Facility for Low Carbon Technology Deployment

Promoting Innovation and Deployment of Low Carbon Technologies

ZedBee Technologies

(Automated HVAC control in buildings)

FLCTD 2019 Grant Winner

Measurement and Verification Report of Technology Demonstration and Validation

Prepared By

Confederation of Indian Industry

CII – Sohrabji Godrej Green Business Centre

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Disclaimer

This measurement and verification report is part of the United Nations Industrial Development Organization (UNIDO), Bureau of Energy Efficiency (BEE), Government of India and CII-Godrej GBC's effort with the support of the Global Environment Facility (GEF); to establish the efficacy of innovation that will lend credibility of the innovation to seek financing for scale-up.

The benefits estimated by CII-GBC were based on data gathered from field trials at different locations. Since this solution/product is not yet commercially available, the return on investment (ROI) has not been estimated.

PREFACE

The “Facility for Low Carbon Technology Deployment” (FLCTD) project was launched in 2016 with funding from GEF and in collaboration with BEE and UNIDO as the implementation partners. The main objective of this project is to facilitate the deployment and scaling up of low-carbon technologies in India that can address technology gaps in mitigating climate change and promote the use of clean energy applications in selected sectors. The main function of the ‘Facility*’ is to identify high-impact challenges that if solved have the potential for large-scale carbon emission reductions. The project aims to locate and link the critical connections between the stakeholders – those who are aware of the high-impact challenge and those with the technical expertise to provide solutions – to solve problems identified by experts. The solution to the high-impact challenges is identified through “Innovation Challenges”, an open award competition, which provides innovative solutions to identified problems and attracts private investments in research to meet the goals stated under the award competition. Each winner receives:

- Grant award up to USD 50,000 for winning technology demonstration at multiple locations.
- Performance Verification to establish the efficacy of the innovative technology in field working conditions.
- Facilitating commercialization by financial mentoring and fundraising guidance.
- Recognition from Bureau of Energy Efficiency and UNIDO.

The grant award enables the deployment and validation of the innovations at field locations; typically, industries/firms are willing for pilot demonstration where the technology is periodically monitored, and performance validated. The technology verification process will help to establish the efficacy of innovation and will lend credibility to innovation to seek financing for scale-up (credible enough to enable banks and other FIs to use the verification reports a collateral).

To achieve these objectives, the project has built a Technology Verification process for all FLCTD grant winning innovations in consultation with the implementation partner, the Confederation of Indian Industry (CII). For the 2018 winners, the CII team worked with each of them in identifying industries/ firms where the winning innovations were installed to demonstrate energy savings.

For each of the 2019 winning innovations, CII-Sohrabji Godrej Green Business Centre, Hyderabad conducted baselining and verification of the efficacy of innovative technologies post commissioning, over a 6 to 8-month period, by applying the Technology Verification process. CII submitted the Technology Verification report to the PMU, which was shall be submitted for the scrutiny of the members of the expert panel and BEE.

**The BEE, the PMU-UNIDO and the Expert Panel are referred to as "The Facility" henceforth.*

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LIST OF ABBREVIATIONS

AC	Air Conditioners
AHU	Air Handling Unit
BEE	Bureau of Energy Efficiency
BMS	Building Management System
BTU	British Thermal Unit
CHW	Chilled Water
CII	Confederation of Indian Industry
DC	Distribution Centre
FLCTD	Facility for Low Carbon Technology Deployment
GHG	Greenhouse Gas
HVAC	Heating Ventilation and Air-Conditioning
INR	Indian Rupees
MD	Maximum Demand
MTOE	Metric Ton of Oil Equivalent
M&V	Measurement and Verification
TR	Tonne of Refrigeration
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

UNIT OF MEASUREMENTS

BTU	British Thermal Unit
CFM	Cubic Feet per Minute
^{o}C	Degree Celsius
Hz	Hertz
Kg	Kilo grams
kW	KiloWatt (Active Power)
kWh	Kilo Watt Hour
L, Lt	Litre
mm WC	Millimetres of Water Column
MT	Metric Tonne
Sq. m	Square meter

TECHNOLOGY VERIFICATION REPORT

ABOUT THE COMPANY

ZedBee Technologies Private Limited (hereinafter referred to as "Zedbee") formerly known as Swadha Energies is an IIT Madras start up providing IoT based innovative solutions for HVAC systems focusing on energy efficiency. They are committed to innovating and inspire the way building operates. Zedbee has both a software and hardware range of solutions - Smart Software solutions include dash boards, cloud-based control, and data modelling using AI/ML. The hardware part includes data monitoring and energy optimization solutions through intelligent controllers and optimizers for comfort and indoor air quality. The company's clientele extends across different industrial sectors by helping them in a significant reduction of energy consumption and making a positive impact on comfort and quality.

Name of the company	ZedBee Technologies Private Limited
Address of registered office and site of operations	B3/4, B-Block, 3rd floor, IIT Madras research park, Taramani, Chennai - 600113
Names & contact details (tel. / email)	Mr. Sreejith S, +91 8943021886, sreejith@zedbee.in

DETAILS OF THE INNOVATION

- **Name of the innovation:** ZedBee – Automated HVAC control in buildings.
- **Areas of application:** For autonomous controlling of the blower and chilled water flow in the AHU in buildings based on the return air temperature.
- **M&V methodology:** As per the International Performance Measurement and Verification Protocol (IPMVP), Option A (Partially Measured Retrofit Isolation) is adopted for validation of the technology.
- **Specifications:**

Table 1: Zedbee system Specifications

Equipment	Make	Model	Application
VFD	Zedbee	Metis	For controlling and monitoring of AHU
Electronic pressure independent valve	Belimo	EP050R+MP	For controlling the chilled water flowrate
Immersion temperature sensor	Zedbee	3K NTC Type	For measuring the chilled water temperature

Air differential pressure switch	Belimo	01APS-10U	For measuring the air filter status
Duct temperature sensor	Zedbee	3K NTC Type	For measuring return air duct temperature
Indoor air quality sensor	Zedbee	IAQ	For measuring the indoor air quality - PM 2.5, PM 10, TVOC, CO2 & RH
Water flow meter	Dwyer	IEF Series	For measuring the chilled water flow
Sensor node	Zedbee	Sensor Node	For monitoring and control of HVAC equipment

- **Working Principle:** Zedbee system uses IoT enabled sensors and controllers for controlling the chilled water flow and air flow in AHUs based on the return air temperature.For day-to-day data monitoring, the system is integrated with a high-end dashboard that shows real time data with various parameters like energy, consumption, water and air flow. All the collected data are stored in the cloud that can be accessed whenever required. The step-by-step working methodology of the system is as follows:

1. Set point temperature is programmed into the Zedbee controller.
2. Temperature sensor measures the supply air, return air temperature of the AHU and inlet temperature of the chilled water, and send feedback to the controller.
3. Flowmeter in the chilled water line gives inputs to the controller about the quantity of incoming chilled water to AHU.
4. With all the inputs received through IoT, the controller analyses them and decides the air flow and chilled water flow as per the pre-defined control logics.
5. Subsequently, chilled water flow is controlled by actuating the position of valves and airflow is varied by changing the AHU blower frequency using VFD.
6. High-end dashboard records and monitors all the data received. It analyses the data to show the hourly consumption of each utility. This also enables to give required user inputs to the controller.

- **Component Overview:**

1. Temperature sensors – Sensors are installed in the supply and return air duct of each AHU and in the chilled water inlet line to measure temperatures respectively.
2. Flow meter – It is installed in the chilled water line to measure the flow of chilled water into the AHU.
3. Control valves – These valves are installed in the chilled water supply/return line to control the flow.
4. Variable Frequency Drive (VFD) – All AHU are enabled with VFD to control the airflow.
5. Smart controller – Zedbee's smart controller receives input from all the sensors through IoT and controls the flow of chilled water using an automated actuator connected to the control valves. Also, controls the frequency of AHU through VFD as per the inputs.

6. Dashboard – All the controllers and sensors are connected to a high-end dashboard which acts as a single point monitor and control system for the entire buildings HVAC. It shows the hourly energy consumption of all the major equipment integrated like chiller, AHU, etc., Since all the data are stored in the cloud, they can view and verified whenever required. Inbuilt wireless interface reduces the supply, installation, and labour charges.

- **Schematic diagram:**

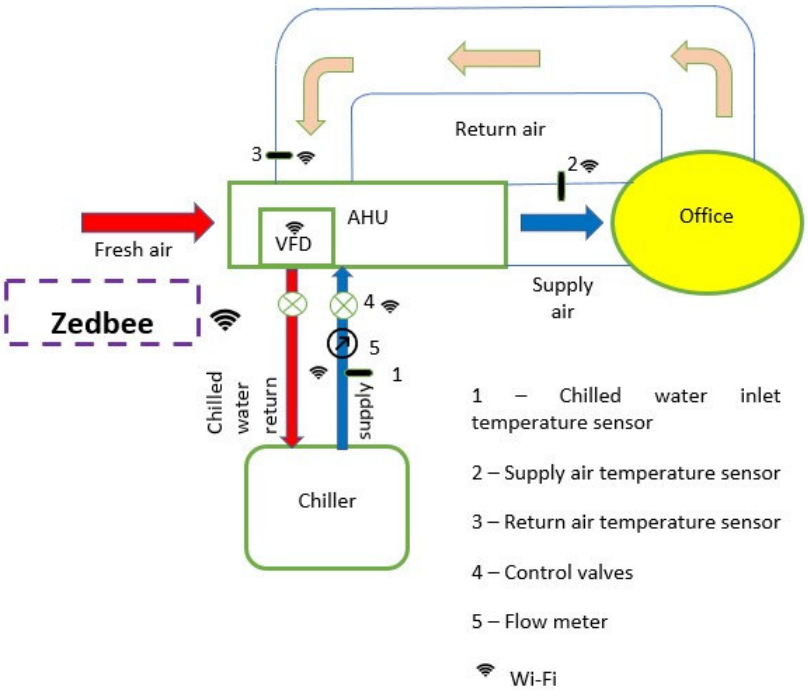


Figure 1: System Schematic

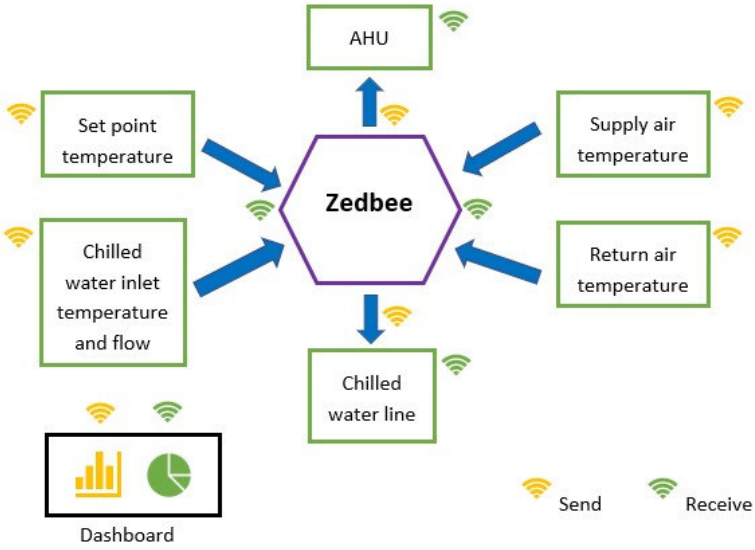


Figure 2: Working Principle

- **Benefits:**
    1. Automated control of chilled water flow in the AHU by controlling actuator based on design set point, return air temperature helps in BTU savings.
    2. Varying the speed of blower in AHU autonomously using VFD as per the inputs from the controller based on sensors data and setpoint temperature. This in turn avoids full load operation of AHU throughout the day, hence saving energy.
    3. Room temperature is maintained +/-1 deg C from the set point temperature (25 deg C)
    4. Chiller and AHU power consumption monitoring in an hourly basis on Zedbee Dashboard integrated with the system.
    5. Dashboard enables to monitor ON/OFF status, auto/manual status and trip status of the chiller, AHU, pumps and cooling tower.

DESIGN OBJECTIVES OF THE INNOVATION

Air conditioning in the workplace has become a necessity for a healthy and productive environment. This also creates a demand for centralised HVAC systems that consume significantly high energy when compared to the split ACs or other decentralised AC systems. Around 50-60% of the annual costs spent on building management is for the energy hence making energy optimization is no longer an option for business. The major problem in the centralised HVAC system in the building is running of equipment at full load all the time regardless of ambient conditions, setpoint and occupancy.

Conventional building control systems which are over designed requires more resources to install, commission and operate which creates high cost of acquisition and operation. There are few other disadvantages exist in the conventional Building Management System (BMS) such as lack of flexibility, poor scalability, complicated integration, manual intervention.

Zedbee technologies come up with an innovative solution for the web-based control of centralised air conditioning systems in buildings. With IoT enabled and Machine Learning (ML) based algorithms in the cloud, Zedbee system can integrate numerous sensors and controllers. Adaptation of Artificial Intelligence (AI) powered self-learning differentiates Zedbee system from the conventional BMS by exhibiting the following features:

1. Simpler installation and configuration of automation system
2. Cloud based control enabling dynamic variation of operating parameters and user friendly compared to the PLC based systems.

Zedbee automated HVAC control requires very minimal/zero manual intervention in turn avoids the manual error and resource need. This technology can help building management sector reduce operational expenses significantly and save energy costs up to 30%

SELECTION UNDER FLCTD INNOVATION CHALLENGE

In 2019 the 2nd Annual Innovation Challenge under the FLCTD project was announced in the 3rd week of May 2019. The Terms of Reference of the Space Conditioning innovation challenge are attached in **Annexure A**. The application submission was closed on 19th August 2019, and 34 applications were received in the Space Conditioning vertical. The review of applications by the expert panel members was held on 5th September 2019 in which five applications were shortlisted for final presentation. The final presentations by the shortlisted applicants under the Space Conditioning vertical were held at the UNIDO project office on 1st October 2019. Based on the merit of innovations and replication potential, all five firms were selected by an expert panel for receiving financial assistance from the FLCTD project.

1. M/s Zedbee Technologies Private Limited (Formerly known as Swadha Energies Private Limited
2. M/s New Leaf Dynamic Technologies private limited (NLD)
3. M/s Inficold India Private Limited
4. M/s Promethean Spenta Technologies Private Limited
5. M/s Tan 90 Thermal Solutions Private Limited

The experts acknowledged that the technology offered an innovative technical solution to strengthen the cold chain sector and given the huge untapped market, recommended to extend support to the company for demonstration.

1. SCOPE OF DEMONSTRATION UNDER FLCTD

The objective of Zedbee technology is to innovate the way building HVAC operates, ensuring:

- Improved quality and comfort.
- Elimination of unwanted full load operation of equipment.
- Reduced energy consumption.
- Low carbon emissions.
- Centralised web-based control with cloud-based automation.

The details of the demonstration site are given below:

Table 2: Pilot Site Details

Demonstration Site Details					
S.No	Name of the pilot/project site	Location	Name of the contact person at the site	Contact details (Tel/Email)	Type of industry for site demonstration
1	CTS Sholinganallur (Elcot SEZ)	Chennai	Mr. Mohan Elango	Mohan.Elango@cognizant.com	Office building
2	CTS Tambaram (Mepz)	Chennai	Mr. Mohan Elango	Mohan.Elango@cognizant.com	Office building
3	Tamarai tech park	Chennai	Mr. Ramesh	ramesh.amti@pioneerasia.com	Office building
4	Airport Authority of India	Chennai	Mr. Raghu Rama Reddy	raghusr@AAI.AERO	Commercial building
5	Phoenix market city	Mumbai	Mr. Ashish	ashishpatre.s@phoenixmills.com	Commercial building
6	CII – Sohrabji Godrej Green Business Centre (CII)	Hyderabad	Mr P V Kiran Ananth	kiran.ananth@cii.in	Office building

2. BASELINE STUDY

The pilot installation was done at different locations across Tamil Nadu & Telangana, for demonstrating the benefits of "Zedbee Technology" which can be used as a smart HVAC management system application in building sectors for automated control and monitoring of equipment. The baseline parameters of all the six sites are mentioned in the table below including

- Design parameters,
- Operating parameters and
- Electrical energy consumption on an hourly basis.

Baseline Parameters:

Table 3: AHU Parameters

Description	Metric	Design Parameters						Remarks
Site name		CII	CTS Sholingan allur	CTS Tambara m	Tamarai Tech Park	Airport Authority of India, Chennai	Phoenix Marketcit y, Mumbai	
Make/model		Zeco	NA	EC fans	NA	NA	NA	Data from the name plate
Airflow	CFM	3,000	16,000	12,000	18,000	16,000	10,806	
Static pressure	mm WC	50	NA	NA	NA	NA	NA	
Motor rating	kW	1.5	NA	NA	NA	NA	NA	Data from the name plate
VFD installed		Yes. Make: ZedBee	Yes. Make: Danfoss	No	Yes. Make: ABB	Yes. Make: Danfoss	No	
Frequency set limit	Hz	30 – 50 Hz	30-50 Hz	50 Hz	30-50 Hz	30-50 Hz	50 Hz	
CHW Actuator		Yes. Make: Belimo	Yes. Make: Danfoss	Yes. Make:	Yes. Make:	Yes. Make: Siemens	Yes. Make: Belimo	

				Honeywell	Johnson Control			
Operating Parameters								
Operating hours	Hours	8	10	10	10	10	14	
Operating timing		9:00 AM to 5:00 PM	9:00 AM to 6:00 PM	9:00 AM to 6:00 PM	9:00 AM to 6:00 PM	9:00 AM to 6:00 PM	9:00 AM to 11:00 PM	
Purpose		Comfort cooling	Comfort cooling	Comfort cooling	Comfort cooling	Comfort cooling	Comfort cooling	
Operating days per month	Days	22	26	26	26	26	30	
Mode of operation		Manual	Manual	Manual	Manual	Manual	Manual	
Electrical Energy Parameters								
Blower power consumption	kWh/hour	2.1						
Electrical energy consumption by CHW usage	kWh/hour	3.3	108	40	41.8	83	38.4	
Total power consumption	kWh/hour	5.4	108	40	41.8	83	38.4	

3. TECHNOLOGY MEASUREMENT AND VERIFICATION

The physical M&V was carried out at CII GBC, Hyderabad, including baseline parameters measurements and technology post installation measurements. Due to the covid pandemic and confidentially policy of pilot sites, it was unable to physically measure the parameters for the other sites.

CII GBC, Hyderabad has 5 AHU for comfort cooling catering to five different areas – Reception, office, PTC, conference hall – 1 and conference hall – 2. The "Zedbee" technology was implemented in all the 5 AHUs for automation. All the 5 AHUs are connected to one chiller of capacity 49TR whose specifications are the following:

Table 4: CII GBC Chiller Specifications

Description	Metric	Values
Capacity	TR	49
Condenser Type		Water cooled
Compressor type		Screw compressor
Refrigerant		R134a
Chilled water supply/return temperature	deg C	7/12
COP @ full load		4.85
SEC @ full load	kW/TR	0.725

M&V was carried out in the Reception AHU whose specifications are the following:

Table 5: CII GBC Reception AHU Specifications

Description	Metric	Values
Airflow	CFM	3,000
Static pressure	mm WC	50
Make/model		Zeco/ belt driven

Catering area/application		Reception/comfort cooling
Motor rating	kW	1.5*2 (one supply blower and one return blower)
VFD	Yes	Make: ZedBee; Model: Metis; Running frequency: 30-50Hz
CHW actuator	Yes	Make: Belimo

The following calibrated instruments have been used to measure instantaneous parameters at CII GBC.

Table 6: List of instruments used for M&V

S No.	Description	Make/ Model No
1	Portable Power Analyser and Accessories	ALM 10 -Krykard
2	Thermometer	Testo 104

M&V was conducted on two consecutive days at CII GBC, with similar ambient conditions. On the first day (24th March 2022), AHU was operated on the manual mode and the data collected is considered as the baseline parameters for savings estimation. On the second day (25th March 2022) AHU was switched to auto mode* and operated without any manual intervention. CII GBC has already installed a BMS of different make that automates chilled water flow and other chiller parameters on the chiller side. The following table gives the conditions of manual and auto mode under which the M&V was carried out:

Table 7: Manual and Auto Mode Conditions – CII GBC

Manual mode	Auto mode
• System switched to manual mode • Blower is operated at 50Hz • CHW valve is manually controlled • Existing BMS – Regin system is completely inactive in AHU	• System switched to auto mode • Blower frequency is automatically varied b/w 30-50Hz • CHW valve is automatically controlled • Existing BMS – Regin system is completely inactive in AHU

Table 8: Ambient conditions

Description	Metric	Values
Average ambient temperature	deg C	37
Room set temperature	deg C	25
Average ambient RH	%	38
Average room occupancy	numbers	5

Table 9: Manual mode power consumption – CII GBC Reception AHU

Date				24th March 2022					
Mode				Manual					
Operating hours				8 (9:00 AM to 5:00 PM)					
Reception AHU									
Time	Set temp. deg C	Room temp. deg C	Power kW*	Total power (supply + return) kW	VFD Hz	Chilled water IN deg C	Chilled water OUT deg C	Flow lph	BTU*
09:00	25	30.6	1.09	1.8	50	27.2	28.5	180	5,886
10:00	25	24.3	1.22	2.3	50	8.1	11.9	5688	5,904
11:00	25	24.4	1.02	2.1	50	7.8	14.4	2304	5,922
12:00	25	24.1	0.98	2.0	50	6.9	14.7	1836	5,944
13:00	25	24.2	1.07	2.1	50	7	17.2	1188	5,958
14:00	25	25	1.09	2.2	50	15.5	26.7	324	5,971
15:00	25	25.1	0.98	2.0	50	7.8	19.4	936	5,983
16:00	25	24	1.04	2.1	50	7.3	16.4	1440	5,997
17:00	25	24	1.14	2.2	50	7.8	22	324	6,014

* US Energy Information Administration: https://www.eia.gov/energyexplained/units-and-calculators/british-thermal-units.php

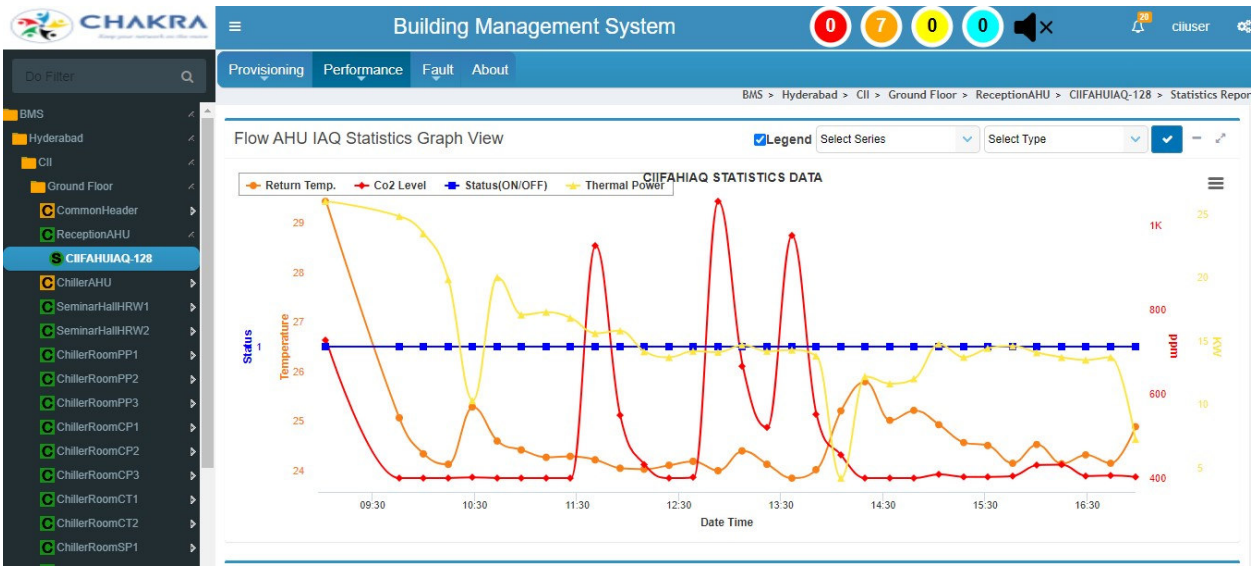


Figure 3: CII GBC Reception AHU Dashboard – Manual mode

Table 10: Auto mode power consumption – CII GBC Reception AHU

Date	25th March 2022
Mode	Auto
Operating hours	8 (9:00 AM to 5:00 PM)

Reception AHU									
Time	Set temp. deg C	Room temp. deg C	Power kW*	Total power (supply + return) kW	VFD Hz	Chilled water IN deg C	Chilled water OUT deg C	Flow lph	BTU
09:00	25	28.5	1.22	2.3	50.2	14.9	20.3	5,652	5,632
10:00	25	24.2	1.19	2.2	50.2	7.9	12.2	5,292	5,654
11:00	25	25.2	1.1	2.2	50.2	7.6	14.5	4,788	5,671
12:00	25	25.2	1.11	2.2	50	7.6	24	360	5,682
13:00	25	24.9	0.79	1.9	38.5	8.1	22.6	396	5,694
14:00	25	24.2	0.59	1.7	35	8.96	10.59	4,680	5,704
15:00	25	25.1	0.6	1.7	32	7.9	22	360	5,713
16:00	25	24	0.54	1.6	31.5	8.4	14.6	1,476	5,725
17:00	25	24.6	0.53	1.6	30.5	8.7	19	5,040	5,736

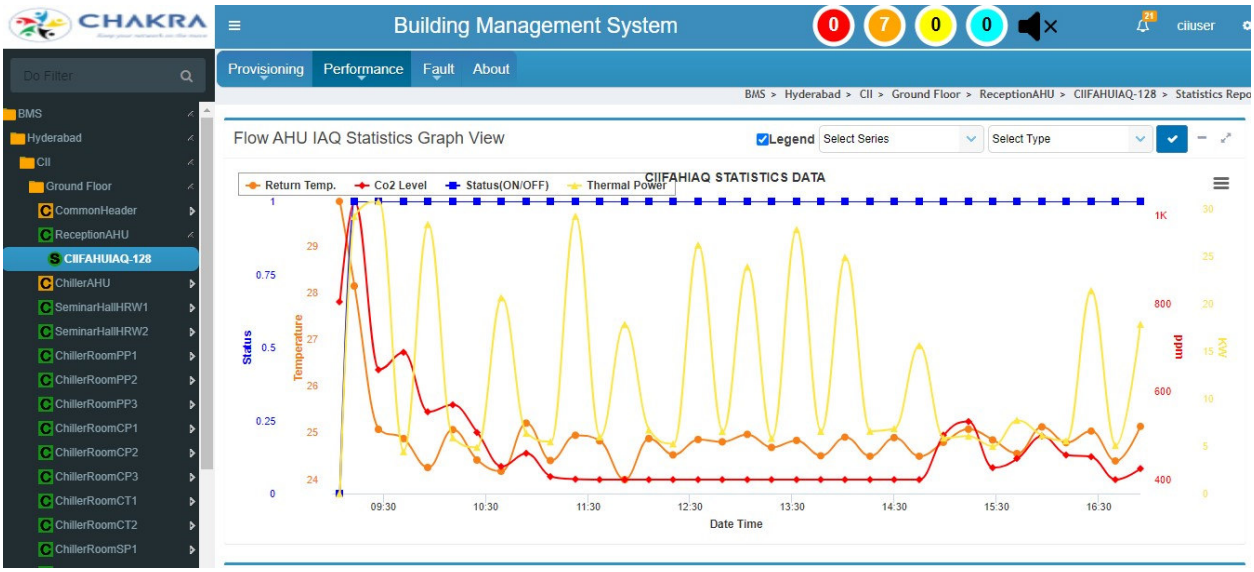


Figure 4: CII GBC reception AHU dashboard – Auto mode

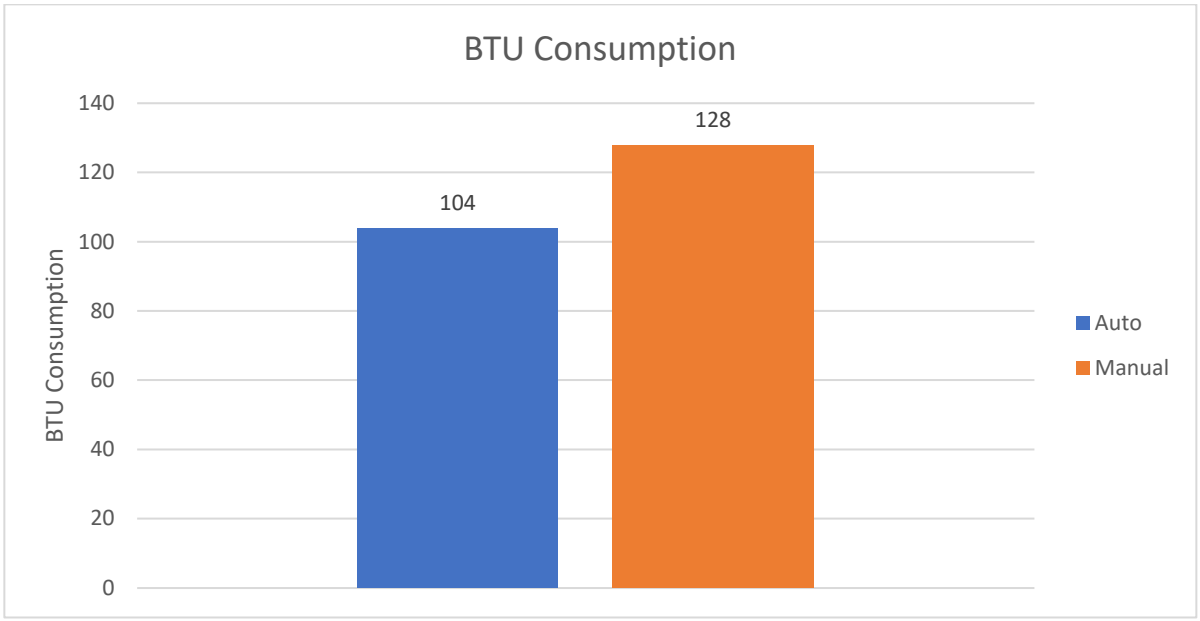


Figure 5: CII GBC Hyderabad –BTU Consumption trends

From the above graph it can be observed that, BTU consumption in manual mode is 128 and in the auto mode is 104. This demonstrates that BTU consumption is reduced by 19% in the auto mode.

Following graphs shows the room temperature in the auto and manual mode over the set point temperature mode collected from dashboard for the month of October and November 2021.

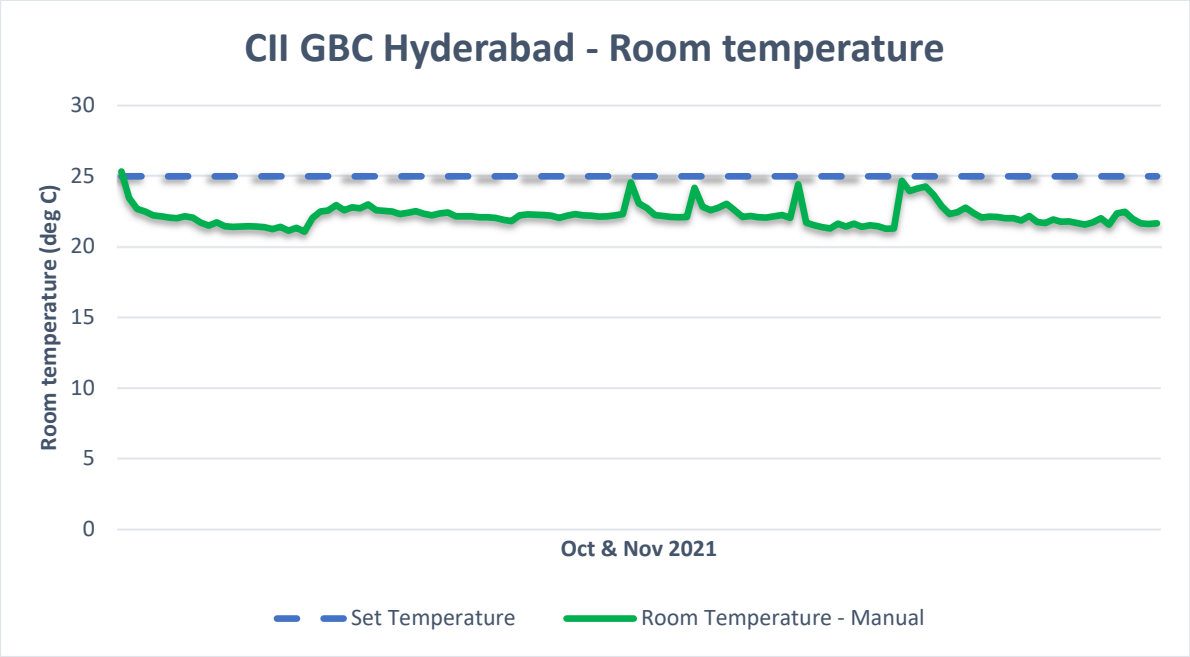


Figure 6: CII GBC Hyderabad – Manual mode room temperature trends

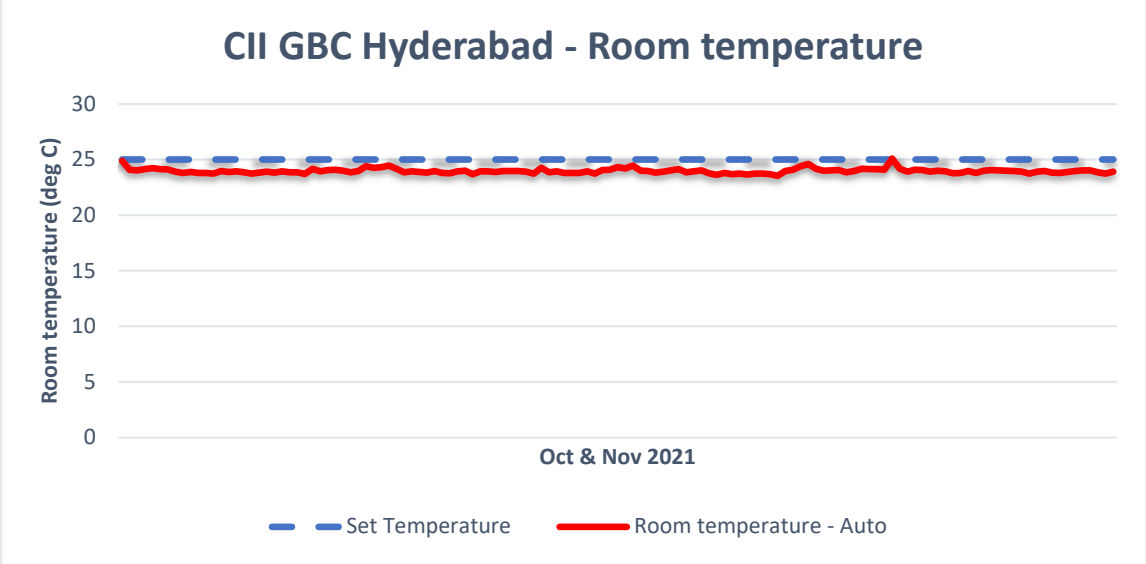


Figure 7: CII GBC Hyderabad – Auto mode room temperature trends

In the auto mode, room temperature trend is almost in line with the set point with very minimal variation. But, in the manual mode, much variation is observed in the room temperature from the set temperature due to manual intervention, causing discomfort to the occupants.

Table 11: CII GBC - Auto vs. Manual mode power consumption

Description	Metrics	Values
Manual mode		
Blower consumption per day	kWh/day	16.7
CHW – Electrical consumption per day	kWh/day	26.5
Total power consumption per day	kWh/day	43.2
Auto mode		
Blower consumption per day	kWh/day	15.3
CHW – Electrical consumption per day	kWh/day	21.5
Total power consumption per day	kWh/day	36.8
Savings Auto mode vs. manual mode*	%	15

**Savings is estimated over the total power consumption*

In CII GBC, with the existing BMS system, around 15% energy savings is observed by implementing the Zedbee system in one AHU.

For the other sites, data are collected through the dashboard and verified. CTS Sholinganallur (ELCOT SEZ) has occupied 7 floors and the Zedbee system is implemented in the 4th floor AHU.

Table 12: CTS Sholinganallur site details

Description	Values
Operating hours	7
Occupancy schedule	9:00 AM to 6:00 PM
Operational days per month	26
Catering area	Workstations, conference room
VFD installed (Yes/No)	Yes. Make: Danfoss
CHW actuator installed (Yes/No)	Yes. Make: Danfoss
Airflow	16,000 CFM

Table 13: CTS Sholinganallur – Auto vs. manual mode power consumption

Mode	Date	No. of days	Operating hours per day	CHW – Electrical consumption per day (kWh)	CHW – Electrical consumption per hour (kWh)
Manual	11/11/2020 to 21/11/2020	8	10	1076	108
Auto	04/12/2020 to 13/12/2020	8	10	812	81
Savings	24%				

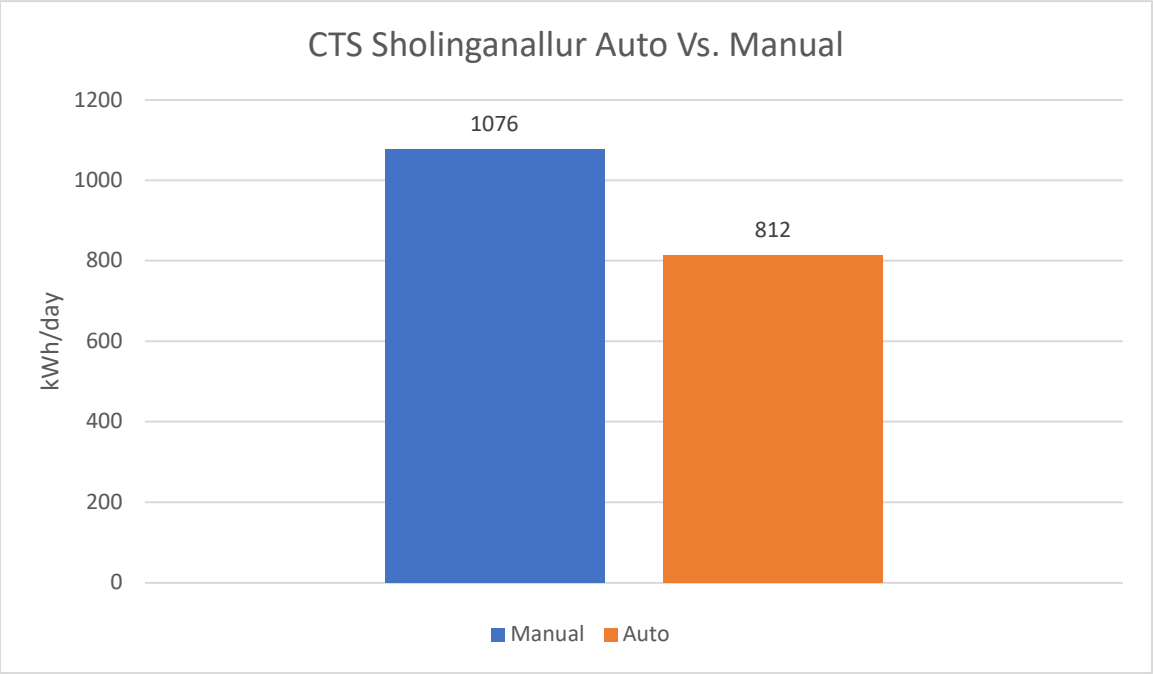


Figure 8: CTS Sholinganallur – Auto vs. manual mode energy consumption in the auto mode operation at CTS Sholinganallur, nearly 24% savings is observed in the electrical energy consumption for chilled water generation.

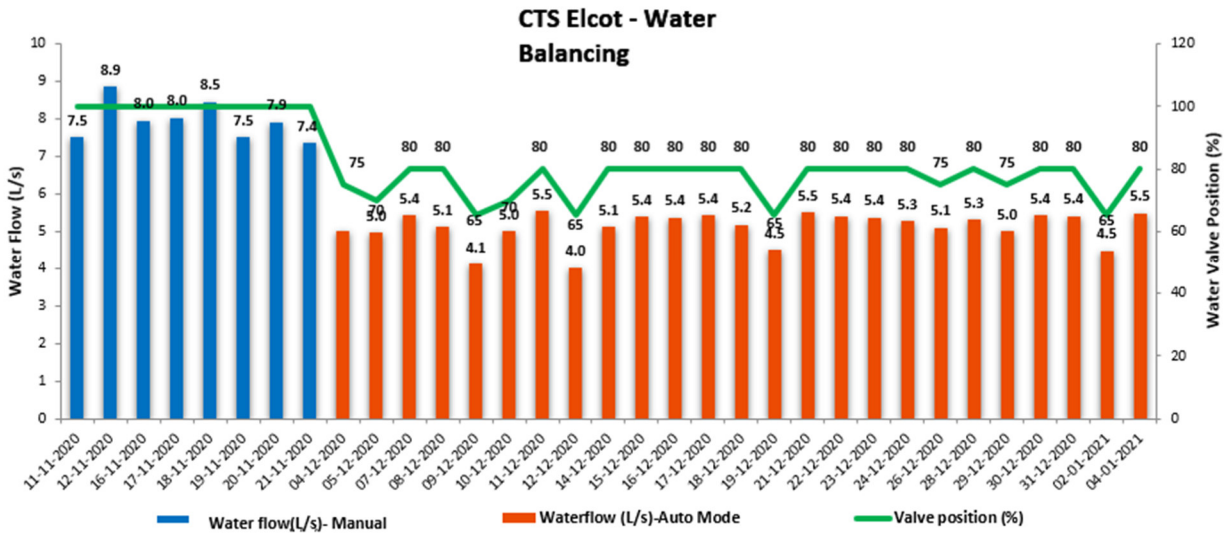


Figure 9: CTS Sholinganallur – CHW flow management Nov – Dec 2020

In CTS Sholinganallur, flow rate of the chilled water is efficiently managed based on the return air temperature to the AHU, in turn energy savings.

At CTS Tambaram (MEPZ), 8 floors have been occupied where the Zedbee's system is installed in the 4th floor AHU.

Table 14: CTS Tambaram site details

Description	Values
Operating hours	10
Occupancy schedule	9:00 AM to 6:00 PM
Operational days per month	26
Catering area	Workstations, conference room
VFD installed (Yes/No)	No
CHW actuator installed (Yes/No)	Yes. Make: Honeywell
Airflow	16,000 CFM (EC motor)

Table 15: CTS Tambaram - Auto vs. manual mode power consumption

Mode	Date	No. of days	Operating hours per day	CHW – Electrical consumption per day (kWh)	CHW – Electrical consumption per hour (kWh)
Manual	20/11/2020 to 27/11/2020	6	10	399	40
Auto	19/12/2020 to 25/12/2020	6	10	229	23
Savings	42%				

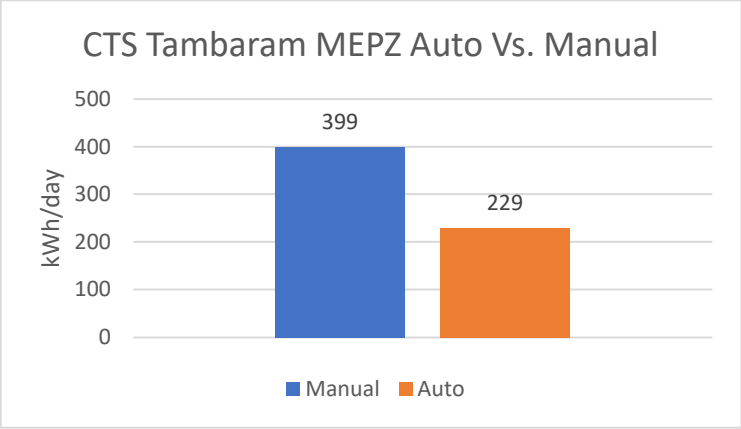


Figure 10: CTS Tambaram – Auto vs. manual mode energy consumption

Above graph for the months of November and December 2020, shows a significant savings in BTU consumption when the AHU is operated in auto mode.

The automation of AHU in CTS Tambaram has given a savings of 42% in the BTU consumption in turn electrical energy consumption.

In Tamarai tech park, the Zedbee system is installed in the South wing AHU used for comfort cooling applications.

Table 16: Tamarai tech park site details

Description	Values
Operating hours	10
Occupancy schedule	9:00 AM to 6:00 PM
Operational days per month	26
Catering area	Workstations, conference room
VFD installed (Yes/No)	Yes. Make: ABB
CHW actuator installed (Yes/No)	Yes. Make: Johnson control
Airflow	18,000 CFM

Table 17: Tamarai tech park – Auto vs. Manual mode power consumption

Mode	Date	No. of days	Operating hours per day	CHW – Electrical consumption per day (kWh)	CHW – Electrical consumption per hour (kWh)
Manual	31/07/2020	1	10	418	41.8
Auto	17/09/2020	1	10	380	38
Savings	9%				

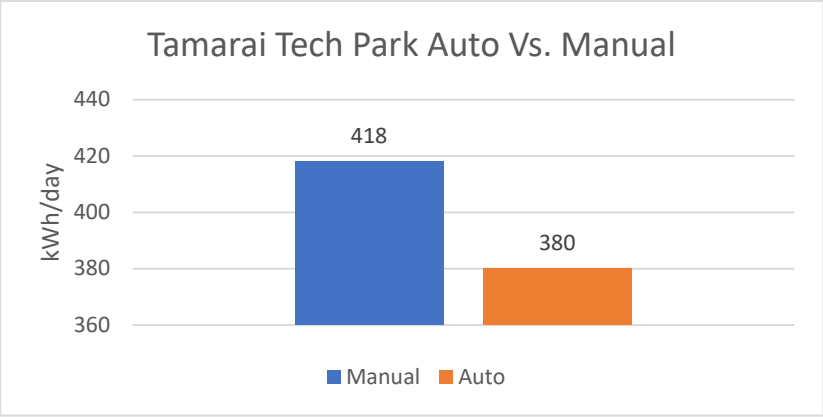


Figure 11: Tamarai tech park – Auto vs. Manual mode energy consumption

With automation of blower speed and CHW flow based on return air temperature using the Zedbee system, 9% energy savings is observed.

Zedbee's system is installed in the Airport Authority of India (AAI), Chennai in the AHU catering the workstation.

Table 18: AAI site details

Description	Values
Operating hours	10
Occupancy schedule	9:00 AM to 6:00 PM
Operational days per month	26
Catering area	Workstations, conference room
VFD installed (Yes/No)	Yes. Make: Danfoss
CHW actuator installed (Yes/No)	Yes. Make: Siemens
Airflow	16,000 CFM

Table 19: AAI, Chennai – Auto vs. manual mode power consumption

Mode	Date	No. of days	Operating hours per day	CHW – Electrical consumption per day (kWh)	CHW – Electrical consumption per hour (kWh)
Manual	20/07/2021 to 04/08/2021	10	10	834	83
Auto	20/07/2021 to 04/08/2021	10	10	641	64
Savings	23%				

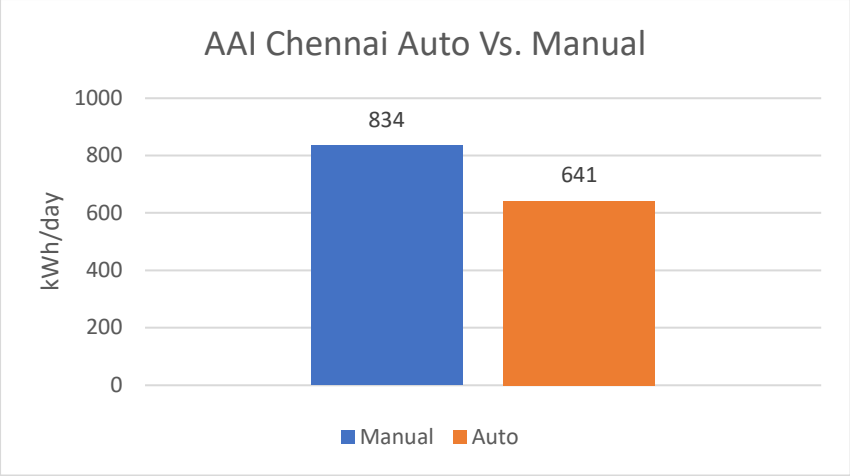


Figure 12: AAI, Chennai – Auto vs. Manual mode energy consumption

AAI, Chennai site has recorded nearly 23% energy savings by automation of their AHU.

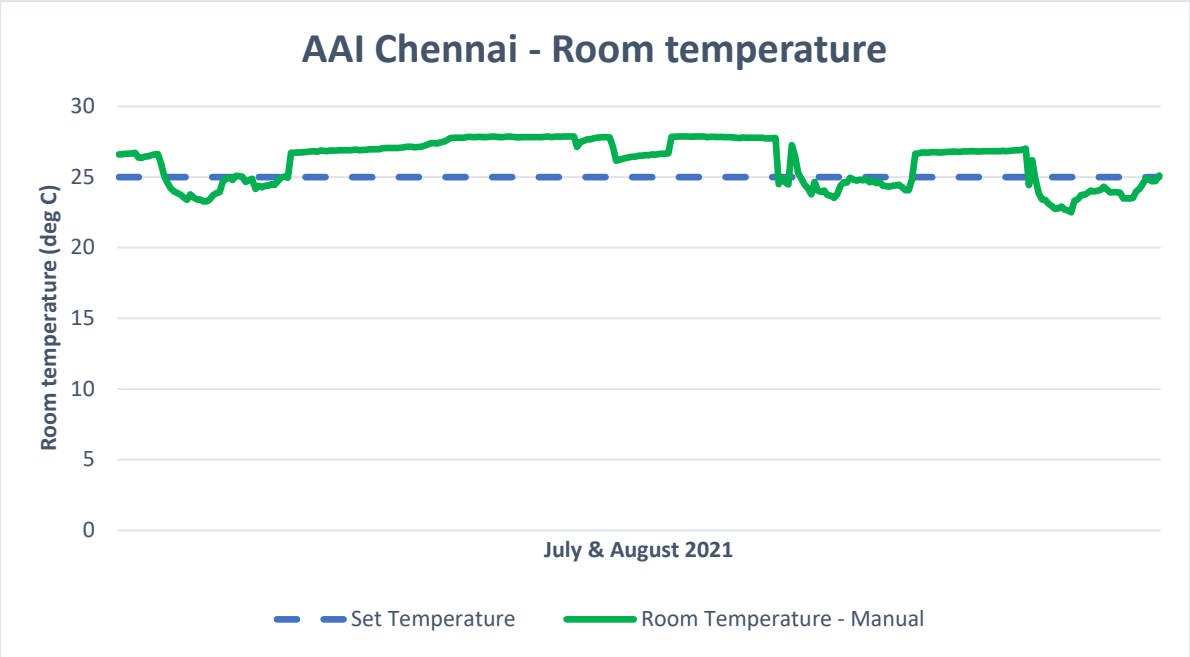


Figure 13: AAI Chennai – Manual mode room temperature trends

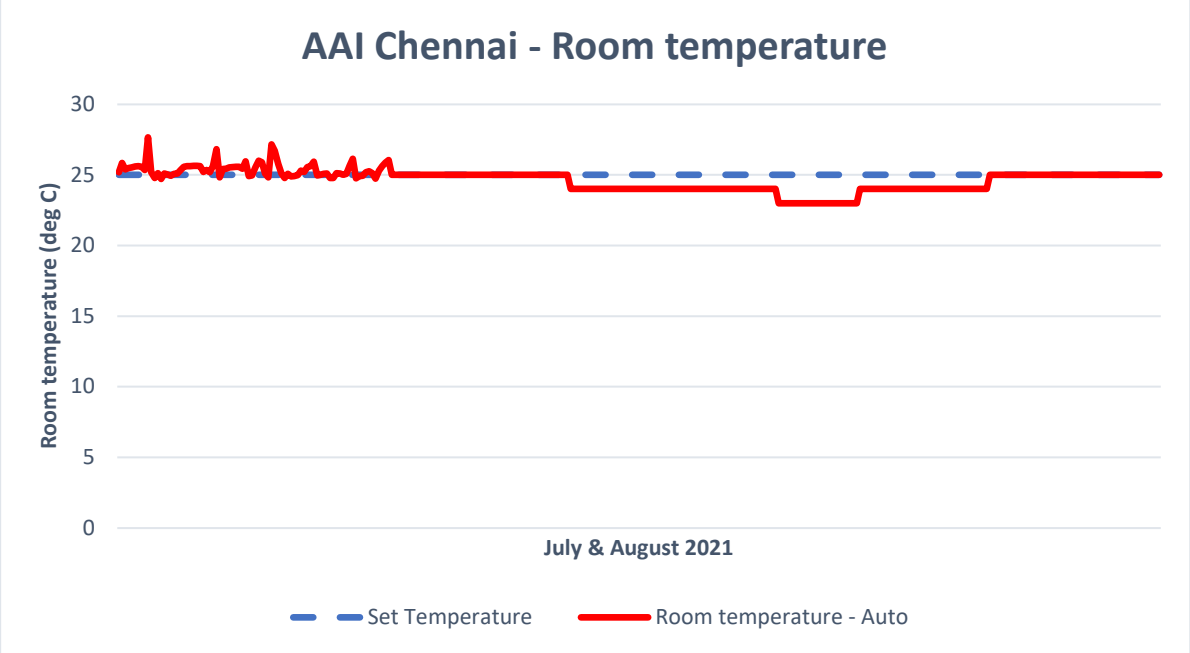


Figure 14: AAI Chennai – Auto mode room temperature trends

The above graph depicted shows that room temperature is very maintained very close to the set temperature in the auto mode by autonomous control of airflow and chilled water flow based on the return air temperature.

Phoenix Market city, Mumbai has installed the Zedbee system in the AHU used for comfort cooling.

Table 20: Phoenix Marketcity, Mumbai site details

Description	Values
Operating hours	14
Occupancy schedule	9:00 AM to 11:00 PM
Operational days per month	30
Catering area	Mall
VFD installed (Yes/No)	No
CHW actuator installed (Yes/No)	Yes. Make: Belimo
Airflow	10,806 CFM

Table 21: Phoenix marketcity, Mumbai – Auto vs. Manual mode power consumption

Mode	Date	No. of days	Operating hours per day	CHW – Electrical consumption per day (kWh)	CHW – Electrical consumption per hour (kWh)
Manual	04/10/2021 to 19/10/2021	12	14	538	38.4
Auto	20/10/2021 to 01/11/2021	12	14	284	20.3
Savings	47%				

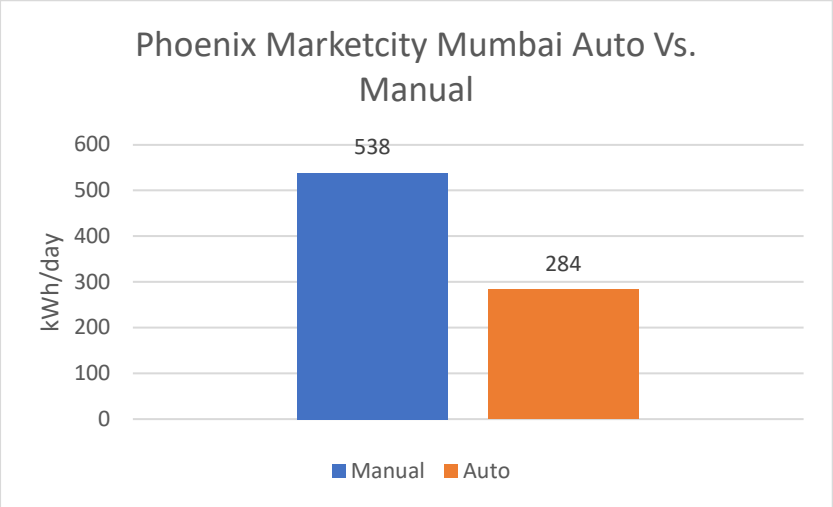


Figure 15: Phoenix marketcity, Mumbai – Auto vs. Manual mode energy consumption

With high operating hours, nearly 47% energy savings had been observed in the Phoenix marketcity, Mumbai through Zedbee's system.

Below graphs shows that similar to all other sites where Zedbee system is installed, room temperature is well maintained as per the requirement ensuring the occupant's comfort.

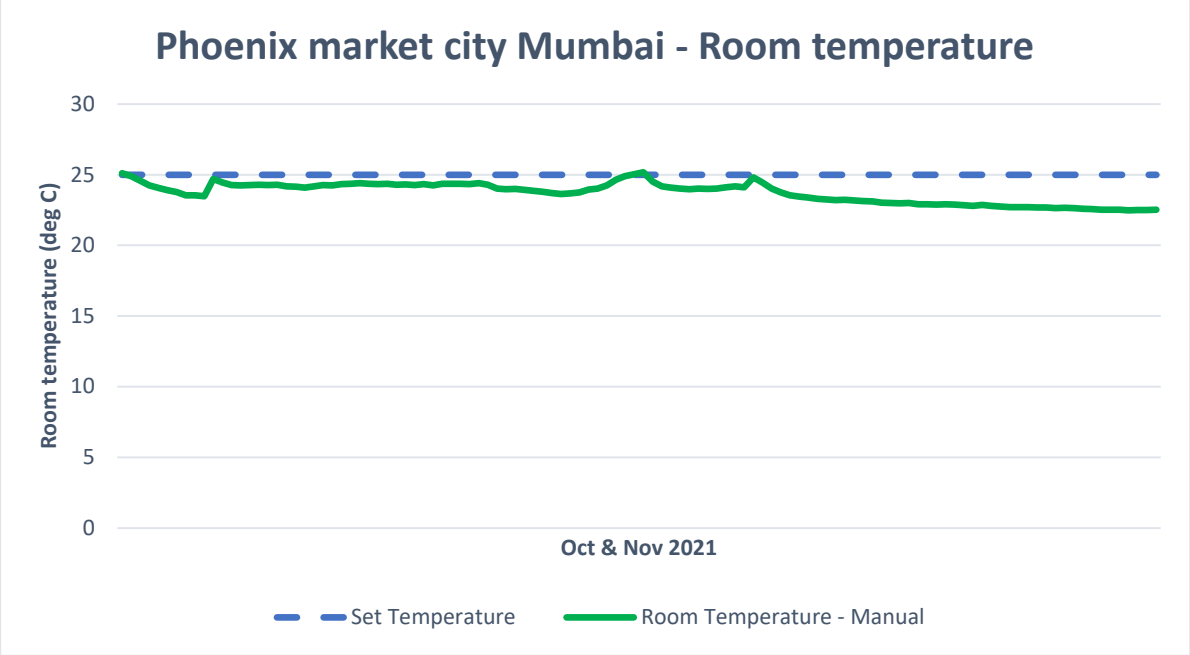


Figure 16: Phoenix Market City Mumbai – Manual mode room temperature trends

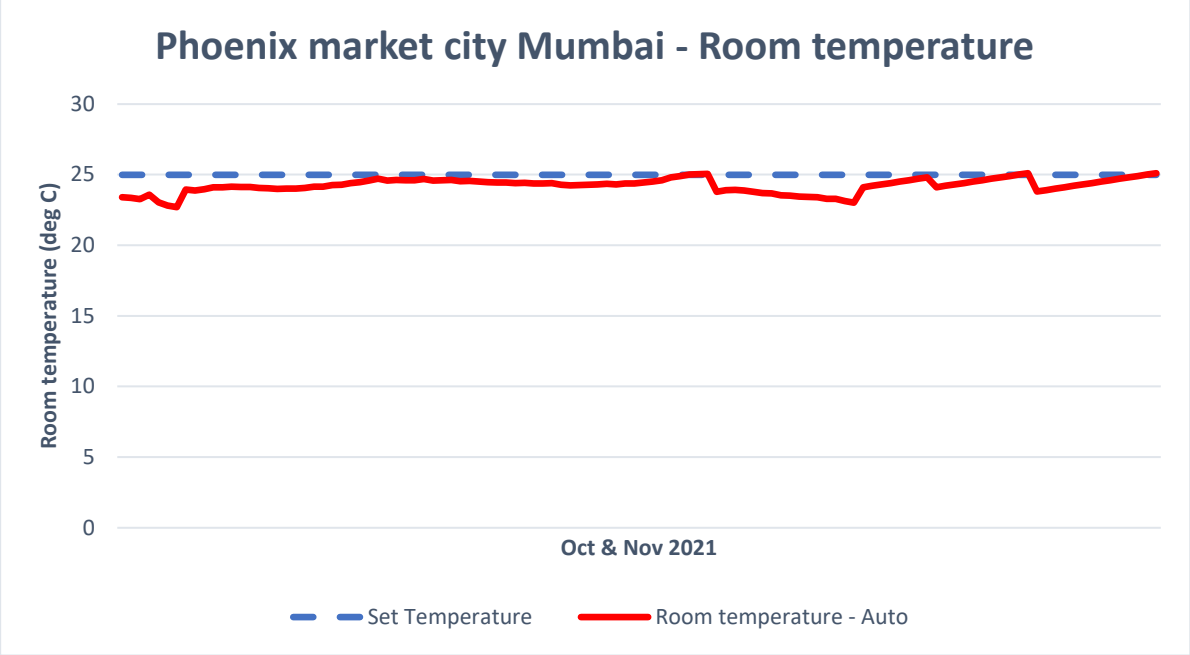


Figure 17: Phoenix Market City Mumbai – Auto mode room temperature trends

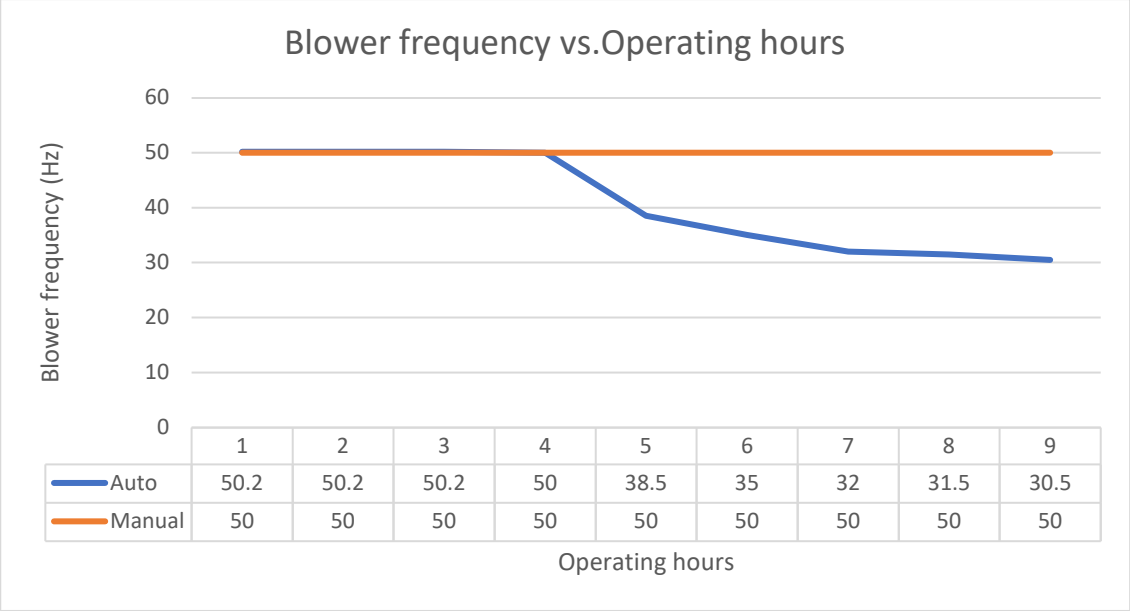
4. FINDINGS

As per the analysis made by comparing an AHU running on a manual mode of operation, with respect to the Zedbee's system, it is evident that the electrical consumption is considerably reduced by using automation of the HVAC using the Zedbee controller.

In addition to the electrical energy savings, various direct and indirect benefits were also observed with the Zedbee automated HVAC control system as below:

- Significant reduction in BTU consumption by proper chilled water flow balancing using the automated actuator.

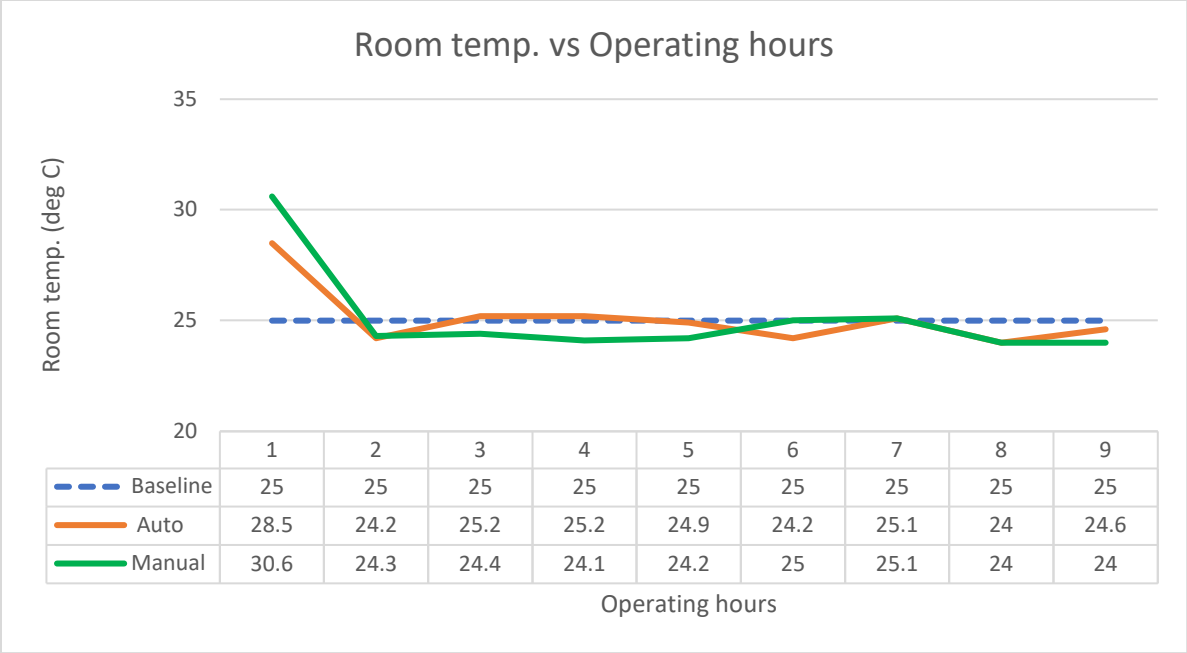
- Blower frequency is varied between 30 – 50 Hz based on the return air temperature and set point temperature in the auto mode. Whereas in the manual mode, the blower was continuously running at full speed i.e., 50 Hz consuming more power.



	1	2	3	4	5	6	7	8	9
Auto	50.2	50.2	50.2	50	38.5	35	32	31.5	30.5
Manual	50	50	50	50	50	50	50	50	50

Figure 18: Blower operating frequency – CII GBC Auto vs. Manual mode

- Room temperature is maintained at or +/- 1 deg C from the set point temperature (25 deg C). Very minimal variation from the set point is observed in the auto mode, ensuring the room occupant's comfort.



	1	2	3	4	5	6	7	8	9
Baseline	25	25	25	25	25	25	25	25	25
Auto	28.5	24.2	25.2	25.2	24.9	24.2	25.1	24	24.6
Manual	30.6	24.3	24.4	24.1	24.2	25	25.1	24	24

Figure 19: Room temperature – CII GBC Auto vs. manual mode

- Auto ON/OFF scheduling of the AHU ensures occupant's comfort and energy savings by avoiding unwanted operation of the HVAC system.
- Dashboard displays all the critical parameters including blower frequency, CHW valve condition, CHW flow, room and return air temperature, indoor air quality, etc., It also helps in monitoring and controlling the AHU by giving required instructions to the controller.

5. CONCLUSION AND REPLICATION POTENTIAL

Zedbee's Automated HVAC control system in buildings is innovative and distinguished from other building management systems by its controller and features of operation in the Auto mode with an IoT enabled platform.

- ✓ Cloud based, AI powered self-learning capability of Zedbee system enables wireless integration of several sensors and controllers. This reduces the cost of automation by 25%.

Automation requires very minimal manual intervention in the AHU operation. With the help of the IoT platform, the system monitors and controls all the critical parameters in the HVAC including blower speed, BTU consumption, O_2, CO_2 content in the indoor air, room temperature, etc., and controls the AHU accordingly. The pilot demonstration has proved its potential for energy savings in the building HVAC with indoor comfort ensured. It is observed from the M&V that a building operated without any prior automation for chiller and cooling system can achieve savings up to 50% from ZedBee's system.

ZedBee system was found to deliver up to 15% energy savings in the building with BMS typically of 20,000 square feet. Utilizing IoT based controls and sensors, certainly ensures the comfort at the user ends without/ very minimal manual intervention. Monitoring and control of critical parameters on the dashboard on a real-time basis has complimented in modifying the operating parameters as per the occupant's comfort in different weather conditions.

The below table represents the details of the market potential for Zedbee's Automated HVAC Control system for the existing buildings in India. It also highlights the investment opportunity along with energy savings and net possible CO_2 savings.

Table 22: Replication potential

2027-28		
Sector		Commercial buildings
Savings potential	%	15.0%
Annual operating hours	hours	2400.0
Annual electrical energy consumption	GWh/annum	91,200
Annual electrical energy savings	GWh/annum	13,680
Power cost	INR/kWh	10
Annual energy cost savings	INR Cr/annum	13,680
Annual energy cost savings	Million USD/annum	1,824
Annual CO2 savings	million tons of CO2/annum	10.81
Market size (no. of units)	units	19,00,000

Investment per unit	INR /unit	80,000
Investment per unit	USD/unit	1,067
Electrical energy savings per unit	GWh/unit/annum	0.0072
Considering Replication potential of 1%		
No. of AHUs facilitated	Units	19,000
Annual electrical energy savings	GWh/annum	137
Investment opportunity	INR cr	152
Investment opportunity	Million USD	20
Annual energy cost savings	INR cr/annum	137
Annual energy cost savings	Million USD/annum	18
Annual CO_2 savings	Million tons of CO_2/annum	0.1
Considering Replication potential of 5%		
No. of AHUs facilitated	Units	95,000
Annual electrical energy savings	GWh/annum	684
Investment opportunity	INR cr	760
Investment opportunity	Million USD	101
Annual energy cost savings	INR cr/annum	684
Annual energy cost savings	Million USD/annum	91
Annual CO_2 savings	Million tons of CO_2/annum	0.54
Considering Replication potential of 10%		
No. of AHUs facilitated	Units	1,90,000
Annual electrical energy savings	GWh/annum	1,368
Investment opportunity	INR cr	1,520
Investment opportunity	Million USD	203
Annual energy cost savings	INR cr/annum	1,368
Annual energy cost savings	million USD/annum	182
Annual CO_2savings	Million tons of CO_2/annum	1.08
Considering Replication potential of 50%		
No. of AHUs facilitated	Units	9,50,000
Annual electrical energy savings	GWh/annum	6,840
Investment opportunity	INR cr	7,600
Investment opportunity	Million USD	1,013
Annual energy cost savings	INR cr/annum	6,840
Annual energy cost savings	million USD/annum	912
Annual CO_2 savings	Million tons of CO_2/annum	5.40
Considering Replication potential of 100%		
No. of AHUs facilitated	Units	19,00,000
Annual electrical energy savings	GWh/annum	13,680
Investment opportunity	INR cr	15,200
Investment opportunity	Million USD	2,027
Annual energy cost savings	INR cr/annum	13,680

Annual energy cost savings	million USD/annum	1,824
Annual CO_2 savings	Million tons of CO_2/annum	10.81

It is estimated that with a 1% replication potential of the system, annually 137 GWh of electrical energy in turn 1,08,000 tons of CO_2 can be saved.

6. ANNEXURE

A1: INSTALLATION PHOTOS

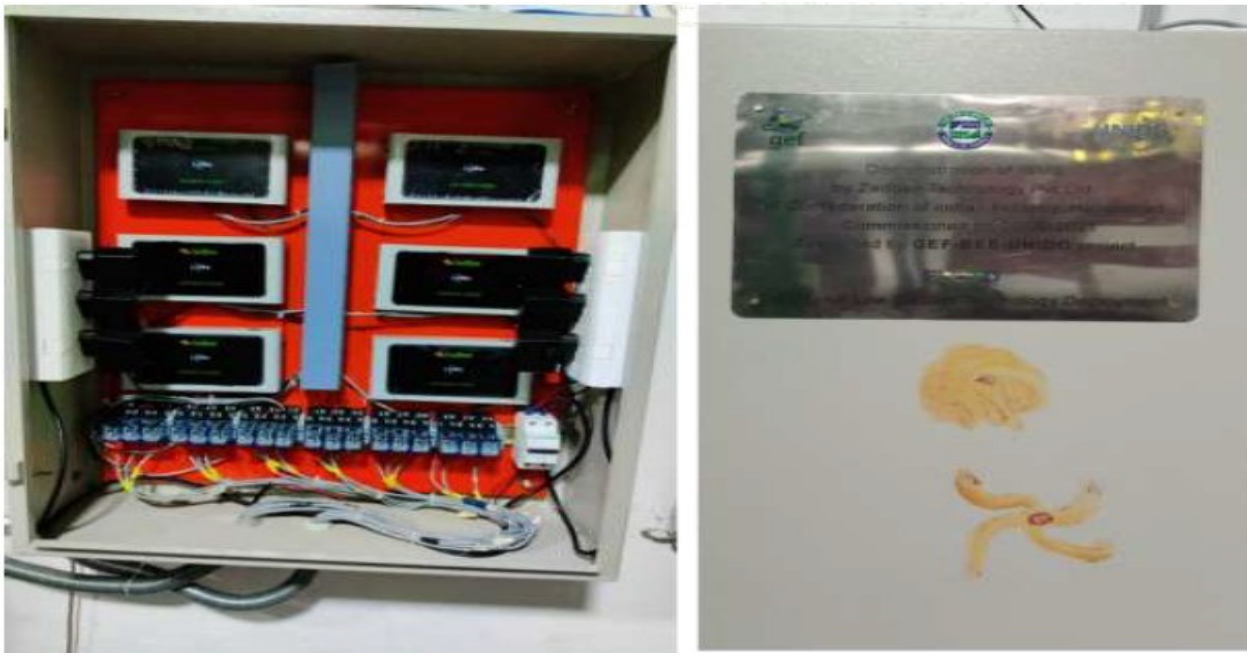


Figure 20: CII GBC, Hyderabad site installation photos

Figure 21: CTS Tambaram site installation photos

Figure 22: Tamarai tech park, Chennai site installation photos

Figure 23: AAI, Chennai site installation photos

Figure 24: Phoenix market city, Mumbai site installation photos

A2: ASSUMPTIONS MADE IN THE REPORT

The following assumptions were made while preparing the report:

- The unit cost of electricity; is INR 10/kWh
- Operating hours are assumed as 8 hrs/day and 300 days/year
- 0.79 kg CO_2/kWh as a grid emission factor
- Investment cost per unit is taken as INR 80,000
- 1 USD = 75 INR
- For Extrapolation of energy savings and other benefits, based on pilot results:
    - The total commercial sector area in India by 2027-28 is estimated as 1,880 million sq.m and the total commercial centralised sir-conditioned area is estimated to be 800 million sq.m[†]
    - EPI value for commercial buildings is assumed as 190 kWh/sq.m/year[‡]
- Considered 60% of total power consumption in a building is by HVAC
- 0.8 kW/TR as chiller SEC
- Chiller compressor power consumption and AHU blower power consumption are considered for energy savings
- 400 CFM/TR
- Considered average airflow of each AHU in replication potential as 10,000 CFM

A3: MAJOR FORMULAE USED IN THE REPORT

The following formulae were used while preparing the report:

- Power consumption (kWh/annum) = EPI (kWh/sq. m/year) X total commercial centralised air-conditioned area (sq. m)
- Cooling capacity (TR) = SEC (kW/TR) X Power (kW)
- Air flow (CFM) = Cooling capacity (TR) X 400 (CFM/TR)
- Annual energy cost savings (INR/annum) = Annual energy savings (kWh/annum) X Energy cost (INR/kWh)
- CO_2 emission (CO_2/annum) = Annual energy savings (kWh/annum) X Grid emission factor (kg CO_2/ kWh)

[†] Building Stock Modelling, Key for Driving Energy Efficiency at National Level - AEEE

[‡] As per BEE 2009 baseline

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PART A: PARTICULARS OF THE ENTERPRISE

Name of the company	ZedBee Technologies Private Limited
Address of registered office and site of operations	B3/4, B-Block, 3rd floor, IIT Madras research park, Taramani, Chennai - 600113
Names & contact details (tel. / email)	Mr. Sreejith S, +91 8943021886, sreejith@zedbee.in

PART B: TECHNICAL INFORMATION FROM DEMONSTRATION SITE

1.1 Details about Innovation

Name of the innovation	ZedBee - Automated HVAC control in buildings
Brief about the innovation	Automated HVAC control in buildings for autonomous controlling of t**he** blower and chilled water flow in the AHU in buildings based on the return air temperature.

1.2 Details of online monitoring

IoT link for viewing the data	https://bmsdev.chakranetwork.com:8080/bms/index.jsp
Login credentials	Username: ciiuser Password: cii@1234

1.3 Base line data of the Pilot site

Site name	Air flow (CFM)	Operating hours and days	Mode of operation	Power consumption (kWh/hour)
CII GBC, Hyderabad	3,000	8 hrs/day 22 days/month	Manual	5.4
CTS Sholinganallur	16,000	10 hrs/day 26 days/month	Manual	108

CTS Tambaram	12,000	10 hrs/day 26 days/month	Manual	40
Tamarai tech park, Chennai	18,000	10 hrs/day 26 days/month	Manual	41.8
AAI, Chennai	16,000	10 hrs/day 26 days/month	Manual	83
Phoenix mall, Mumbai	10,806	14 hrs/day 30 days/month	Manual	38.4

1.4 Post implementation pilot site data

Site name	Mode of operation	Power consumption (kWh/hour)	Savings over the baseline
CII GBC, Hyderabad	Auto	4.6	15%
CTS Sholinganallur	Auto	81	24%
CTS Tambaram	Auto	23	42%
Tamarai tech park, Chennai	Auto	38	9%
AAI, Chennai	Auto	64	23%
Phoenix mall, Mumbai	Auto	11.6	47%

1.5 Emission reduction & replication potential details:

2027-28		
Sector		Commercial buildings
Savings potential	%	15.0%
Annual operating hours	hours	2400.0
Annual electrical energy consumption	GWh/annum	91,200
Annual electrical energy savings	GWh/annum	13,680

Power cost	INR/kWh	10
Annual energy cost savings	INR Cr/annum	13,680
Annual energy cost savings	Million USD/annum	1,824
Annual CO2 savings	million tons of CO2/annum	10.81
Market size (no. of units)	units	19,00,000
Investment per unit	INR /unit	80,000
Investment per unit	USD/unit	1,067
Electrical energy savings per unit	GWh/unit/annum	0.0072
Considering Replication potential of 1%		
No. of AHUs facilitated	Units	19,000
Annual electrical energy savings	GWh/annum	137
Investment opportunity	INR cr	152
Investment opportunity	Million USD	20
Annual energy cost savings	INR cr/annum	137
Annual energy cost savings	Million USD/annum	18
Annual CO_2 savings	Million tons of CO_2/annum	0.1
Considering Replication potential of 5%		
No. of AHUs facilitated	Units	95,000
Annual electrical energy savings	GWh/annum	684
Investment opportunity	INR cr	760
Investment opportunity	Million USD	101
Annual energy cost savings	INR cr/annum	684
Annual energy cost savings	Million USD/annum	91
Annual CO_2 savings	Million tons of CO_2/annum	0.54
Considering Replication potential of 10%		
No. of AHUs facilitated	Units	1,90,000
Annual electrical energy savings	GWh/annum	1,368
Investment opportunity	INR cr	1,520
Investment opportunity	Million USD	203
Annual energy cost savings	INR cr/annum	1,368
Annual energy cost savings	million USD/annum	182
Annual CO_2savings	Million tons of CO_2/annum	1.08
Considering Replication potential of 50%		
No. of AHUs facilitated	Units	9,50,000
Annual electrical energy savings	GWh/annum	6,840
Investment opportunity	INR cr	7,600
Investment opportunity	Million USD	1,013
Annual energy cost savings	INR cr/annum	6,840
Annual energy cost savings	million USD/annum	912
Annual CO_2 savings	Million tons of CO_2/annum	5.40
Considering Replication potential of 100%		

No. of AHUs facilitated	Units	19,00,000
Annual electrical energy savings	GWh/annum	13,680
Investment opportunity	INR cr	15,200
Investment opportunity	Million USD	2,027
Annual energy cost savings	INR cr/annum	13,680
Annual energy cost savings	million USD/annum	1,824
Annual CO_2 savings	Million tons of CO_2/annum	10.81

PART C: QUALITATIVE SUMMARY OF THE INNOVATION

2.1 FINAL SUMMARY OF THE INNOVATION

This system can give significant savings in AHU power consumption, 20-50% in buildings without an existing BMS or any prior automation and the building with existing BMS, up to 15% savings can be achieved. By utilizing the cutting-edge controller and sensors, this system ensures comfort at the user end without/ very minimal manual intervention.

With the 1% replication potential of this technology, nearly 0.5 million tons of CO_2 can be saved annually.

2.2 ISSUES FACED DURING INSTALLATION AND OPERATION

Due to the pandemic, a few offices site operating hours were reduced post installation. Unable to do physical M&V due to covid restrictions at 5 sites of installation other than CII-GBC, Hyderabad.

2.3 OTHER (NON-EMISSIONS) BENEFITS OF TECHNOLOGY

- Reduced cost of automation when compared to the conventional BMS.
- Simpler integration and configuration.
- Automation of AHU has significantly reduced manual intervention. As the AHU ON/OFF time is scheduled, indoor comfort is ensured.
- Very minimal variation, +/- 1 deg C from set point temperature is observed in the room temperature during the auto mode of operation.
- Dashboard board (LCD monitor) records and stores all the critical parameters of the AHU like blower power, CHW flow rate, supply/return temperature, and blower frequency. Also, indoor air quality parameters include O_2, CO_2 levels, room temperature, etc.,