Rating Levels. Produced by CII-IGBC and LBNL, 2020. https://datacenters.lbl.gov/resources/ecbc-2017-data-center-user-guide Link

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