Innovation in Energy Efficiency: Infosys-Bangalore Data Center

OVERVIEW

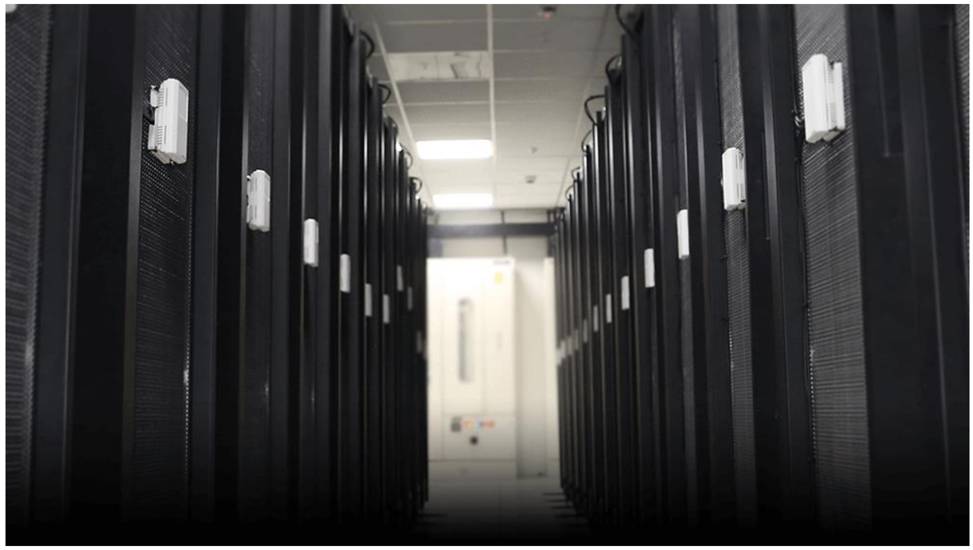

Figure 1. Infosys data center server room

Organization & Data Center Background

Infosys Limited is a multinational consulting, information technology and outsourcing firm that maintains millions of square feet of its own offices and data centers. For its headquarters campus In Bangalore, Infosys built a 250 square meter data center to be a model of innovation and energy efficient computing. Tucked inside a four-story office building, the small data center features a creative combination of novel IT, electrical and cooling technologies. Designers aimed for a Power Use Effectiveness (PUE) score of 1.12. PUE = the total energy/IT equipment energy, so the closer to one the better. Actual energy performance thus far has averaged 1.37, which nonetheless denotes strong performance, based on available data for India.

Infosys has encountered challenges and continues to refine the data center in pursuit of higher performance with the ultimate goal of approaching the design target.

Project Highlights

- *Designed to achieve a PUE of 1.12*
- *Achieved PUE of 1.37 at <50% load*
- *First project in India to maintain high server hall temperatures (~27°C) to enable warm-water cooling to avoid compressor use and thus lower cooling energy cost*
- *Passive Rear Door Heat Exchangers (RDHx) for efficient cooling at the cabinet level*
- *Sophisticated Building Management System (BMS) for automation and optimization*

Table 1. Design and operational parameters

Facility Characteristics	***Description***	
IT Load (Design)	0.3 MW Design, up to 10 kW/rack	0.14 MW Operational
Cooling System Specs	Designed to maintain server room temperature of 27ºC (vs. a more typical 17-18ºC)	
UPS Capacity	300 kVA + 300 kVA in a 2N configuration for Tier III availability	
Total Current Energy Use	1,533 MWh/year	
PUE	1.12 Design	PUE: 1.37 Operational

PROJECT INFORMATION

Project Summary

Infosys intended its Bangalore data center to challenge India's data center design practices and inspire the enterprise data center industry by demonstrating best-available technology and world-class performance. The data center was designed to minimize infrastructure energy yet maintain robust (Tier III) availability.

"Infosys has defined new boundaries for innovation in its Data Centres. We continue to optimise resource use and demonstrate newer implementations by deploying a mix of advanced technologies and robust solutions, that are further fully supported by our excellence in operations. I am delighted that LBNL, IGBC and Infosys worked tirelessly to deliver this case study for the benefits of Data Center Industry".

- Sudhir Ramnath, Associate Vice President, Regional Head - Facilities, Infosys Limited

To minimize infrastructure energy use and achieve a very low PUE, designers aimed for high indoor air temperatures and cooling primarily with warm water. These choices took advantage of Bangalore's relatively moderate climate to maximize "free" evaporative cooling by outside air and minimize the use of energy-intensive compressors and fans. Infosys also selected highly efficient uninterruptible power supplies (UPS) and set up a monitoring and control system to optimize IT operations and cooling for low energy use.

These design objectives drove the selection of the technologies:

Cooling Design

Warm-water cooling system uses evaporative cooling to cool water with minimum fan power and no compressors. The cooling tower system handles cooling requirements of the data center for the 99% of the year when weather conditions are favorable for "free" cooling. A conventional chilled water plant covers the remaining 1% of cooling times.

Rear Door Heat Exchangers

Passive Rear Door Heat Exchangers (without fans) are mounted to the back of the racks enabling heat removal at the rack level. Warmer than normal cooling water is pumped to the heat exchangers behind the racks. Typically, the closer the liquid cooling is to the heat source, the more efficient the cooling system.

Equipment Efficiency

All pumps and fans were equipped with ultra-high efficient motors and Variable Frequency Drives (VFDs) so power can adjust to load. The UPS system is highly efficient to minimize power losses and is "hot swappable" to minimize downtime for maintenance.

Building Monitoring System (BMS)

A BMS is used to eliminate inefficiencies by selecting the best mode of operation based on load and ambient conditions. The BMS pushes the team to set new performance boundaries for data center operation. Health of IT equipment is closely and deeply monitored, and allows faster corrective measures to eliminate inefficiencies.

DESIGN AND IMPLEMENTATION OF INNOVATIVE MEASURES

Project Implementation

Infosys is implementing its data center in three phases. It was first commissioned and operational in 2015. The data center is now in its second phase at 0.14 MW of IT load (versus a 0.3 MW design load) and with a PUE lagging the design target of 1.12, as shown in Table 1. Operating at partial load has depressed infrastructure efficiency. Further, higher-than-designed approach temperatures and air management issues have reduced the amount of "free" (compressor less) cooling. In the third phase, Infosys expects to bring the data center up to full load and enable the data center to operate at design performance, yielding a significant reduction in PUE.

Cooling System

The Infosys strategy for minimizing cooling energy use has three interlocking elements: high indoor air temperatures, passive rack-level cooling with warm water, and "free" evaporative cooling at the tower.

Higher indoor air temperatures at the servers leads to higher data center efficiency. As a rule of thumb, every 1°C reduction in air temperature requires 3% more power for cooling. The HVAC system was designed to supply warm water at 24°C to maintain server inlet air temperature at 27°C at full capacity. Keeping the server inlet air in that range is consistent with ASHRAE temperature guidance (see references) and minimizes load on the cooling plant. Figure 2 depicts the ASHRAE recommended and allowable specifications for IT equipment classes A1-A4.

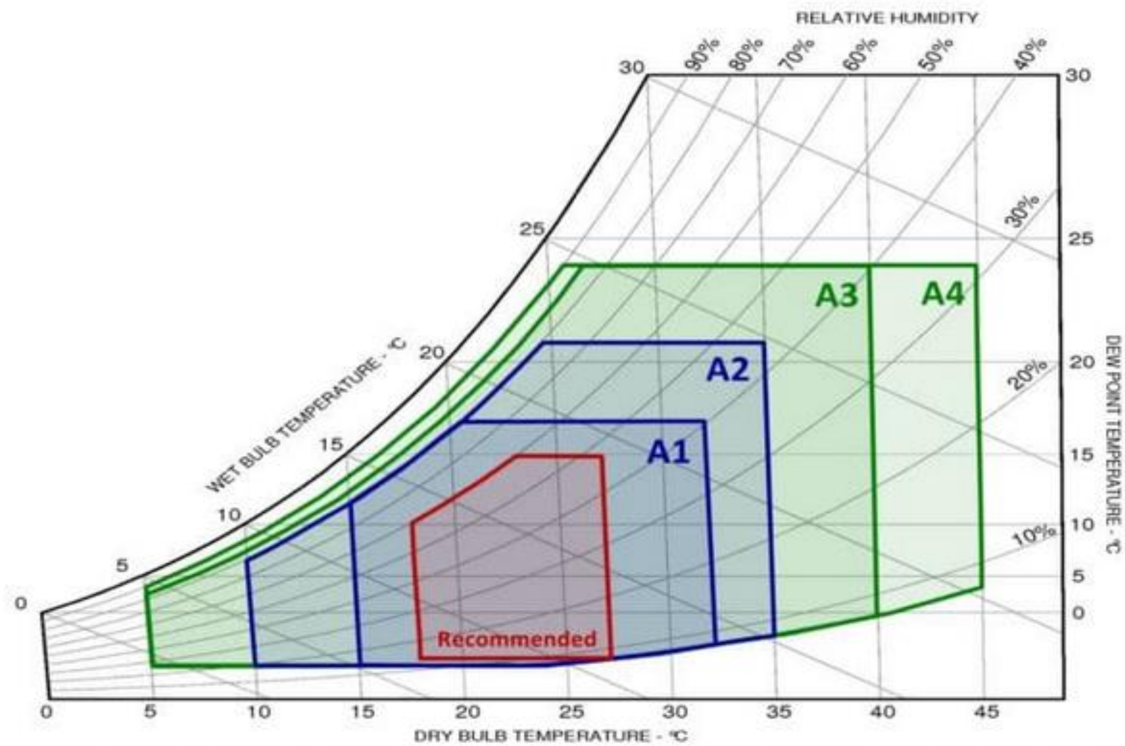

Figure 2. ASHRAE specifications for environmental conditions for IT equipment classes (Note: Ranges are for air entering IT equipment operating at sea level)

INFOSYS-BANGALORE DATA CENTER

Under the ASHRAE guidelines, data center operators can run servers outside the recommended envelope and into the allowable range for brief periods without affecting overall reliability. The Infosys-Bangalore data center is operating within the recommended limits while having the “buffer” permitted by the allowable limits.

Figure 3. A fan-less or passive rear-door heat exchanger of the type installed at the Infosys-Bangalore

Server cabinets were fitted with fan-less or “passive” Rear Door Heat Exchangers (RDHx) supplied by Coolcentric and installed by Schneider Electric (see Figure 3). Water circulates through a tube and fin coil mounted in the door with quick-connect flexible tubing. Figure 4 depicts the cooling performance of an RDHx using warm water cooling at the rack. RDHx can cool rack densities of 10 kW or more at much lower energy cost than typical computer room air-conditioners.

Internal server fans provide the airflow through the rack and rear door. For RDHx to work properly, the water temperature must be kept above the dew point to avoid condensation. It is also important to manage airflow with blanking panels and other techniques to prevent reverse airflow (airflow from back to front). Further, even distribution of heat within the server cabinets is required to take advantage of the door’s full heat exchanger area.

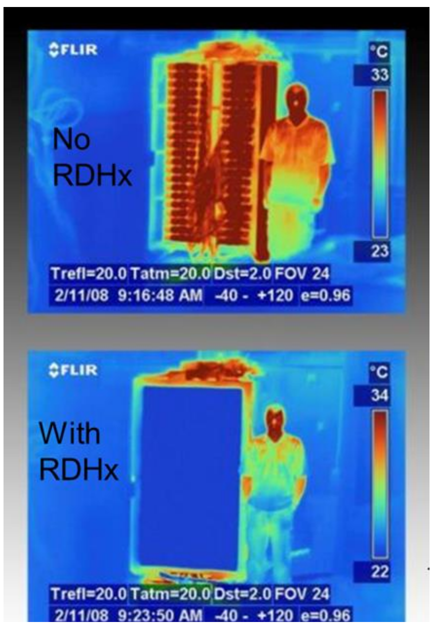

Figure 4. Infrared imagery of a RDHx system

The project has provided lessons learned. The passive RDHx coils required an approach temperature of 7ºC rather than the intended 3ºC. Thus, to maintain a server inlet temperature of 26°-27ºC, the cooling system has had to supply water at 19°C. Cooler-than-design chilled water not only increases energy use at the chiller, it dramatically reduces the opportunity for “free” cooling.

Infosys’s original strategy relied on cooling towers for evaporative cooling. The towers would use ambient wet bulb conditions for effective cooling and were intended to reduce the use of chillers for all but ~1% of the year. The cooling towers were designed for a 1ºC approach temperature to maximize cooling without compressor energy use. Since Bangalore is in a temperate climate zone, evaporative cooling alone could meet the data center’s cooling requirements nearly all the time. A high efficiency central water-cooled chiller plant utilizing Centrifugal Chillers (Magnetic Bearing Chiller from York Johnson Controls) provides backup capacity, however the system is intended only for a few very hot and humid days each year. An air-cooled chiller provides another layer of redundancy at the data center building itself. Due to the lower cooling water temperature, the percent of free cooling is much less than anticipated, and the compressors run almost all the time. Further, because the central plant runs only during occupied hours (daytime), the small, much less efficient air-cooled chillers pick up a large portion of the load. These factors contribute to less than desired performance. Table 2 describes the 3 modes of operation and their relative efficiencies.

Table 2. Configuration of chiller plant systems, capacities, and efficiency

Design Mode	System	Capacity (TR)	Qty	Total Capacity	ISEER	PUE
Mode 1	Cooling tower	30	4	120	Very high	1.12
Mode 2	Water-cooled chiller	200	2	400	8.79	1.18
	Water-cooled chiller	400	1	400	10.00	
Mode 3	Air-cooled chiller	30	4	120	3.90	1.4

As described below, a building management system (BMS) selects among the cooling modes for optimal energy efficiency and reliability. For routine operations, the data center is limited to a certain chiller configuration because it shares its main water-cooled chiller with offices occupied during workdays. When those offices are closed at night and on weekends, the data center switches to a small, less efficient air-cooled chiller that elevates the PUE from 1.18 to 1.4. The average PUE when alternating between the chillers is 1.37. Further, PUE can substantially be improved by reducing the approach temperature at the racks, raising the chilled water temperature to enable more evaporative cooling, and increasing utilization of the water-cooled chiller plant.

Infosys has continuously been working to improve cooling performance through air management inside and outside of the serve cabinets since inception of the data center. Of late, Infosys initiated testing of fan-powered RDHxs (active RDHx) to limit multi-directional (reverse) airflow inside the cabinets to fully utilize the heat exchanger area. Fan-powered RDHxs will also allow for higher power densities.

Many data centers owners (enterprises as well as colocation data centers) are reluctant to bring water into the data center. Infosys did so by installing RDHx systems that can serve as a steppingstone to direct liquid cooling solutions.

Automation

The Infosys-Bangalore data center is monitored and controlled through an Automated Logic building management system (BMS) that tracks load and indoor/outdoor air and automatically selects the best mode of operation. Highly granular performance data is collected throughout the data center on a continuous basis to identify improvement opportunities. Figure 5 shows a console

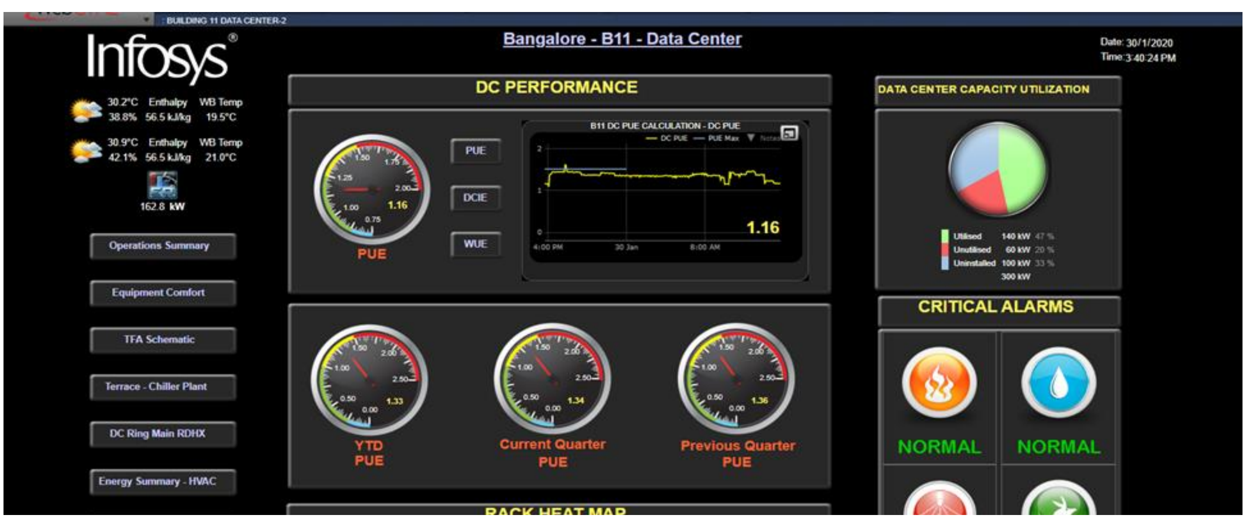

Figure 5. A main console for the building management system in the Infosys-Bangalore data center

of the central system that meters, monitors, and takes corrective actions based on the logic control developed for the BMS.

Among other values, the system monitors the weather, UPS input and output health, aisle temperatures, and server-level temperatures, humidity and energy demand and use. The fine-grained data enables more extensive benchmarking and an understanding that allows the data center team to push performance boundaries and consider refinements or integration of new technologies. The BMS manages the UPSs, the cooling system and other systems to optimize for reliability and energy efficiency. To date, the data center has not reported any server failures.

Uninterruptible Power Supplies (UPS)

Two high-efficiency American Power Corporation (APC)/Schneider Electric UPSs were installed in a 2N configuration to support the data center's Tier III rating. Each of the 300 kVa UPSs is modular and "hot swappable," meaning any module can be removed while the rest of the UPS continues operating and thus preserves uptime during maintenance. The UPSs are rated as 96% efficient, and even at the current low loads, they are operating at 95.3% efficiency.

Costs and Benefits

Infosys reports that implementing these measures was highly cost-effective, ranging from a three- to five-year simple payback.

PROJECT PERFORMANCE

Project Results & Benefits: Design and Operational Performance

Total annual facility energy consumption is about 1,533 MWh. Monthly consumption varies by nearly 25%, falling between 109 MWh and 136 MWh. PUE trends seasonally as shown in Figure 6.

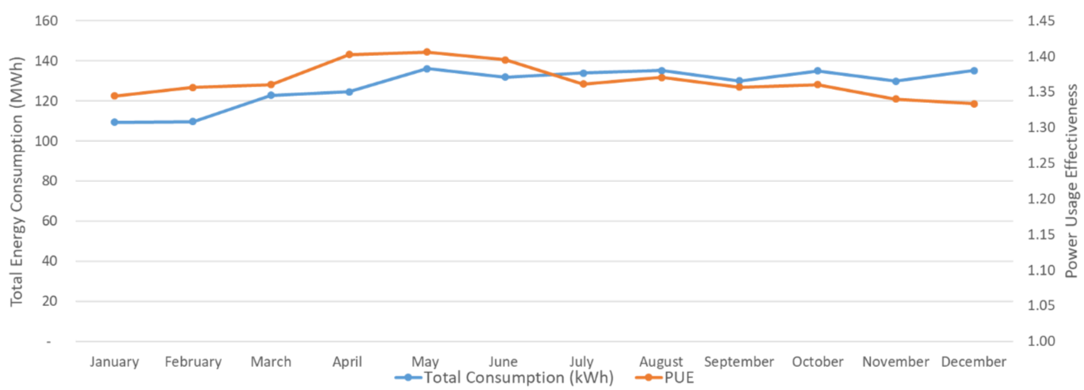

Figure 6. Monthly total energy consumption and PUE in 2019 for the Infosys-Bangalore data center

The design performance target PUE of 1.12 was based on a warm-water cooling system. Cooling towers alone would provide enough cooling to the RDHxs most of the time. Since, the required water temperature in actual operation was lower than the design conditions, it resulted in the need for considerable compressor-based cooling. Using the higher efficiency, water-cooled chiller plant, the PUE goes to 1.18. While this is 50% more infrastructure energy than originally anticipated, it is still among the best in India and throughout the world. The operational energy breakdown when using the central plant is shown in Figure 7. On average, while on the central plant, IT equipment consumes about 85%, the cooling system uses about 10%, the UPS about 4%, and other about 1%.

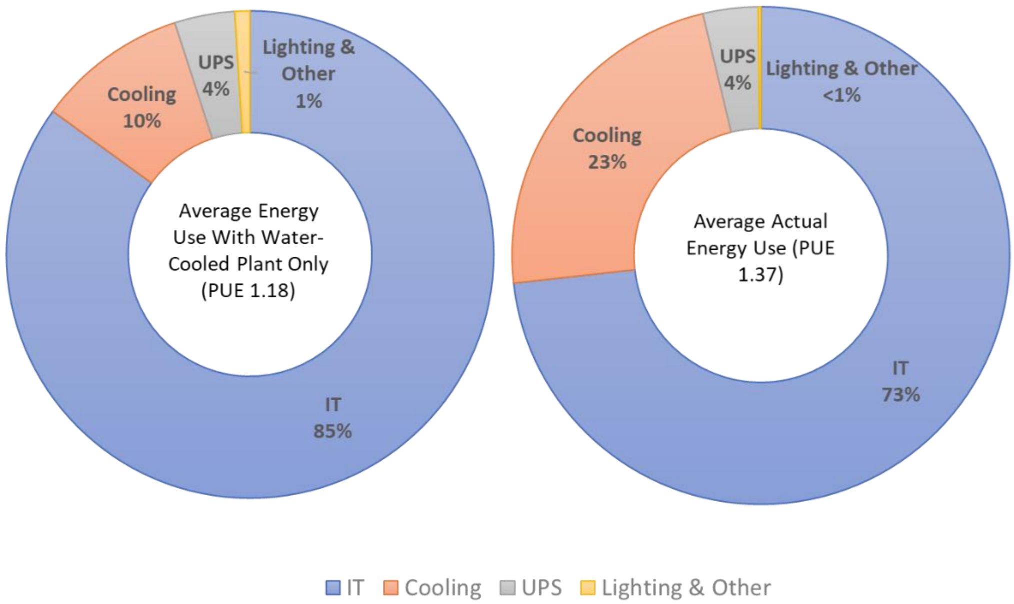

Figure 7. Data center energy breakdown using only the water-cooled central plant and the actual operational average using all cooling options

> *"Infosys believes in pushing the boundaries of innovation and questioning every assumption. In our endeavor to lead the way in sustainability, we decided to design a world-class, highly energy efficient data center that could demonstrate a strong case for green data centers in the world. We decided to challenge the global average PUE of 1.8-2.0 for small data centers and set an ambitious target to achieve, a PUE of 1.12, which is approximately an 85% reduction in infrastructure power."*
>
> - **Punit Desai, Regional Head – Infrastructure and Green Initiatives, Infosys Limited**

In addition to the performance penalty associated with needing colder temperatures, a bigger penalty involves greater use of the small air-cooled chiller. This chiller consumes more than twice the energy of the central cooling plant and raises the PUE to 1.40 when it is operating. While that performance is still good by industry standards, use of the air-cooled chiller results in more than three times the infrastructure energy use anticipated in the design. The combined performance of the three operating modes yields an annual average PUE of 1.37 as shown in Figure 7 above. While this compares extremely well to many data centers (see Kumar, Jain 2020), it points to opportunities for further improvement.

Carbon Neutrality

Infosys also has set a target of carbon neutrality for its infrastructure and has invested in renewable energy sources. For now, Infosys reports supplying 65% of the load to the Bangalore campus (including the data center) from on- and off-site renewables.

NEXT STEPS

Infosys is planning a number of improvements to bring the PUE closer to the design target:

- Reduce hot/cool air mixing by better managing the air path within the server cabinets and raise the water temperature by 1ºC.
- Convert the RDHxs to fan-powered doors to reduce backflow mixing, increase door capacity, and reduce the approach temperature. A proof of concept test is underway, and the goal is to raise the supply cooling water temperature from 19°C to 24°C while maintaining the server inlet air temperature at 27°C. Infosys estimates that this will enable "free" evaporative cooling for most of the year.
- Add 24-hour loads to the high efficiency central cooling plant to allow it to provide all the remaining data center cooling and eliminate use of the small air-cooled chiller (except for emergencies). Implementing this improvement alone would reduce the infrastructure energy use more than 50%.
- Increase the IT load closer to design conditions.

It is anticipated that with these improvements, the performance will approach the PUE design target.

COMPARISON TO INDUSTRY BEST PRACTICES

The Bureau of Energy Efficiency promulgates 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 – Indian Green Building Council and the Lawrence Berkeley National Laboratory, developed a "User Guide for Implementing ECBC in Data Centers" (see references). The 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 Infosys data center's performance already meets most of the recommended specifications for Level III which sets the highest-achievable level of compliance above and beyond the national Energy Conservation Building Code. Figure 8 illustrates how Infosys's PUE compares to typical data centers, as well as estimated performance for Levels I, II, and III compliance.

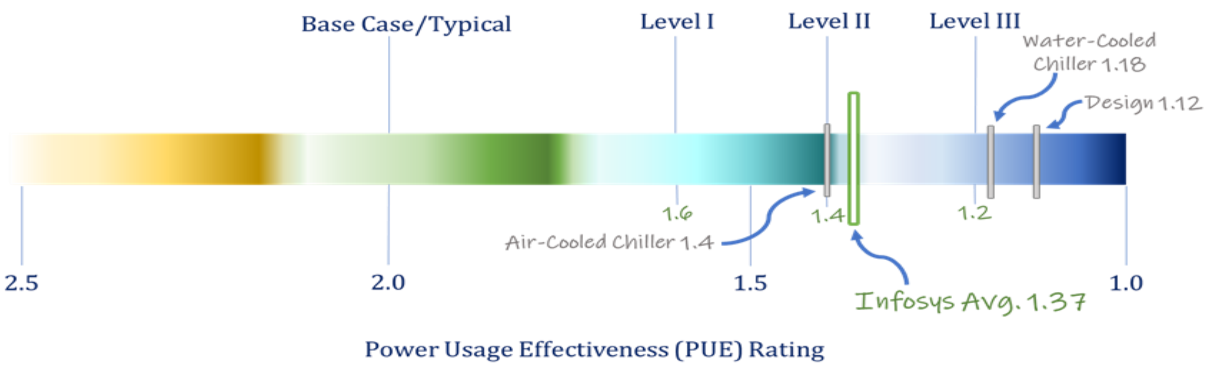

Figure 8. Infosys-Bangalore data center PUEs compared to User Guide-ECBC 2017 and design performance level

Table 3 outlines the performance of subsystems of the Infosys-Bangalore data center relative to the recommended levels in the ECBC data center guide.

Data Center Measure Category	Level I	Level II	Level III	Relevant Measures Meeting or Exceeding Level
Room Cooling System				
CRAC Efficiency			**NA**	Data center uses passive rear door heat exchangers
Air Management			**X**	Blanking panels and other sealing techniques used
Environmental Control			**X**	Set to upper end of ASHRAE recommended range
Fan Systems			**NA**	No fans
Air-Side Economizing			**NA**	Water side economizer used
Chiller Plant				
Chillers		**X**	**X**	200 TR and 400 TR Water-cooled chillers have an ISEER of 8.8 and 10.0, respectively, whereas Level-III recommends 8.2 and 8.7. The 30 TR back-up air-cooled chillers have an ISEER of 3.9 better than the 3.6 recommended Level-II, but Level-III does not recommend air cooled chillers.
Cooling Towers			**X**	0.005 kW/kWr. Level II & III recommended is 0.006 kW/ kWr or lower for chiller plants > 530 kWr capacity.
Pump Systems			**X**	Chilled Water Pump (Primary and Secondary 14.3 W/kWr) (max Level III is 14.9) with VFD. Condenser Water Pump 14.2 W/kWr (max Level III is 14.6). Pump Efficiency (minimum): 85%.
Chiller Plant – Performance Approach			**X**	kW/kWr of 0.14 with Level III recommended 0.187 kW/kWr
Water -Side Economizing			**X**	Dedicated tower only cooling system, supplemented by a central chiller plant with a water side economizer
Electrical System				
Diesel Generators			**NA**	Existing central generators not star rated
Metering & Monitoring		**X**		There is significant monitoring of the system including PUE, and temperature at every rack, however it doesn't meet the specific recommendations for level III.
Uninterruptible Power Supply (UPS)		**X**		UPS rated 96% efficiency equal to Level II recommended.

CONCLUDING REMARKS

With a host of innovative technologies and operational solutions, Infosys and its partners built a data center in Bangalore with world-class energy performance and a likelihood of further improvement. Infosys-Bangalore demonstrates that achieving ambitious efficiency targets is possible, even in a tropical climate. The data center is a model of high-efficiency design for the industry to examine, emulate, and where warranted, improve upon.

Higher than anticipated approach temperatures have resulted in a lower required cooling water temperature which has dramatically reduced the ability to use the cooling towers alone to cool the IT racks. A high efficiency cooling plant yields a PUE of 1.18, however the plant only runs during occupied office hours requiring the use of a small, relatively inefficient, air cooled chiller to serve the data center during "off" hours. The air-cooled chiller takes the operation to a PUE of 1.4. The combined operation in all modes performs at a 1.33 PUE. Infosys is planning the following improvements:

1. Increase 24-hour loads on the central cooling plant to allow full-time operation.
2. Further improve air management and move to fan-powered rear door heat exchangers to increase the cooling water supply setpoint and significantly increase hours of tower cooling (water-side economizer).
3. Increase IT load to fully utilize infrastructure.

Infosys anticipates that with the improvements outlined, the design goal of a 1.12 PUE can be achieved.

REFERENCES

1. 2015 Thermal Guidelines for Data Processing Environments, 4th Edition. Guide, 2015. With the 2016 Errata to Thermal Guidelines for Data Processing Environments, 4th Edition. Guide, 2016. ASHRAE Technical Committee 9.9. Link: https://www.ashrae.org/File Library/Technical Resources/Publication Errata and Updates/90577_errata.pdf

2. Kumar R, Jain S. Performance analysis of an in-situ data centre. *Energy Build*. 2020; 209. doi:10.1016/j.enbuild.2019.109679 https://www.sciencedirect.com/science/article/abs/pii/S0378778819320729

3. User Guide for Implementing the ECBC In Data Centers: Complying With the Energy Conservation Building Code (2017) and Higher Rating Levels. Produced by the Confederation of Indian Industry, Lawrence Berkeley National Laboratory and the Indian Green Building Council. 2020. https://datacenters.lbl.gov/resources/ecbc-2017-data-center-user-guide

Confederation of Indian Industry

www.cii.in

Indian Green Building Council

https://igbc.in/igbc/

S Karthikeyan

Shivraj Dhaka

Himanshu Prajapati

Lawrence Berkeley National Laboratory

datacenters.lbl.gov

https://datacenters.lbl.gov/indian-data-centers-initiative

Dale Sartor

Ian M. Hoffman

Infosys

www.infosys.com

Punit Desai, Regional Head-Infrastructure

Shubham Agarwal, Senior Manager – Green Initiatives

October 2020