

Sustainable Cooling Innovation – Indian Hospitality

Sofitel, Mumbai

M&V Report

Endocool

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Abbreviations

S/N	Abbreviation	Full form
1.	AHU	Air Handling Unit
2.	BKC	Bandra Kurla Complex
3.	CHW	Chilled water
4.	DBT	Dry Bulb Temperature
5.	EDS	Environmental Design Solutions
6.	GHG	Green House Gas
7.	HMI	Human Machine Interface
8.	IFC	International Finance Corporation
9.	ikW/TR	Indicated Kilowatt/Tonnage of Refrigeration
10.	IPMVP	International Performance Measurement and Verification Protocol
11.	kW	Kilo Watt
12.	kWh	Kilo Watt Hour
13.	M&V	Measurement and Verification
14.	TE-SCI	TechEmerge Sustainable Cooling Innovation
15.	TR	Tons of Refrigeration
16.	WBG	World Bank Group
17.	WBT	Wet Bulb Temperature

1. Executive summary

IFC's TechEmerge program accelerates the adoption of technologies in emerging markets to drive sustainable innovation where it is needed most. As part of this initiative, IFC partnered with Sofitel and Endo Enterprise to implement the EndoCool technology in its facility at BKC, Mumbai. IFC has engaged Environmental Design Solutions Pvt. Ltd. (EDS) to conduct measurement and verification (M&V) for the pilot project implemented at Sofitel BKC, Mumbai. EDS executed the M&V study in collaboration with stakeholders from IFC, Sofitel, and Endo Enterprises.

EndoCool is an organic chemical heat transfer fluid additive that is engineered to enhance the performance of HVAC systems. The fluid properties of the solution, such as optimized heat capacity and improved dynamic viscosity/turbulence (rheology) have the capability to improve the cooling, reduce transport losses and wastage in the chilled water circuit. The solution aims to achieve improved heat transfer in chilled water circuit. The M&V study was conducted to determine the improvements in chiller parameters and electrical power savings post addition of fluid additive to the chilled water circuit.

The study considered the baseline period from June 01, 2024 to June 22, 2024 (22 Days) and reporting period considered from July-August 2024 period (22 Days).

The results of the M&V study are mentioned below:

Table 1: Executive summary

S/n	Key performance indicator	Parameter	Baseline period value	Reporting period value	M&V outcomes
1	Chiller 02	ikW/TR	0.60	0.56	0.04 (6.7%)
2		Evaporator approach (°C)	3.39	2.98	0.41
3		Evaporator Saturated temperature (°C)	5.35	5.90	-0.54
4		Chilled water inlet temp (°C)	11.86	11.93	-0.07
5		Chilled water outlet temp (°C)	8.75	8.88	-0.13
6		Consumption in kWh (normalized)	53,630	50,031	3,599 (6.7%)
7		Average TR delivered	186.42	183.0	3.42
8		Running Hours	480	491	-11
9	Total Chiller consumption (Kwh) (3 chillers)		1,54,933	1,30,458	24,475 (15.8%)
10	Total Chiller Running Hours (3 chillers)		1293	1120	173
11	GHG Emission (Kg of CO ₂)		1,27,044.98	1,06,975.69	20,069.29

The analysis outcomes during the M&V study of Endo Cool pilot are mentioned below:

- The total running hours of the chillers decreased by 173 hours during the reporting period, indicating improved and more efficient heat exchange within the system. In the M&V study, the occupancy data was not provided to understand the load profile of the facility.

- Based on information conveyed by the Sofitel team that the building's occupancy slightly increased in the reporting period. The analysis outcomes indicate significant reduction in running hours of the chillers which shows the positive impact of the fluid additive in the heat transfer across chilled water circuit.
- The data for Chiller 2 shows a 6.7% improvement in efficiency and a reduction in the evaporator approach by 0.41°C. This improvement is likely due to an increase in the saturated evaporator temperature of 0.54°C during the reporting period. These changes suggest better heat exchange performance and optimized chiller operation.
- The electrical consumption of Chiller 2 shows a 6.75% savings when normalized to the baseline running hours. There is only a slight difference in the running hours between the baseline and the reporting period, as well as in the average tonnage (TR). These savings further emphasize the improvement in chiller efficiency following the pilot implementation.
- The efficiency improvements observed in Chiller 2 suggest similar improvements in the other chillers. The reduction in total chiller plant running hours indicates that the savings are not limited to Chiller 2 but are generated across all three chillers.
- The system-wide improvement has led to a total consumption reduction of 15.8% across all three chillers due to improved chiller efficiency and reduced running hours.

2. Introduction

International Finance Corporation (IFC), a member of the World Bank Group (WBG), is the largest global development institution focused on the private sector in developing countries. IFC's TechEmerge program accelerates the adoption of technologies in emerging markets to drive sustainable innovation where it is needed most. TechEmerge involves a structured and curated process through which companies ("Innovators") from around the world, are matched with corporates and other organizations ("Adopters") to undertake technology field testing (pilot projects), with the aim of building long-term commercial partnerships. In India, the Tech Emerge - Sustainable Cooling Innovation (TE-SCI) program was launched in 2019 with the objective of piloting and scaling-up innovative cooling solutions and business models across sectors, including in hospitality and the retail cold chain (i.e., across the temperature-controlled logistics or TCL value chain).

Sofitel hotel located at BKC, Mumbai, features a total built-up area of 4.7 lakhs Sq.ft, comprising a single tower spanning 14 floors and 2 basements. In a dedicated effort to explore and implement energy-efficient, climate-smart cooling solutions across its properties, Sofitel hotel has partnered with IFC's TechEmerge Sustainable Cooling Innovation (TE-SCI) program. The designated pilot at Sofitel involved dosing Endo Enterprises 'EndoCool' into the chilled water system. This innovative solution enhances the heat capacity and dynamic viscosity/turbulence of the chilled water, leading to improved cooling,

reduce transport losses and wastage in the chilled water circuit. The solution also improves heat transfer in the HVAC system.

3. Existing system - Sofitel

The hotel's HVAC cooling plant consists of three chillers (each with two compressors: 2 x 370 TR and 1 x 350 TR) and is supported by three cooling towers. The chilled water (CHW) system has a volume of approximately 39 cubic meters, with three primary chilled water pumps, each rated at 18.75 kW, and two secondary pumps rated at 30 kW. Additionally, there are three condenser pumps, each rated at 56.25 kW. Typically, one chiller along with one primary, secondary, and condenser pump operates 24 hours a day to meet the facility's cooling load. During the daytime, an additional chiller is usually turned on to meet increased cooling demand, along with the corresponding primary, secondary, and condenser pumps.

4. Pilot technology – EndoCool

EndoCool is an organic chemical heat transfer fluid additive that is engineered to enhance the performance of HVAC systems. The fluid properties of the solution, such as optimized heat capacity and improved dynamic viscosity/turbulence. These improvements help to boost cooling performance, reduce transport losses and wastage, and ultimately improve the overall heat transfer in the HVAC system.

EndoCool makes several key changes to the heat transfer properties of water, influencing multiple aspects of system performance:

- **Improved Wetness/Thermal Contact:** Enhances the contact between water and heat exchange surfaces, boosting heat transfer efficiency.
- **Improved Entrained Bubble Behaviour:** Reduces the negative impact of entrained air bubbles, which normally act as barriers to heat transfer.
- **Improves Warm-Up/Cool-Down Time:** Shortens the time required to reach target temperatures, improving system responsiveness.
- **Reduction of Excessive Heating/Cooling:** Prevents overcompensation during heating and cooling cycles, resulting in more consistent temperatures.
- **Reduces Transport Losses:** Minimizes energy loss as heat travels through the system.
- **Reduction in End-of-Cycle Wastage:** Improves system reactivity, reducing wasted energy at the end of heating/cooling cycles.

Additionally, the solution addresses issues related to:

- **Surface Bubbles During Degassing:** Air bubbles, which act as heat transfer barriers, are reduced, further enhancing efficiency.
- **Nucleate Boiling:** Promotes nucleate boiling for improved heat dissipation.

- **Reduced Heat Capacity:** Though lowering heat capacity may seem counterintuitive, it makes the system more responsive to demand changes.
- **Improved Rheology (Turbulence/Drag Reduction):** Improves water flow dynamics, reducing drag and improving system efficiency. This effect is similar to the Toms Effect, where polymers reduce drag by up to 80%. Similar surfactants are used in district heating systems in countries like Denmark, Germany, and Czechia to achieve the same benefits.

Since the pilot implementation was a simple chemical infusion to the chilled water circuit, there was no need for a training section to be conducted as part of the pilot implementation.

5. Measurement & Verification

5.1 Measurement option

According to the IPMVP Volume I, the most suitable measurement option for the M&V study of the EndoCool pilot is 'Option A (Retrofit Isolation – Key Parameter Measurement)'. This approach involves isolating the impact of the retrofit—in this case, the dosing 'EndoCool' in the chilled water system—and focusing on measuring key parameters of chiller. By adopting this method, we can accurately evaluate the performance and effectiveness of the EndoCool solution without interference from other independent variables. This ensures a reliable M&V study that will provide valuable insights for future sustainable cooling solutions.

5.2 Measurement boundary

EndoCool focuses on improving heat transfer of chilled water, thereby increasing chiller efficiency. This technology aims to optimize the chiller's temperature parameters, which must be monitored on the chiller side. To calculate the energy savings generated by the pilot, the total consumption data from all three chillers must be included within the measurement boundary. Although three AHUs were selected for data collection to assess the impact of EndoCool, the unavailability of necessary data from all AHUs excludes the lowside from the measurement boundary. Therefore, the boundary is confined to the three chillers.

5.3 Measurement period

The data collection period of the baseline and reporting period was 22 days each. During the reporting period, on some days the BMS network connectivity was not available and there were also some days on which Chiller 2 operated for few hours. As a result, the 22 days in the reporting period were not continuous compared to the baseline period. The days considered for measuring baseline and reporting period data is mentioned below:

Table 2: Measurement periods

Day No:	Baseline	Reporting
Day 1	01-06-2024	01-07-2024
Day 2	02-06-2024	02-07-2024
Day 3	03-06-2024	03-07-2024
Day 4	04-06-2024	04-07-2024
Day 5	05-06-2024	05-07-2024
Day 6	06-06-2024	06-07-2024
Day 7	07-06-2024	07-07-2024
Day 8	08-06-2024	13-07-2024
Day 9	09-06-2024	14-07-2024
Day 10	10-06-2024	17-07-2024
Day 11	11-06-2024	18-07-2024
Day 12	12-06-2024	20-07-2024
Day 13	13-06-2024	22-07-2024
Day 14	14-06-2024	23-07-2024
Day 15	15-06-2024	26-07-2024
Day 16	16-06-2024	27-07-2024
Day 17	17-06-2024	28-07-2024
Day 18	18-06-2024	29-07-2024
Day 19	19-06-2024	30-07-2024
Day 20	20-06-2024	31-07-2024
Day 21	21-06-2024	01-08-2024
Day 22	22-06-2024	02-08-2024

5.4 M&V parameters

The M&V parameter finalized for this pilot's M&V study are mentioned below:

Table 3: List of M&V parameters

Sr. No.	Parameters	Frequency
1	Chilled water in and out temperature	Daily
2	Chilled water approach	Daily
3	Condenser water in and out temperatures	Daily
4	Condenser water approach	Daily
5	Chiller kW/TR	Daily
6	Chiller evaporator saturated temperature	Daily
7	Chiller power consumption	Daily

5.5 Tasks & Responsibilities

The responsibilities executed by the stakeholders involved in the pilot M&V study are mentioned below:

Table 4: Task & Responsibilities

S/N	Task	Responsibilities
1.	Installation and commissioning	Endo Enterprises
2.	Training of O&M team	Endo Enterprises
3.	Data collection process	Sofitel
4.	Analysis and reporting	EDS

6. Baseline Data

To assess the performance of the chiller during the baseline period, data from Chiller 2 was used as it was the only chiller connected to the BMS and provided reliable data. The Human Machine Interface (HMI) data from the other two chillers was found to be unreliable, so the analysis focused solely on Chiller 2 parameters to understand the impact of the pilot and the total power consumption of the chillers for calculating energy savings.

Furthermore, data from three AHUs were collected to gain a comprehensive view of the pilot's effect on the low side of HVAC system. Wet Bulb Temperature (WBT) and Dry Bulb Temperature (DBT) were monitored to track changes in weather conditions. Although occupancy didn't have a direct relationship with chiller consumption from the baseline data, the Sofitel team was asked to alert stakeholders in case of a significant change in occupancy, which did not occur. There was only a slight increase in occupancy during the reporting period.

The BMS recorded data from Chiller 2 every minute. The average values of the readings for each day were calculated when the chiller 2 was operational. The baseline data for Chiller 2 is tabulated below:

Table 5: Baseline chiller 2 data-1

Date	Running Hrs	Average CHW Set Point(°C)	Average Running Capacity	Evap Entering Water Temp(°C)	Evap Leaving Water Temp(°C)	Evap DT (°C)	Evap Saturated Temp(°C)	Evap Approach Temp(°C)	Calculated Average TR
Jun-01	18.1	8.00	86%	12.44	8.31	4.12	4.92	3.39	247.14
Jun-02	16.4	7.80	82%	11.69	8.42	3.27	4.95	3.46	195.86
Jun-03	23.8	8.00	80%	11.66	8.66	3.00	5.17	3.49	179.94
Jun-04	23.8	8.00	80%	11.48	8.38	3.10	5.11	3.27	185.68
Jun-05	11.9	7.80	83%	11.81	8.51	3.30	5.17	3.35	197.53
Jun-06	19.2	8.00	79%	12.09	9.01	3.08	5.37	3.65	184.76
Jun-07	23.7	7.39	82%	10.61	7.68	2.92	4.40	3.28	175.31
Jun-08	13.1	8.00	81%	11.92	8.57	3.34	5.10	3.48	200.37
Jun-09	23.5	8.00	80%	11.66	8.41	3.24	5.06	3.35	194.43
Jun-10	23.7	8.00	76%	11.55	8.61	2.94	5.33	3.27	175.92
Jun-11	17.1	8.00	77%	12.31	9.06	3.25	5.47	3.59	194.67
Jun-12	23.6	7.68	70%	13.02	10.17	2.85	6.58	3.60	170.57
Jun-13	22.7	7.92	74%	12.52	9.45	3.08	5.90	3.54	184.36

Jun-14	17.5	8.00	81%	11.68	8.49	3.19	5.21	3.28	191.24
Jun-15	23.6	8.00	76%	11.77	8.89	2.88	5.48	3.40	172.68
Jun-16	23.3	8.00	76%	12.20	9.08	3.11	5.52	3.56	186.54
Jun-17	22.1	8.00	78%	11.60	8.70	2.90	5.60	3.09	173.78
Jun-18	23.9	8.00	79%	11.50	8.46	3.04	5.16	3.30	182.43
Jun19	20.2	7.99	76%	12.42	9.36	3.06	5.81	3.55	183.31
Jun20	23.9	8.00	76%	11.91	9.02	2.90	5.75	3.27	173.73
Jun21	17.8	8.00	81%	11.46	8.56	2.89	5.32	3.24	173.51
Jun22	23.7	8.00	75%	11.57	8.60	2.96	5.39	3.21	177.58
Average	20.8	7.94	0.79	11.86	8.75	3.11	5.35	3.39	186.42

The average instantaneous TR delivered by the chiller was calculated using a constant flow rate of 181.25 m³/hr for both the reporting and baseline periods.

Table 6: Baseline chiller 2 data-2

Date	Cond Saturated Temp(°C)	Cond Entering Water Temp(°C)	Cond Leaving Water Temp(°C)	Cond Approach temp (°C)	Average Power (KW)	ikW/TR
Jun-01	38.54	30.39	36.42	2.12	126.45	0.51
Jun-02	38.03	30.71	36.00	2.03	120.49	0.62
Jun-03	36.67	29.99	34.52	2.15	116.79	0.65
Jun-04	36.35	30.01	34.30	2.04	111.11	0.60
Jun-05	38.09	31.04	36.11	1.98	119.79	0.61
Jun-06	36.60	30.13	34.51	2.10	116.17	0.63
Jun-07	36.92	30.52	34.96	1.97	115.50	0.66
Jun-08	37.22	29.58	35.29	1.93	115.58	0.58
Jun-09	36.31	29.28	34.30	2.01	111.78	0.57
Jun-10	34.83	28.72	32.87	1.95	102.51	0.58
Jun-11	37.16	30.23	35.17	2.00	116.34	0.60
Jun-12	35.70	29.94	33.76	1.94	105.36	0.62
Jun-13	36.07	29.78	34.08	1.99	108.72	0.59
Jun-14	37.19	30.23	35.31	1.89	112.53	0.59
Jun-15	36.08	29.84	34.15	1.93	108.04	0.63
Jun-16	36.33	29.65	34.30	2.02	113.22	0.61
Jun-17	36.08	29.96	34.25	1.83	102.43	0.59
Jun-18	36.05	29.11	34.12	1.93	108.56	0.60
Jun19	36.15	29.40	34.15	2.01	109.30	0.60
Jun20	36.15	30.15	34.24	1.92	106.57	0.61
Jun21	38.06	31.58	36.27	1.80	111.23	0.64
Jun22	35.17	29.03	33.30	1.87	102.36	0.58
Average	36.63	29.97	34.65	1.97	111.86	0.60

The daily power consumption of the three chillers were recorded and is tabulated below for the baseline period.

Table 7: Baseline chiller power consumption

Date	Chiller 1 kWh	Chiller 2 kWh	Chiller 3 kWh	Total kWh
Jun-01	0	2,320	4,385.5	6,705.54
Jun-02	5,570	2,030	1,027.4	8,627.39
Jun-03	2,780	2,840	800.0	6,420.02
Jun-04	3,170	2,710	866.7	6,746.66
Jun-05	5,470	2,170	480.2	8,120.19
Jun-06	4,030	2770	205.1	7,005.56
Jun-07	3,800	2780	1,780.9	8,360.95
Jun-08	3,960	2270	1,182.7	7,412.67
Jun-09	3,210	2710	274.9	6,194.91
Jun-10	3,080	2470	480.9	6,030.87
Jun-11	3,610	2040	1,383.2	7,033.23
Jun-12	4,040	2790	14.2	6,844.22
Jun-13	4,520	2340	276.0	7,136.02
Jun-14	3,330	1990	2,234.6	7,554.60
Jun-15	3,170	2580	1,363.9	7,113.85
Jun-16	4,240	2630	0	6,870.00
Jun-17	3,810	2360	761.4	6,931.39
Jun-18	3,450	2530	0	5,980.00
Jun19	2,790	2240	1,181.7	6,211.66
Jun20	3,760	2580	490.5	6,830.45
Jun21	5,420	2090	1,239.3	8,749.29
Jun22	3,270	2390	393.4	6,053.44
Sum	80,480	53630	20,822.9	1,54,932.9

Initially, it was decided to select three AHUs to analyze and track the effects of the EndoCool chemical on the low side. Temperature data was collected for all three AHUs, while energy consumption data was available only for two AHUs. Running hours of the AHUs were not collected since the selected AHUs were operating for 24 hours. The data collected from the selected AHUs during the baseline period is tabulated below:

Table 8: Baseline AHU 1 Data

LT Room AHU 1					
Date	Energy consumption (kWh)	Supply water temperature (°C)	Return water temperature (°C)	Set point (Air) (°C)	Return air temp (°C)
01-06-2024	NA	11.78	19.38	20.00	29.18
02-06-2024	NA	11.80	19.83	19.92	30.17
03-06-2024	NA	11.60	18.70	20.00	28.55
04-06-2024	NA	11.52	19.05	20.00	28.85
05-06-2024	NA	12.45	19.50	20.00	29.55
06-06-2024	NA	11.90	18.32	20.00	29.22
07-06-2024	NA	10.82	19.33	20.00	30.47

08-06-2024	NA	11.62	19.27	20.00	30.53
09-06-2024	NA	12.01	18.47	20.00	29.75
10-06-2024	NA	11.30	19.25	20.00	29.38
11-06-2024	NA	11.56	19.60	20.00	29.68
12-06-2024	NA	13.03	19.93	20.00	29.73
13-06-2024	NA	12.63	20.37	20.00	30.05
14-06-2024	NA	12.20	19.60	20.00	30.15
15-06-2024	NA	11.70	19.26	20.00	29.96
16-06-2024	NA	11.92	19.15	20.00	29.88
17-06-2024	NA	12.15	19.48	20.00	29.52
18-06-2024	NA	11.38	19.07	20.00	29.37
19-06-2024	NA	11.44	18.58	20.00	29.30
20-06-2024	NA	11.83	19.42	20.00	29.73
21-06-2024	NA	11.67	19.43	20.00	30.37
22-06-2024	NA	11.77	19.30	20.00	29.80
Average	NA	11.82	19.29	20.00	29.69

Table 9: Baseline AHU 2 Data

Pondicherry AHU 2					
Date	Energy consumption(kWh)	Supply water temperature(°C)	Return water temperature(°C)	Set point (Air) (°C)	Return air temp (°C)
01-06-2024	66.86	11.96	17.94	20.00	27.14
02-06-2024	89.96	11.34	18.52	20.00	26.94
03-06-2024	68.90	12.68	18.16	20.00	26.80
04-06-2024	69.70	11.00	17.00	20.00	26.06
05-06-2024	73.53	12.52	51.94	20.00	26.80
06-06-2024	71.11	12.32	18.04	20.00	26.64
07-06-2024	64.71	10.66	18.56	20.00	27.06
08-06-2024	95.29	11.48	17.58	20.00	26.72
09-06-2024	69.78	12.53	18.60	20.00	26.80
10-06-2024	73.29	11.10	18.05	20.00	25.83
11-06-2024	53.78	10.98	17.46	20.00	25.26
12-06-2024	77.65	12.78	19.48	20.00	26.53
13-06-2024	78.45	12.54	19.48	20.00	26.50
14-06-2024	99.01	11.86	18.36	20.00	63.88
15-06-2024	33.68	11.80	18.28	20.00	25.93
16-06-2024	73.16	11.88	17.70	20.00	25.96
17-06-2024	104.70	12.34	18.22	20.00	26.26
18-06-2024	67.52	11.45	18.55	20.00	25.63
19-06-2024	57.64	11.63	17.63	20.00	25.63
20-06-2024	65.20	12.10	18.16	20.00	25.44
21-06-2024	79.83	11.32	18.48	20.00	25.96

22-06-2024	56.40	11.18	16.88	20.00	25.83
Average	72.28	11.79	19.69	20.00	27.98
Sum	1590.2				

Table 10: Baseline AHU 3 Data

SOFIT AHU 3					
Date	Energy consumption(kWh)	Supply water temperature(°C)	Return water temperature(°C)	Set point (Air) (°C)	Return air temp (°C)
01-06-2024	43.31	9.45	15.25	24.00	26.68
02-06-2024	34.15	10.88	16.60	24.75	25.38
03-06-2024	53.66	10.13	15.10	22.00	24.90
04-06-2024	44.77	11.38	16.65	22.00	25.53
05-06-2024	43.21	9.50	15.00	24.25	25.03
06-06-2024	40.12	10.35	15.65	24.00	25.53
07-06-2024	39.28	10.53	15.80	22.00	25.50
08-06-2024	40.50	9.40	14.93	22.00	24.20
09-06-2024	42.99	10.73	15.80	20.00	25.00
10-06-2024	34.82	10.03	15.10	20.00	24.48
11-06-2024	42.29	10.05	15.35	20.00	24.05
12-06-2024	39.62	10.35	15.22	20.00	24.12
13-06-2024	50.76	12.00	16.70	22.00	24.95
14-06-2024	44.59	10.90	15.80	20.00	24.65
15-06-2024	43.53	10.00	15.07	20.00	24.80
16-06-2024	45.88	10.20	15.55	22.00	25.20
17-06-2024	41.98	10.23	15.28	20.00	24.43
18-06-2024	38.98	9.88	15.18	20.00	24.70
19-06-2024	45.15	10.20	13.93	20.00	25.90
20-06-2024	46.17	10.58	15.35	20.00	26.63
21-06-2024	39.80	10.78	16.04	20.00	24.28
22-06-2024	56.32	9.88	15.35	20.00	24.53
Average	43.27	10.34	15.49	21.32	25.02
Sum	951.9				

To analyze changes in weather conditions, WBT and DBT were recorded during the baseline period. However, analysis of the data showed no strong relationship between chiller consumption and these variables. The WBT and DBT data is provided below:

Table 11: Baseline WBT and DBT Data

Date	WBT (°C)	DBT (°C)
Jun-01	29.0	35.0
Jun-02	28.6	35.1
Jun-03	26.0	34.0
Jun-04	27.0	35.0

Jun-05	29.0	34.0
Jun-06	29.0	34.0
Jun-07	29.0	35.0
Jun-08	28.0	34.0
Jun-09	27.0	30.0
Jun-10	26.0	30.0
Jun-11	26.0	30.0
Jun-12	27.0	30.0
Jun-13	28.0	33.0
Jun-14	27.0	30.0
Jun-15	28.0	33.0
Jun-16	28.0	32.0
Jun-17	27.0	32.0
Jun-18	27.0	29.0
Jun-19	27.0	31.0
Jun-20	27.0	31.0
Jun-21	28.0	33.0
Jun-22	28.0	33.2
Average	27.57	32.42

7. Reporting Period

During the reporting period, data from Chiller 2 was utilized, as it remained the only chiller connected to the BMS, ensuring consistent and reliable data. The data from the Chiller 2 was used in reporting period to assess the impact of the pilot. The power consumption of all three chillers was considered to determine energy savings.

Additionally, data from two AHUs was collected to evaluate the pilot's effect on the low side of HVAC system. WBT and DBT were tracked to account for weather conditions. Occupancy levels had only a slight variation during this period and did not have a significant impact on chiller consumption.

BMS data for Chiller 2 was averaged daily. However, due to BMS data loss and reduced operating hours for Chiller 2, some days had to be omitted in the reporting period. As a result, the 22 days in the reporting period are not continuous like in the baseline period. The data collected for the reporting period is tabulated below:

Table 12: Reporting chiller 02 data-1

Date	Run Hrs	Average CHW Set Point(°C)	Average Running Capacity	Evap Entering Water Temp(°C)	Evap Leaving Water Temp(°C)	Evap DT(°C)	Evap Saturated Temp(°C)	Evap Approach Temp(°C)	Calculated Average TR
Jul-01	23.8	8.0	80%	11.7	8.7	3.0	5.5	3.2	177.3
Jul-02	23.6	8.0	70%	12.5	9.9	2.7	6.7	3.2	159.1
Jul-03	19.6	8.0	70%	12.0	9.2	2.8	6.1	3.1	165.0

Jul-04	23.6	8.0	70%	12.5	9.8	2.8	6.6	3.2	166.5
Jul-05	23.6	8.0	80%	11.1	8.3	2.8	5.6	2.8	165.5
Jul-06	17.5	8.0	80%	11.2	8.3	3.0	5.5	2.8	178.6
Jul-07	23.4	8.0	70%	11.4	8.8	2.7	5.9	2.9	159.6
Jul-13	23.7	8.0	80%	11.6	8.3	3.3	5.5	2.8	199.9
Jul-14	23.8	8.0	80%	11.3	8.3	3.0	5.5	2.8	178.3
Jul-17	23.6	8.0	80%	12.1	8.7	3.3	5.6	3.1	200.3
Jul-18	17.6	8.0	70%	12.1	8.8	3.3	5.9	2.9	195.7
Jul-20	23.6	8.0	80%	12.0	8.4	3.5	5.4	3.0	212.3
Jul-22	21.8	8.0	80%	12.6	9.1	3.5	5.7	3.4	211.3
Jul-23	23.8	8.0	80%	12.3	8.9	3.4	5.5	3.4	206.3
Jul-26	17.7	8.0	80%	12.0	8.7	3.3	5.7	3.0	197.4
Jul-27	23.8	8.0	80%	11.6	8.5	3.1	5.4	3.1	187.5
Jul-28	23.2	8.0	80%	11.6	8.4	3.2	5.4	3.0	191.2
Jul-29	23.7	8.0	60%	12.1	9.7	2.4	7.3	2.4	141.6
Jul-30	23.7	8.0	80%	11.5	8.4	3.1	5.5	2.9	185.8
Jul-31	23.7	8.0	80%	12.3	9.1	3.3	5.7	3.4	195.9
Aug-01	23.8	8.0	70%	12.3	9.0	3.3	5.9	3.1	199.5
Aug-02	23.8	8.2	60%	12.6	10.0	2.5	7.8	2.2	151.8
Average	22.6	8.0	75%	11.9	8.9	3.1	5.9	3.0	183.0

The average instantaneous TR delivered by the chiller was calculated using a constant flow rate of 181.25 m³/hr for both the reporting and baseline periods.

Table 13: Reporting chiller 02 data-2

Date	Cond Saturated Temp(°C)	Cond Entering Water Temp(°C)	Cond Leaving Water Temp(°C)	Cond Approach temp (°C)	Average Power (KW)	ikW/TR
Jul-01	36.15	29.75	34.23	1.91	105.09	0.59
Jul-02	35.78	30.05	34.00	1.79	98.73	0.62
Jul-03	36.71	30.73	34.96	1.76	100.38	0.61
Jul-04	36.64	30.31	34.81	1.84	103.87	0.62
Jul-05	35.60	29.72	33.82	1.78	94.08	0.57
Jul-06	36.97	30.59	35.27	1.71	100.57	0.56
Jul-07	35.27	29.64	33.52	1.76	93.62	0.59
Jul-13	34.68	28.40	32.66	2.02	98.64	0.49
Jul-14	35.00	29.19	32.98	2.02	100.02	0.56
Jul-17	35.41	28.69	33.31	2.10	108.98	0.54
Jul-18	35.05	28.55	33.13	1.92	96.22	0.49
Jul-20	35.32	28.46	33.19	2.13	107.78	0.51
Jul-22	35.50	28.50	33.24	2.26	114.06	0.54
Jul-23	35.73	28.56	33.44	2.29	116.47	0.56
Jul-26	35.95	29.21	34.03	1.93	105.47	0.53
Jul-27	35.07	28.67	33.00	2.07	107.23	0.57
Jul-28	35.40	29.04	33.37	2.04	106.70	0.56

Jul-29	29.82	29.04	32.53	1.59	81.85	0.58
Jul-30	35.51	29.12	33.70	1.87	101.46	0.55
Jul-31	36.05	29.29	33.94	2.11	114.22	0.58
Aug-01	35.56	29.01	33.56	2.04	110.30	0.55
Aug-02	29.35	28.76	32.63	1.38	80.06	0.53
Average	35.11	29.24	33.61	1.92	102.08	0.56

The daily power consumption of all three chillers were recorded and is tabulated below for the reporting period:

Table 14: Reporting period chiller power consumption

Date	Chiller 1 kWh	Chiller 2 kWh	Chiller 3 kWh	Total kWh
Jul-01	4,020.00	2,550.00	388.11	6,958.11
Jul-02	510.00	2,370.00	3,811.77	6,691.77
Jul-03	640.00	1,970.00	4,915.45	7,525.45
Jul-04	0.00	2,510.00	4,364.61	6,874.61
Jul-05	0.00	2,260.00	4,433.46	6,693.45
Jul-06	0.00	1,770.00	6,286.58	8,056.58
Jul-07	0.00	2,210.00	4,509.84	6,719.84
Jul-13	0.00	2,360.00	3,539.65	5,899.65
Jul-14	0.00	2,340.00	2,747.95	5,087.95
Jul-17	0.00	2,603.37	3,340.58	5,943.95
Jul-18	0.00	1,674.23	5,141.77	6,816.00
Jul-20	0.00	2,557.17	2,346.25	4,903.42
Jul-22	0.00	2,694.49	2,063.28	4,757.77
Jul-23	200.00	2,804.94	2,011.14	5,016.08
Jul-26	0.00	1,811.51	3,533.01	5,344.52
Jul-27	0.00	2,574.43	1,893.05	4,467.48
Jul-28	0.00	2,512.00	2,364.29	4,876.29
Jul-29	0.00	1,964.30	3,468.41	5,432.71
Jul-30	0.00	2,407.30	2,741.54	5,148.84
Jul-31	0.00	2,703.39	3,049.53	5,752.92
Aug-01	0.00	2,616.53	2,686.00	5,302.53
Aug-02	0.00	1,913.62	4,274.60	6,188.22
Sum	5,370.00	51,177.28	73,910.88	1,30,458.16

For the reporting period, the same approach was applied as followed during the baseline period i.e. temperature data was recorded for all three AHUs, while energy consumption data was available for two of them.

Table 15: Reporting period AHU 1 data

LT Room AHU 1					
Date	Energy consumption(kWh)	Supply water temperature(°C)	Return water temperature(°C)	Set point (Air) (°C)	Return air temp (°C)
Jul-01	NA	11.80	19.74	20.00	29.88
Jul-02	NA	12.32	19.94	20.00	30.23
Jul-03	NA	12.33	19.80	20.00	30.42
Jul-04	NA	12.50	19.18	20.00	29.92
Jul-05	NA	10.70	18.32	20.00	29.66
Jul-06	NA	10.77	18.87	20.00	29.15
Jul-07	NA	10.71	18.68	20.00	29.56
Jul-13	NA	11.43	18.45	24.00	28.30
Jul-14	NA	10.85	17.93	24.00	28.25
Jul-17	NA	11.67	18.62	24.00	28.28
Jul-18	NA	11.50	18.80	24.00	28.66
Jul-20	NA	11.60	18.62	24.00	27.68
Jul-22	NA	11.82	18.23	24.00	28.05
Jul-23	NA	12.50	18.48	24.00	28.17
Jul-26	NA	11.60	18.35	24.00	28.58
Jul-27	NA	11.55	17.98	24.00	27.83
Jul-28	NA	11.55	18.27	24.00	27.98
Jul-29	NA	11.48	17.82	24.00	28.08
Jul-30	NA	11.12	17.58	24.00	27.82
Jul-31	NA	11.73	18.28	24.00	28.35
Aug-01	NA	11.40	18.37	24.00	28.80
Aug-02	NA	11.62	18.40	24.00	28.92
Average	NA	11.57	18.58	22.73	28.75

Table 16: Reporting period AHU 2 data

Pondicherry AHU 2					
Date	Energy consumption(kWh)	Supply water temperature(°C)	Return water temperature(°C)	Set point (Air) (°C)	Return air temp (°C)
Jul-01	50.36	11.84	18.80	20.00	25.82
Jul-02	71.82	12.22	19.30	20.00	26.34
Jul-03	65.76	12.24	19.26	20.00	26.11
Jul-04	67.04	12.34	19.34	20.00	25.80
Jul-05	70.83	10.37	17.47	20.00	25.97
Jul-06	70.83	10.44	18.66	20.00	26.22
Jul-07	68.03	10.42	17.22	20.00	25.42
Jul-13	66.00	10.62	18.80	24.00	24.42
Jul-14	66.96	10.36	17.78	24.00	24.48
Jul-17	67.21	11.50	18.12	24.00	24.78
Jul-18	67.37	10.92	18.86	24.00	24.62

Jul-20	66.60	10.98	18.20	24.00	24.68
Jul-22	64.32	11.08	17.94	24.00	24.56
Jul-23	64.33	11.42	17.76	24.00	24.88
Jul-26	105.14	11.17	18.60	24.00	24.70
Jul-27	42.57	12.18	16.34	24.00	24.92
Jul-28	77.10	11.30	17.52	24.00	24.62
Jul-29	82.27	11.18	17.74	24.00	24.64
Jul-30	72.73	10.74	17.36	24.00	24.82
Jul-31	69.98	11.44	18.56	24.00	25.16
Aug-01	79.38	11.03	17.23	24.00	24.88
Aug-02	53.18	10.92	18.06	24.00	25.32
Average	68.63	11.21	18.13	22.73	25.14
Sum	1,509.8				

Table 17: Reporting period AHU 3 data

SOFIT AHU 3					
Date	Energy consumption(kWh)	Supply water temperature(°C)	Return water temperature(°C)	Set point (Air) (°C)	Return air temp (°C)
Jul-01	29.69	10.48	16.33	20.00	23.90
Jul-02	51.45	11.20	16.88	20.00	24.50
Jul-03	43.60	10.95	15.88	20.00	24.43
Jul-04	39.46	11.90	15.08	20.75	24.78
Jul-05	55.76	10.27	15.50	21.33	24.53
Jul-06	32.25	9.43	14.87	21.00	27.67
Jul-07	36.20	9.90	14.98	20.00	24.00
Jul-13	36.60	9.75	14.15	20.00	22.23
Jul-14	41.84	9.55	13.90	20.00	22.60
Jul-17	38.31	9.73	17.15	23.00	23.15
Jul-18	31.22	9.33	15.05	23.50	23.00
Jul-20	44.34	9.93	14.30	22.67	22.37
Jul-22	38.55	10.40	14.87	23.33	22.50
Jul-23	35.75	12.35	10.20	22.00	22.03
Jul-26	40.68	11.50	15.75	22.00	23.05
Jul-27	38.68	10.18	15.03	22.00	22.83
Jul-28	42.12	10.10	15.03	22.00	22.50
Jul-29	35.52	10.33	15.03	22.50	23.45
Jul-30	43.47	9.78	17.35	23.50	23.38
Jul-31	44.45	11.08	16.03	24.00	24.33
Aug-01	44.99	11.00	15.07	24.00	22.43
Aug-02	44.67	13.03	15.18	24.00	23.13
Average	40.44	10.55	15.16	21.89	23.49
Sum	889.6				

In the reporting period, WBT and DBT were recorded for the ambient conditions but no significant correlation between these variables and chiller consumption was found, as was the case in the baseline period.

Table 18: Reporting period WBT and DBT Data

Date	WBT(°C)	DBT(°C)
Jul-01	26.0	30.0
Jul-02	26.0	30.0
Jul-03	27.0	31.0
Jul-04	NA	NA
Jul-05	28.0	28.0
Jul-06	27.0	30.0
Jul-07	28.0	30.0
Jul-13	26.0	30.0
Jul-14	26.0	29.0
Jul-17	27.0	29.0
Jul-18	NA	NA
Jul-20	27.0	32.0
Jul-22	27.0	32.0
Jul-23	27.0	32.0
Jul-26	27.0	29.0
Jul-27	26.0	28.0
Jul-28	26.0	29.0
Jul-29	26.0	28.0
Jul-30	27.0	32.0
Jul-31	27.0	31.0
Aug-01	27.0	31.0
Aug-02	27.0	31.0
Average	26.75	30.10

8. Data analysis

The data analysis was conducted to assess the impact of the pilot on chiller performance parameters and the energy savings obtained by the pilot. The comparative analysis of chiller evaporator and condenser water temperatures of baseline and reporting period is tabulated below:

Table 19: Baseline x Reporting-Chiller parameters 1

Day	Evap Entering Water Temp(°C)		Evap Leaving Water Temp(°C)		Cond Entering Water Temp(°C)		Cond Leaving Water Temp(°C)	
	Baseline	Reporting	Baseline	Reporting	Baseline	Reporting	Baseline	Reporting
Day 1	12.44	11.70	8.31	8.74	30.39	29.75	36.42	34.23
Day 2	11.69	12.55	8.42	9.90	30.71	30.05	36.00	34.00
Day 3	11.66	12.00	8.66	9.25	29.99	30.73	34.52	34.96
Day 4	11.48	12.55	8.38	9.77	30.01	30.31	34.30	34.81

Day 5	11.81	11.09	8.51	8.33	31.04	29.72	36.11	33.82
Day 6	12.09	11.24	9.01	8.26	30.13	30.59	34.51	35.27
Day 7	10.61	11.42	7.68	8.76	30.52	29.64	34.96	33.52
Day 8	11.92	11.62	8.57	8.29	29.58	28.40	35.29	32.66
Day 9	11.66	11.30	8.41	8.33	29.28	29.19	34.30	32.98
Day 10	11.55	12.06	8.61	8.72	28.72	28.69	32.87	33.31
Day 11	12.31	12.07	9.06	8.80	30.23	28.55	35.17	33.13
Day 12	13.02	11.97	10.17	8.43	29.94	28.46	33.76	33.19
Day 13	12.52	12.60	9.45	9.08	29.78	28.50	34.08	33.24
Day 14	11.68	12.33	8.49	8.88	30.23	28.56	35.31	33.44
Day 15	11.77	12.02	8.89	8.73	29.84	29.21	34.15	34.03
Day 16	12.20	11.61	9.08	8.48	29.65	28.67	34.30	33.00
Day 17	11.60	11.57	8.70	8.38	29.96	29.04	34.25	33.37
Day 18	11.50	12.05	8.46	9.69	29.11	29.04	34.12	32.53
Day 19	12.42	11.48	9.36	8.38	29.40	29.12	34.15	33.70
Day 20	11.91	12.34	9.02	9.08	30.15	29.29	34.24	33.94
Day 21	11.46	12.31	8.56	8.99	31.58	29.01	36.27	33.56
Day 22	11.57	12.57	8.60	10.04	29.03	28.76	33.30	32.63
Average	11.86	11.93	8.75	8.88	29.97	29.24	34.65	33.61

A day-to-day comparison between the baseline and reporting values does not provide precise insights of the pilot effects. Instead, analyzing the average values over the 22-day period gave better insights. The analysis shows that the evaporator entering and leaving water temperatures of both the periods were almost identical.

The comparative analysis of chiller condenser approach, evaporator approach, and saturated temperatures of baseline and reporting period is given below:

Table 20: Baseline x Reporting-Chiller parameters 2

Day	Cond. Approach(°C)		Evap. approach(°C)		Evap. Saturated temp(°C)		Cond. Saturated temp(°C)	
	Baseline	Reporting	Baseline	Reporting	Baseline	Reporting	Baseline	Reporting
Day 1	2.12	1.91	3.39	3.21	4.92	5.53	38.54	36.15
Day 2	2.03	1.79	3.46	3.22	4.95	6.68	38.03	35.78
Day 3	2.15	1.76	3.49	3.14	5.17	6.11	36.67	36.71
Day 4	2.04	1.84	3.27	3.16	5.11	6.62	36.35	36.64
Day 5	1.98	1.78	3.35	2.75	5.17	5.58	38.09	35.60
Day 6	2.10	1.71	3.65	2.76	5.37	5.50	36.60	36.97
Day 7	1.97	1.76	3.28	2.89	4.40	5.87	36.92	35.27
Day 8	1.93	2.02	3.48	2.78	5.10	5.51	37.22	34.68
Day 9	2.01	2.02	3.35	2.84	5.06	5.48	36.31	35.00
Day 10	1.95	2.10	3.27	3.07	5.33	5.65	34.83	35.41
Day 11	2.00	1.92	3.59	2.87	5.47	5.94	37.16	35.05
Day 12	1.94	2.13	3.60	3.02	6.58	5.41	35.70	35.32
Day 13	1.99	2.26	3.54	3.40	5.90	5.68	36.07	35.50

Day 14	1.89	2.29	3.28	3.36	5.21	5.53	37.19	35.73
Day 15	1.93	1.93	3.40	3.02	5.48	5.71	36.08	35.95
Day 16	2.02	2.07	3.56	3.06	5.52	5.43	36.33	35.07
Day 17	1.83	2.04	3.09	2.96	5.60	5.43	36.08	35.40
Day 18	1.93	1.59	3.30	2.42	5.16	7.25	36.05	29.82
Day 19	2.01	1.87	3.55	2.91	5.81	5.47	36.15	35.51
Day 20	1.92	2.11	3.27	3.42	5.75	5.67	36.15	36.05
Day 21	1.80	2.04	3.24	3.13	5.32	5.86	38.06	35.56
Day 22	1.87	1.38	3.21	2.18	5.39	7.78	35.17	29.35
Average	1.97	1.92	3.39	2.98	5.35	5.90	36.62	35.11

The analysis indicates that the condenser approach remained unchanged between the two periods, reinforcing the analysis of improved and efficient heat transfer within the chiller. Additionally, the evaporator approach improved by 0.41°C while evaporator saturated temperature increased by 0.54°C. Efficiency and consumption of Chiller 2 in the table below also shows improvements.

Table 21: Baseline x Reporting-Chiller efficiency and consumption

Day	Running hours		ikW/TR		Chiller 02 kWh		Difference
	Baseline	Reporting	Baseline	Reporting	Baseline	Reporting	
Day 1	18	24	0.51	0.59	2,320	2,550	-230
Day 2	17	24	0.62	0.62	2,030	2,370	-340
Day 3	24	19	0.65	0.61	2,840	1,970	870
Day 4	25	24	0.60	0.62	2,710	2,510	200
Day 5	18	24	0.61	0.57	2,170	2,260	-90
Day 6	24	18	0.63	0.56	2,770	1,770	1000
Day 7	23	24	0.66	0.59	2,780	2,210	570
Day 8	19	24	0.58	0.49	2,270	2,360	-90
Day 9	24	24	0.57	0.56	2,710	2,340	370
Day 10	24	24	0.58	0.54	2,470	2,603	-133
Day 11	18	18	0.60	0.49	2,040	1,674	366
Day 12	24	24	0.62	0.51	2,790	2,557	233
Day 13	23	24	0.59	0.54	2,340	2,694	-354
Day 14	18	24	0.59	0.56	1,990	2,805	-815
Day 15	24	17	0.63	0.53	2,580	1,812	768
Day 16	24	24	0.61	0.57	2,630	2,574	56
Day 17	22	24	0.59	0.56	2,360	2,512	-152
Day 18	24	18	0.60	0.58	2,530	1,964	566
Day 19	20	24	0.60	0.55	2,240	2,407	-167
Day 20	25	24	0.61	0.58	2,580	2,703	-123
Day 21	17	24	0.64	0.55	2,090	2,617	-527
Day 22	25	17	0.58	0.53	2,390	1,914	476
Average	21.82	22.32	0.60	0.56	2,320	2,550	111.49
Sum	480.00	491.00			53,630	51,177	2,453

The aforementioned data shows an improvement in the chiller's efficiency (iKW/TR), with a reduction of 0.04 in the reporting period, representing a 6.7% improvement over the baseline period value. The consumption data indicates an energy savings of 2,453 kWh over the 22-days of the reporting period which equates to a 4.6% reduction compared to the baseline period, solely from Chiller 02. There is a difference in running hours between baseline & reporting period for chiller 2 and savings are normalized to get more accurate and precise figures which is calculated in the table below:

Table 22: Chiller 2 power consumption post normalization

Chiller 2 Data	Baseline	Reporting
Total running hours (A)	480.00	491.00
Total kWh (B)	53,630	51,177
kWh/Running hours (C = B/A)	111.73	104.23
Normalized kWh of reporting period as per baseline running hours (D=C2*A1)	50,031	
Energy savings kWh (B1-D)	3,599	
Energy savings %	6.7%	

The effect of EndoCool is evident from chiller 2 data and a more comprehensive understanding of the savings from the pilot can be obtained by analyzing the consumption data from all three chillers. Running hours normalization was not applied for chiller 1 & 3 due to the significant difference in the running hours between the baseline and reporting periods. The consumption data for all three chillers are provided in the table below:

Table 23: Baseline x Reporting-Chiller Consumption

Day	Chiller 1 kWh		Chiller 2 kWh		Chiller 3 kWh		Total Chiller kWh	
	Baseline	Reporting	Baseline	Reporting	Baseline	Reporting	Baseline	Reporting
Day 1	0	4,020	2,320	2,550	4,386	388	6,706	6,958
Day 2	5,570	510	2,030	2,370	1,027	3,812	8,627	6,692
Day 3	2,780	640	2,840	1,970	800	4,915	6,420	7,525
Day 4	3,170	0	2,710	2,510	867	4,365	6,747	6,875
Day 5	5,470	0	2,170	2,260	480	4,433	8,120	6,693
Day 6	4,030	0	2,770	1,770	206	6,287	7,006	8,057
Day 7	3,800	0	2,780	2,210	1,781	4,510	8,361	6,720
Day 8	3,960	0	2,270	2,360	1,183	3,540	7,413	5,900
Day 9	3,210	0	2,710	2,340	275	2,748	6,195	5,088
Day 10	3,080	0	2,470	2,603	481	3,341	6,031	5,944
Day 11	3,610	0	2,040	1,674	1,383	5,142	7,033	6,816
Day 12	4,040	0	2,790	2,557	14	2,346	6,844	4,903
Day 13	4,520	0	2,340	2,694	276	2,063	7,136	4,758
Day 14	3,330	200	1,990	2,805	2,235	2,011	7,555	5,016
Day 15	3,170	0	2,580	1,812	1,364	3,533	7,114	5,345
Day 16	4,240	0	2,630	2,574	0	1,893	6,870	4,467
Day 17	3,810	0	2,360	2,512	761	2,364	6,931	4,876

Day 18	3,450	0	2,530	1,964	0	3,468	5,980	5,433
Day 19	2,790	0	2,240	2,407	1,182	2,742	6,212	5,149
Day 20	3,760	0	2,580	2,703	490	3,050	6,830	5,753
Day 21	5,420	0	2,090	2,617	1,239	2,686	8,749	5,303
Day 22	3,270	0	2,390	1,914	393	4,275	6,053	6,188
Average	3,658.18	244.09	2,437.73	2,326.24	946	3,360	7,042	5,930
Sum							1,54,933	1,30,458
Savings in kWh (%)							24,475 (15.8%)	
Opex savings (Rs 9.5/kWh)							₹ 2,32,510.08	

During the reporting period, the total energy consumption of the chillers was 130,458 kWh, compared to 154,933 kWh during the baseline period. This reflects an energy savings of 24,475 kWh, a 15.8% reduction. These energy savings translated into operational cost (Opex) savings of Rs. 2,32,510.08 considering an electricity unit cost of Rs.9.5/kWh. Additionally, a comparison of WBT and DBT is conducted to assess any changes in weather conditions which is shown in the table below:

Table 24: Baseline x Reporting-WBT and DBT

Particular	WBT(°C)		DBT(°C)	
	Baseline	Reporting	Baseline	Reporting
Average	27.57	26.75	32.42	30.10
Difference	0.82		2.32	

There is a reduction of 0.82°C in WBT and 2.23°C in DBT during the reporting period. But there was no clear relationship between WBT, DBT and chiller consumption in the data collected for both baseline and reporting period. Additionally, due to a slight increase in occupancy as reported by the Sofitel team, it is assumed that the impact of higher occupancy may have offset the effects of the WBT and DBT reduction. Running hours of three chillers were collected in both baseline and reporting period, which gives more insights into improvements made by the pilot technology.

Table 25: Baseline x Reporting-chiller running hours

Chiller Number	Baseline Running hours	Reporting Running hours
Chiller 1	645	42
Chiller 3	168	587
Chiller 2	480	491
Total	1,293	1,120
Difference	173	

The data indicates that Chiller 2 operated for nearly the same number of hours during both the baseline and reporting periods. In contrast, the other two chillers, which functioned as standby units, ran significantly fewer hours combined to the reporting period. When examining all three chillers collectively, there was a reduction of 173 hours in operation during the reporting period. This

reduction, occurred without any major changes in the building's load profile, showed an improvement in the heat transfer efficiency of the chillers during the reporting period. While the efficiency differences of chillers 1 and 3 may also have influenced this outcome, the lack of data to quantify their performance, the similarity in model and make of these chillers led to an assumption that their efficiencies are approximately equivalent.

Data collected from the AHUs was also compared between the baseline and reporting periods. Three AHUs were selected for low side data collection and the comparison was conducted using the two AHUs for which energy consumption data was available. The results of this comparison are provided in the table below:

Table 26: Baseline X Reporting- AHU Data

Parameter	Pondicherry AHU 2			SOFIT AHU 3		
	Baseline	Reporting	Change	Baseline	Reporting	Change
Average Supply water temperature (°C)	11.79	11.21	0.58	10.34	10.55	-0.21
Average Return water temperature (°C)	19.69	18.13	1.56	15.49	15.16	0.33
DT(°C)	7.9	6.92	0.98	5.15	4.61	0.54
Average Set point (Air) (°C)	20	22.73	-2.73	21.32	21.89	-0.57
Average Return air temp: (°C)	27.98	25.14	2.84	25.02	23.49	1.53
Average Energy Consumption	72.28	68.63	3.65	43.27	40.44	2.83
Total Energy consumption	1,590.2	1,509.8	80.4	951.9	889.6	62.3
Savings (%)	5.1%			6.5%		

When the data from two AHUs with their energy consumption data was compared, a reduction in energy consumption is evident. The room temperature set point of Pondicherry AHU was increased during the reporting period, making it difficult to attribute the savings solely to the EndoCool pilot. However, the Sofit AHU, which maintained a similar setpoint in both the baseline and reporting periods, showed a reduction of 6.5% in energy consumption. This suggests that EndoCool is contributing to savings on the low side as well. Additionally, both AHUs exhibited a reduction in chilled water delta T, along with an improvement in room temperature as indicated by the return air temperature. This indicates enhanced heat transfer in the AHU coils as well. To calculate the savings from EndoCool on low side, a comprehensive study is required. This would involve collecting data at regular intervals and recording additional parameters for a defined period for all AHUs including actual running hours and the occupancy levels of the spaces served by the AHUs.

9. GHG Emission

To calculate the GHG emissions avoided by the pilot technology, the amount of electricity saved by the pilot was taken into account. An emission factor of 0.82 kg CO₂ per kWh was used to determine the GHG emission reductions achieved through the pilot implementation (Refer Annexure A). The detailed calculation is shown in the table below:

Table 27:GHG Emission

Particular	Kg of CO ₂ /kWh	kWh	Kg of CO ₂
Baseline period	0.81	1,54,933	1,27,044.98
Reporting period	0.81	1,30,458	1,06,975.69
Savings	0.81	24,475	20,069.29

The results indicate that the EndoCool system achieved a total GHG savings of 20.06 tCO₂ over 22 days of operation.

10. Conclusion

The M&V study aimed at evaluating the impact of EndoCool chemical on the chilled water system of HVAC plant at Sofitel BKC, Mumbai. The analysis focused on the performance of Chiller 02, the only unit consistently connected to the BMS, along with data from AHUs across both the baseline and reporting periods. The measurement boundary considered for the study was all the three chillers of the facility. The data collection period of the baseline and reporting period was of 22 days each.

The data from chiller 2 shows a 0.04 (6.7 %) reduction in iKW/TR and energy savings of 2,453 kWh over the 22-day reporting period, representing a 4.6% reduction in energy consumption compared to the baseline data of chiller 2. Post normalizing the running hours of chiller 2, the energy savings was recalculated to be 3,599 kWh, equating to a 6.75% reduction.

The evaporator side showed improvements in chiller 2 parameters, with a 0.41°C reduction in evaporator approach and a corresponding 0.54°C increase in the saturated temperature of the refrigerant in evaporator. These improvements indicate more efficient heat transfer within the chiller, leading to optimized performance in the evaporator.

While considering all three chiller energy consumption, the total energy savings obtained was 24,475 kWh (15.8%) during the 22-day reporting period, indicating that the positive effects of the EndoCool chemical were not limited to Chiller 02 alone but were consistent across all the chillers.

Weather data analysis shows a reduction of 0.82°C in WBT and 2.23°C in DBT during the reporting period. However, no significant relationship was found between these variables and chiller consumption. This indicates that the DBT & WBT reduction had minimal effect on chiller performance. Additionally, a slight increase in occupancy during the reporting period may have offset potential savings resulting from the DBT & WBT variation.

To fully confirm the extent of EndoCool's benefits across both the high and low side of the HVAC system, a more comprehensive study needs to be conducted. This would involve regular data collection for the defined period, monitoring additional variables such as actual running hours, occupancy, and more detailed AHU performance metrics. This will help quantify the complete energy savings potential and further validate the positive effects of EndoCool across the entire HVAC system.

In conclusion, the pilot study demonstrated that EndoCool improved heat transfer in the chilled water loop, which lead to significant energy savings at the chillers. The energy savings achieved the expected 15% energy savings proposed by EndoCool prior to the pilot implementation which confirmed the expected performance from the pilot. The results support the broader adoption of this technology as a key component in enhancing energy-efficient cooling strategies for the commercial facilities. However, a comprehensive study of the EndoCool's chemical additive across high side and low side collectively needs to be conducted to understand its benefits at the HVAC system level.

11. Appendix

11.1 Non-M&V parameters

Please refer Appendix - A_Non-M&V Parameters

11.2 Data analysis sheet

Please refer Appendix - B_Data analysis sheet

11.3 GHG Emission factor

Please refer Appendix - C_GHG Emission factor