IGBC

Confederation of Indian Industry

SHAKTI SUSTAINABLE ENERGY FOUNDATION

“Compendium on NET ZERO Energy Buildings”

Compendium
on
Net Zero Energy Buildings

part of

Facilitate the Uptake of Net Zero Energy Buildings in India by Enabling the Development of Policy Mechanisms and Supporting Ecosystem

Shakti Sustainable Energy Foundation

Mr Shubhashis Dey, Director – Climate Policy Programme

Dr Sachin Kumar | Associate Director – Energy Efficiency Programme

Ms Ritika Jain, Senior Programme Manager – Energy Efficiency

CII Teeam

Mr S Karthikeyan, Deputy Executive Director

Dr Shivraj Dhaka, Senior Counsellor

Mr Yasin Khan, Associate Counsellor

IGBC Confederation of Indian Industry SHAKTI SUSTAINABLE ENERGY FOUNDATION

Disclaimer

This report is part of Shakti Sustainable Energy Foundation (SSEF) and CII-Godrej GBC's effort to facilitate the 'Uptake of Net Zero Energy Buildings in India by Enabling the Development of Policy Mechanisms and Supporting Ecosystem'.

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Organization Description

Shakti Sustainable Energy Foundation:

Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the areas of clean power, energy efficiency, sustainable urban transport, climate change mitigation and clean energy finance.

Confederation of Indian Industry:

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government, and civil society through working closely with Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for Industry.

For more than 125 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. The premier business association has around 9000 members, from the private as well as public sectors, and an indirect membership of over 300,000 enterprises from around 286 national and regional sectoral industry bodies.

With 62 offices, including 10 Centres of Excellence in India, and 8 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and USA, as well as institutional partnerships with 350 counterpart organizations in 133 countries, CII serves as a reference point for Indian Industry and the international business community.

CII Sohrabji Godrej Green Business Centre (CII Godrej GBC) is a joint initiative of Government of Andhra Pradesh, Godrej & Boyce Mfg Co and CII with the technical support of USAID – a unique model of public-private partnership. The Green Business Centre was established in 2004. CII Godrej GBC is the CII "Centre of Excellence" for energy, environment & recycling, green buildings, renewable energy and climate change activities in India. CII Godrej GBC strives to promote Green initiatives through creation of "Islands of Excellence" and then spread the results and learnings.

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The real estate market in India is growing at an unprecedented rate and is expected to cross USD 850 billion by 2028. The rapid growth of the building industry has resulted in significant energy use in buildings. This, coupled with the energy demand from the existing building stock has resulted in significant contribution to GHG emissions. The building sector alone accounts for about 22% of the total GHG emissions in the country.

Enhancing energy efficiency in building sector can reduce considerable energy. With advancements in renewable energy technologies and the multiple options available for the buildings to purchase renewable power at competitive price; there are opportunities exist to off-set grid energy use by renewable energy sources, thus buildings can achieve Net Zero Energy Status and reap huge energy cost savings.

Adoption of Net Zero Energy concepts can minimise GHG emissions and related environmental impacts. However, the concepts of NZE buildings in India are at nascent stage. One of the main reasons is lack of awareness about NZEB amongst various stakeholders, insufficient capacity of the service providers to implement net zero projects, low access to latest technologies which can increase on-site RE generation.

The net zero energy building compendium provides some of the best practices in building sector especially on energy efficiency and renewable energy. Hence, the compendium will be helpful for building owners, facility managers, builders & developers, consulting firms and Architects/Engineers to design/construct buildings which can operate at Net/Near Zero performance. Further the compendium showcases business cases (case studies of successful implementations), to encourage stakeholders about adoption of Net Zero Energy concepts in their existing and new projects. Various examples of energy efficient technologies and renewable energy shows the viability of measures and their immense socio-economic benefits. The pay-back period of most of the technologies is less than three years.

We are sure that the Compendium will support the building industry to a great extent in showcasing Net Zero Energy projects.

Acknowledgment

CII acknowledges the support provided by several organisations in compiling case studies, sharing best practices and key implementations related to energy efficiency and renewable energy, showcasing energy/cost savings achieved across the country. We are CII are thankful to all stakeholders from the following organisations for their continued support and contribution.

A.T.E. GROUP (BU: HMX)
AAD TECH (India) Pvt. Ltd
ABB India Ltd.
Amplus Solar
Aspiration Energy Private Limited
Basil Energetics Private Limited
Capgemini
Daikin Airconditioning India Pvt Ltd
Danfoss
Desiccant Rotors International Pvt. Ltd.
Eview Global PVt Ltd
Emerson Climate Technologies (India) Pvt. Ltd
Fusion Building Materials Pvt Ltd
Godrej & Boyce Mfg. Co. Ltd.
Godrej Construction
Gujarat Guardian Limited
ICICI Foundation
Idam Infra Pvt Ltd
Integrum Energy
Jakson Power
Johnson Controls (I) Pvt. Ltd
Midori Architects
NCL Buildtek
New leaf dynamics
Oorja Pvt Ltd
Paharpur Cooling Tower Ltd
Panache Greentech Solutions Pvt. Ltd
PPAM SOLKRAFT
S.A.P. Automations (India) Pvt Ltd
Saint-Gobain India Pvt Ltd
Siemens Ltd
SunSource Pvt. Ltd.
Tata BlueScope Steel Pvt Ltd
Thermax Ltd
Trane HVAC Systems & Services
UltraTech Cement Ltd
Versa Drives
Xero Energy
Zedbee

Introduction to the Compendium

Key requirement of a building to demonstrate Net Zero Energy performance is to achieve energy efficiency and off-set 100% grid energy use by renewable sources (either on-site or off-site or by any mix). Most of the buildings have limited roof top area available for installation of Solar Photovoltaic (SPV) or any Renewable Energy (RE) system hence, it is difficult to replace the entire fossil-fuel based energy consumption by on-site RE sources. This has been considered a key challenge in achieving NZE Status. Firstly, in most of the States policies defined for on-site and (or) off-site RE do not the support the vision of Net Zero Energy Buildings. Secondly, the end users (owners/developers/builders/consultants etc.) are not fully aware about the advancement in energy efficiency and renewable energy technologies which can support the building to reach the target of 'Net Zero Energy'.

To facilitate the selection of technologies and details of relevant service providers, a compendium on technologies and service providers is developed. This will support building stakeholders to identify new/advance technologies for designing most energy efficient buildings and also select RE system or chose business model wherein green power can be wheeled to replace the usage of fossil-fuel based energy by renewables.

Net Zero Energy Rating Programme

The Indian Green Building Council (IGBC) is spearheading 'Advancing Net Zero' initiative. 'Net Zero Energy' is the first step towards 'Achieving Net Zero' in buildings in terms of Water, Waste and Carbon. IGBC launched Net Zero Energy rating programme in 2018. As on date more than 16 projects are registered and total 8 projects are certified for Net Zero Energy: Capgemini EPIP Campus Bangalore, Plant-13, G&B Mumbai, ICICI-RSETI Jodhpur, Shairu Gems Surat, MLDL Bangalore, Bhawar House Chennai, Globicon terminals (Warehouse) Mumbai etc.

What is Net Zero Energy Building?

Net Zero Energy buildings are those that are designed to have the lowest energy demand, high energy efficiency during its operation and thereafter its energy requirements are met through renewable energy sources.

NZEB rating is a tool which enables the designer to apply energy efficiency concepts and adopt appropriate renewable sources to design a Net Zero Energy building. In case of an existing building, the tool enables implementation of energy efficient measures to reduce energy consumption and meet rest of the energy requirements through renewable energy sources.

Benefit of Net Zero Energy Buildings

The benefits of adopting Net Zero Energy concepts in a building are as follows:

- Improvement in energy efficiency hence, reduction in annual energy consumption to the tunes of about 25-30% with respect to National baseline

- Overall reduction in energy cost, at least 30%
- Reliable source of power supply if combined with energy storage devices

Intangible benefits of Net Zero Buildings include compliance to National codes & Standards on energy efficiency, increased daylighting and enhanced thermal comfort for the occupants.

- For communities, Net Zero support a healthier and more sustainable built environment, creating thriving and resilient communities.
- For the Planet - buildings account for more than one-third of global carbon emissions. It’s vital we prioritise net zero buildings today to protect our planet and future generations.
- Net Zero Buildings for Economies - investing in new and existing net zero buildings today can stimulate innovation, activate supply chains and create jobs

Section I Energy Efficiency

Section-1 highlights energy efficiency measures and technologies which can improve energy efficiency significantly. These measures can enable the building to meet Net Zero Energy Compliance with regard to ECBC 2017. Key components included in this section are building envelope (wall, roof and fenestration), HVAC (Heating, Ventilating, and Air-conditioning), passive measures, lighting load and controls.

1 Building Envelope

1.1 Wall and Roof

Building envelope plays important role in creating desirable indoor environmental conditions. Also, there is a scope of significant energy savings by designing energy efficient building envelope components such as wall, roof and fenestration. Energy efficient wall and roof are designed with thermal insulation to reduce heat ingress.

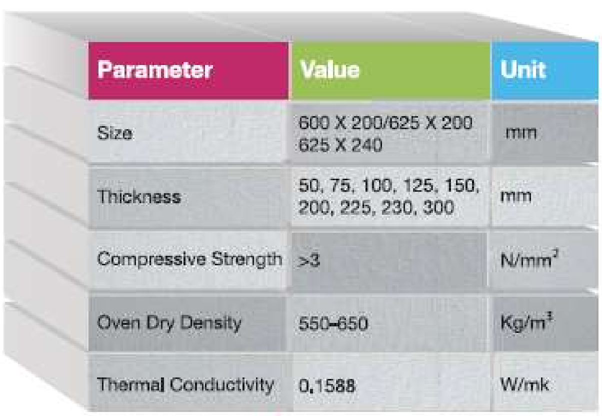
Insulated thermal mass reduces energy usage for heating/cooling, also occupants experience thermally comfortable environment. Insulation refers to cellulose, glass wool, rock wool, polystyrene, urethane foam, vermiculite, perlite, wood fibre, plant fibre (cannabis, flax, cotton, cork, etc.), recycled cotton denim, plant straw, animal fibre (sheep's wool), cement, and earth or soil, reflective insulation (also known as radiant barrier) and blocks such as AAC etc. These insulating materials can be chosen based on building type, its usage and specifications defined by ECBC 2017. Use of energy efficient building envelope, energy efficiency can be improved by 8-10% at least.

Advantage of Using AAC Blocks

- AAC (Autoclaved Aerated Concrete) block reduces the dead load significantly which results less use of steel and concrete in construction
- AAC blocks are light in weight however offer higher compressive strength
- Offers low heat transmittance (U-value: 0.95 W/ m^2-K) ff

Case Study:

Use of AAC blocks in buildings can reduce energy usage by 1.5-2% of total energy consumption. At present, several buildings use AAC blocks in wall construction.



Parameter	Value	Unit
Size	600 X 200/625 X 200 625 X 240	mm
Thickness	50, 75, 100, 125, 150, 200, 225, 230, 300	mm
Compressive Strength	>3	N/mm^2
Oven Dry Density	550-650	Kg/m^3
Thermal Conductivity	0.1588	W/mk

Figure 1 Photographs of AAC Block, used in wall construction

Some of the suppliers of AAC blocks are NCL Buildtek, UltraTech Cement Ltd and Godrej Constructions.

NCL Buildtek

NCL Buildtek Ltd is part of NCL Group, and it comprises of ALLTEK & SECCOLOR divisions. Over period of time the product portfolio is expanded to AAC blocks, dry-mix mortars, tile adhesives & flooring segments. Today, NCL Buildtek ltd has four successful business verticals under its realm: NCL coatings, NCL windows, NCL wall solutions and NCL services. Through the coatings division, NCL manufactures putties, textures and wide range of emulsion paints. Walls division, NCL manufactures AAC blocks, dry-mix cement mortars & wide range of tile adhesives.

Contact Details:
Mr B Vishnuvardhan
vishnuvardhan.b@nclbuildtek.com
+91 98660 15188
www.nclbuildtek.com

UltraTech Cement Ltd

In the endeavour to provide complete sustainable solutions to customers and to be 360 degree building material destination, UltraTech Cement has established UltraTech building products division. UltraTech building products division manufactures and markets technologically re-engineered products for construction and infrastructure industry. Product range includes tiles adhesives, repair products, waterproofing, industrial and precision grout, plasters, masonry products, light weight AAC Blocks etc.

Contact Details:
Mr Santosh V Kori
Santosh.vkori@adityabirla.com
+91 9164010326
www.ultratechcement.com

Fusion Building materials Private Limited

Fusion is a subsidiary of Fusion group of companies. Fusion group is a multifaceted organization that is well-established in the infrastructure industry. The business journey of the group was started with the thought of making the industry eco-friendly. The company is a certified manufacturer of a new age green building material called AAC blocks which is lightweight and high in strength. This company is providing AAC blocks as eco-friendly bricks.

Contact Details:
Jubilee Hills, Hyderabad
info@fusionblock.com
+91 9966030748/49/

Godrej Construction

Godrej Construction is a strategic business unit of the highly diversified, Godrej & Boyce Mfg. Co. established in 1897. Their competencies include expertise in construction materials, development of modern living spaces and leasing state-of-the-art commercial real estate. They offer a wide range of construction materials which include specially engineered ready-mix concrete products, AAC blocks, recycled concrete blocks and pavers for different types of applications.

Contact Details:
Ms. Shweta Bhoyar
shwetab@godrej.com
+91 8806111668
www.godrejconstruction.com

1.2 Solar Reflective Paint

Cool roof is installed to mitigate Urban Heat Island (UHI), additionally cool coating/roof helps to reduce heat gain. Cool roof is applied to roof surfaces that have both a high solar reflectance and a high thermal emittance. Cool roof stays 8-10 ^{o}C cooler than the normal or gray roof as shown in below figure. In some of experiments carried out by research institutions, it has observed that cool roof showed reduction in surface temperature by 15-18 ^{o}C, and reduced indoor/room temperature by 4-5 ^{o}C. However, variation in surface and indoor temperatures depend on climatic conditions.

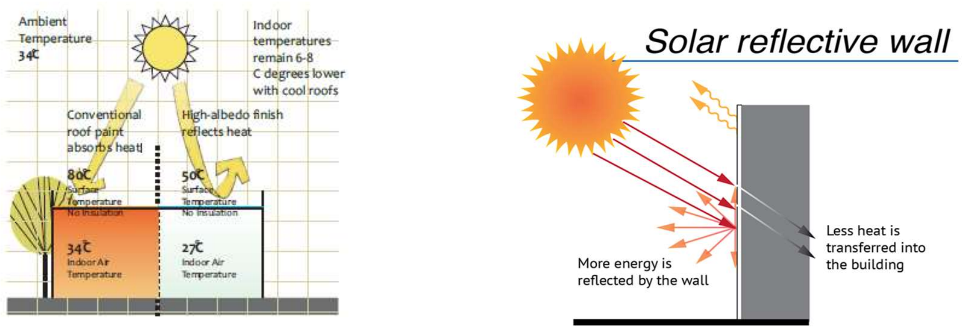


Figure 2 Representation of solar radiation[1] and effect of SRI coating

Increasing the albedo (solar reflectance) of walls/roof reduce unwanted solar heat gain. It also saves electricity and lowers peak power demand (as load of air-conditioning system get reduced). Solar reflectance reduces microclimate temperature and mitigates UHI.

Case Study:

High SRI coating implemented at ECON Packaging which resulted almost 8°C temperature reduction (ambient versus indoor surface temperature of roofing sheet).

[1] ECBC User Manual

Figure 3 SRI coated Industrial roofing sheet

Project: Econ Packaging (temperature measurement before & after coating)						
Applications	Premium 5 Coat (2 coat of Cool Guard + 2 Coat of Cool Top + Transeal) along with fiber mesh reinforcement & Hi seal Slurry					
	Temperature, recorded, time		2.30 to 3.00 pm	Temperature, recorded, time		2.30 to 3.00 pm
	Before Cool Tops Coating			**After Cool Tops Coating**		
Area	Surface over deck	Underdeck	Ambient	Surface Over deck	Underdeck	Ambient
Warehouse	59°C	48-49°C	45°C	44.9°C	37-38.5°C	32°C
Production	59°C	50°C	45°C	50°C	36°C	32°C

Service Providers:

Company Name	Contact Person	Email ID
Panache Greentech Solutions Pvt. Ltd	Ms. Neetu Jain	panachegreen@gmail.com
Espee India Pvt Ltd	Mr Pradip Vaidya	espee@espeeindia.com
Innovative Surface Coating Technologies	Mr Pankaj Patil	patilpankaj08@yahoo.com
Tata BlueScope Steel Pvt Ltd	Mr Swapnil Dandi	swapnil.dandi@tatabluescopesteel.com

1.3 High Performance Glazing

High performance glasses can significantly reduce energy demand in commercial buildings or the buildings/spaces which are designed for higher Window to Wall Ratio (WWR). High performance glasses have lower value of SHGC or SC and U-value.

Along with lower values of SHGC and U-values, high performance glasses shall offer high visible light transmittance (VLT) which can increase day-lighting (reduce the use of artificial lighting).

- U-value represents heat flow through a unit area of fenestration when there is a one-degree temperature difference between the air on one side and the air on the other side.
- The solar heat gain coefficient (SHGC) is the ratio of solar radiation that passes through fenestration to the amount of solar radiation that falls on the fenestration.

Selection of façade glazing influences the energy use in building, visual & thermal comfort and psychological well-being of the occupants. Modern efficient glazing system consists of two or more panes of glass which are separated by air or a low conductivity gas or vacuum. Glazing also plays an important role in reducing the load of artificial lighting by providing daylighting illuminance. This optical property is known as visible transmittance. While selecting a glass, proper trade off shall be analyzed. Developers/builders and endusers are advised to select a glass based on LSG ratio (ratio between Visible Light Transmittance - VLT and Solar Heat Gain Coefficient - SHGC) as it compensates between visible daylight and heat gain (higher the number indicates more the light transmitted to the space without adding excessive heat.

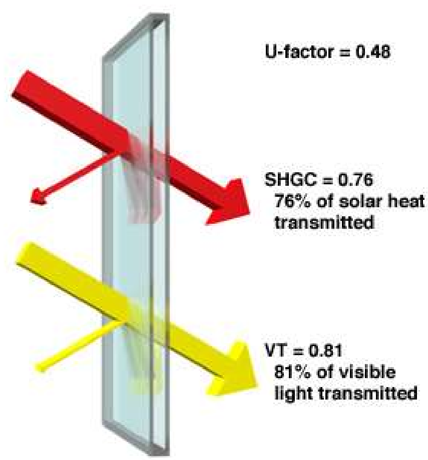


Figure 4 Window Glass and heat transmittance[2]

Generally, in tropical climate SHGC is more important than U-value of glazing. However, for a high perfromacne glass U-value varies from 1.5 to 3.0 W/sqm-K. Glass specifications for some of high performing glasses are as follows:

S No.	Product Series	Product Code	SHGC	VLT	VLT/SHGC
1	SunGuard High Performance	Gold 31	0.21	0.33	1.6
2	SunGuard High Performance	Silver 35	0.26	0.33	1.3
3	SunGuard High Performance	Neutral 40	0.31	0.4	1.3
4	SunGuard High Performance	Royal Blue 40	0.28	0.4	1.4
5	SunGuard High Performance	Silver 40	0.28	0.4	1.4

[2] https://efficientwindows.org/gtypes-2lowe/

6	SunGuard High Performance	Neutral Plus 50	0.32	0.48	1.5
7	SunGuard High Performance	Neutral 60	0.39	0.58	1.5
8	SunGuard High Performance	Neutral 70	0.52	0.69	1.3
9	SunGuard High Performance	Green 35	0.2	0.29	1.5
10	SunGuard High Performance	Green 40	0.24	0.34	1.4
11	SunGuard High Performance	Aquamarine 40	0.22	0.34	1.5
12	SunGuard High Performance	GreenPlus 50	0.25	0.41	1.6
13	SunGuard High Performance	Green 60	0.29	0.49	1.7
14	SunGuard High Performance	Green 70	0.36	0.59	1.6
15	SunGuard DS	DS 30	0.21	0.29	1.4
16	SunGuard DS	DS 40	0.24	0.38	1.6
17	SunGuard DS	DS 50	0.29	0.5	1.7
18	SunGuard DS	DS N 40	0.25	0.38	1.5
19	SunGuard Solar	Silver Grey 32	0.28	0.26	0.9
20	SunGuard Solar	Neutral 34	0.28	0.3	1.1
21	SunGuard Solar	Light Blue 52	0.4	0.41	1
22	SunGuard Solar	Neutral 67	0.49	0.52	1.1
23	SunGuard Solar	Green 32	0.21	0.22	1
24	SunGuard Solar	Green 34	0.22	0.25	1.1
25	SunGuard Solar	Green 52	0.28	0.35	1.3
26	SunGuard Solar	Green 67	0.33	0.45	1.4
27	SunGuard HD Colours	HD Green	0.27	0.3	1.1
28	SunGuard Solar	Silver Grey 32	0.33	0.29	0.9
29	SunGuard Solar	Neutral 34	0.32	0.33	1
30	SunGuard Solar	Light Blue 52	0.48	0.46	1
31	SunGuard Solar	Neutral 67	0.58	0.59	1
32	SunGuard Solar	Green 32	0.26	0.25	1
33	SunGuard Solar	Green 34	0.26	0.29	1.1
34	SunGuard Solar	Green 52	0.34	0.4	1.2
35	SunGuard Solar	Green 67	0.4	0.51	1.3
36	SunGuard Solar	Silver Grey 32	0.43	0.32	0.7
37	SunGuard Solar	Neutral 34	0.41	0.37	0.9
38	SunGuard Solar	Green 32	0.37	0.28	0.8
39	SunGuard Solar	Green 34	0.36	0.32	0.9
40	SunGuard Solar	Green 52	0.46	0.44	1
41	SunGuard Solar	Green 67	0.51	0.57	1.1
42	SunGuard HD Colours	HD Blue	0.4	0.26	0.7
43	SunGuard HD Colours	HD Green	0.47	0.33	0.7

S No.	Product Details	SHGC	VLT	VLT/SHGC
1	SKN 176	0.37	0.69	1.9
2	SKN 476	0.3	0.57	1.9
3	SKN 776	0.26	0.44	1.7
4	Blu De	0.3	0.46	1.5
5	Equinox N	0.2	0.3	1.5
6	Equinox G	0.17	0.25	1.5
7	Equinox B	0.15	0.19	1.3
8	KS 130	0.22	0.3	1.4
9	KS 430	0.18	0.25	1.4
10	KS 730	0.16	0.19	1.2

11	Clear Harmony	0.21	0.24	1.1
12	Green Harmony	0.16	0.2	1.3
13	Blue Harmony	0.15	0.15	1
14	Horizon Bronze	0.26	0.22	0.8
15	Horizon Green	0.27	0.33	1.2
16	Horizon Blue	0.25	0.26	1
17	Horizon Clear	0.37	0.4	1.1
18	Aurum	0.22	0.22	1
19	Midas Gold	0.26	0.24	0.9
20	Rosa	0.36	0.28	0.8
21	Horizon Bronze	0.34	0.29	0.9
22	Horizon Green	0.36	0.37	1
23	Horizon Blue	0.34	0.29	0.9
24	Horizon Clear	0.45	0.45	1
25	Midas Gold	0.33	0.27	0.8
26	Rosa	0.44	0.31	0.7
27	ET 425	0.18	0.21	1.2
28	ET 725	0.16	0.16	1
29	ET 735	0.19	0.19	1
30	KS 738	0.18	0.23	1.3
31	KS 730	0.18	0.2	1.1
32	KT 740	0.2	0.24	1.2
33	PLLT Bronze	0.36	0.41	1.1
34	PLLT DGU	0.57	0.75	1.3
35	ST DGU	0.6	0.6	1

Service Providers:

Company Name	Contact Person	Email
Asahi India Glass	Mr Shailesh Ranjan	shailesh.ranjan@aisglass.com
Gujarat Guardian Limited	Mr Vivek Buch	vbuch@guardian.com
Saint-Gobain India Pvt Ltd	Mr Murali N	murali.n@saint-gobain-glass.com

2 Heating, Ventilation and Air Conditioning System (HVAC)

2.1 Magnetic Bearing Chiller

Magnetic bearing chiller uses permanent magnet synchronous compressor motor. This motor has a significant increased efficiency over an induction motor, especially at low motor speed. Instead of physical bearings, magnetic levitation makes frictionless operation. The motor does not require oil lubrication; oil in the evaporator decreases efficiency over time as the tubes foul, reduce heat transfer. In addition, the motor has an extremely low inrush current at start-up and the regenerative power system keeps bearings powered until the shaft stops spinning, which enables it to ride through short durations of power loss [1].

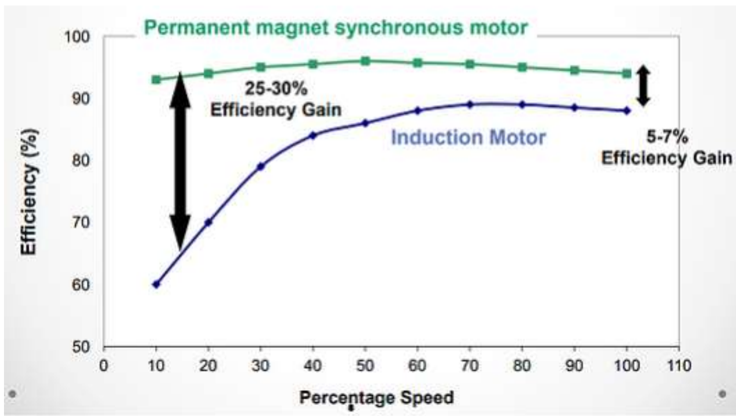


Figure 5 Induction motor v/s permanent magnet synchronous motor

Case Study:

Sun-n-Sand is a leading group of five-star hotels, carried out retrofitting. Oil-free Magnasmart Inverter Chiller from Blue Star using Danfoss Turbocor compressors was chosen as a replacement[3]. The cost of operation drastically decreased. Savings were approximately of 200,000 to 250,000 INR (US$3,200 to 4,000) per month. Payback was within 18 months.

Figure 6 Case study building – retrofitting of chiller

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[3] https://www.danfoss.com/en/service-and-support/case-stories/dcs/hotel-with-chiller-retrofit/

Benefits of Magnasmart inverter chiller with Danfoss Turbocor compressor over the old cooling unit was the following:

- On board inverter reduces the starting current of the compressor to only 2 amps
- Only one moving part - reliability of chiller is improved due to lower complexity of the system
- Oil-free operation - removing oil completely from the compressor eliminates lubrication issues. Lubricating oil hinders heat transfer significantly - a chiller with an oil content of 4% loses 9% efficiency
- Remote monitoring enables to optimize performance and reliability of the chiller
- Chiller control panel provides operational information and system parameters are readily available at the unit

Service Providers:

Company Name	Contact Person	Email ID
Danfoss	Mr Ramesh Reddy	Ramesh_reddy@danfoss.com
Johnson Controls	Mr Nanthagopalan	nantha.gopalan@jci.com
Trane HVAC Systems & Services	Mr Kallol Datta	kallol_datta@trane.com

2.2 Variable Refrigerant Flow

In VRF system, multiple indoor units are connected to one outdoor unit which has one or more inverter driven compressors. VRF system has capability to control the flow of refrigerant according to the cooling load of fan coil units located inside the building/space. Due to modulation of speed with inverter technology, it is more efficient than conventional split air-conditioning system.

Case Study:

The International Copper Promotion Council India (ICPCI) Powai, Mumbai is the Indian centre of the International Copper Association, a leading organization for the promotion of copper worldwide. ICPCI has done retrofitting of old split air-conditioning system by VRF system to improvise office thermal environment and to reduce the energy bill . As per the audit conducted, the project achieved 31% energy savings and improved thermal comfort [2].

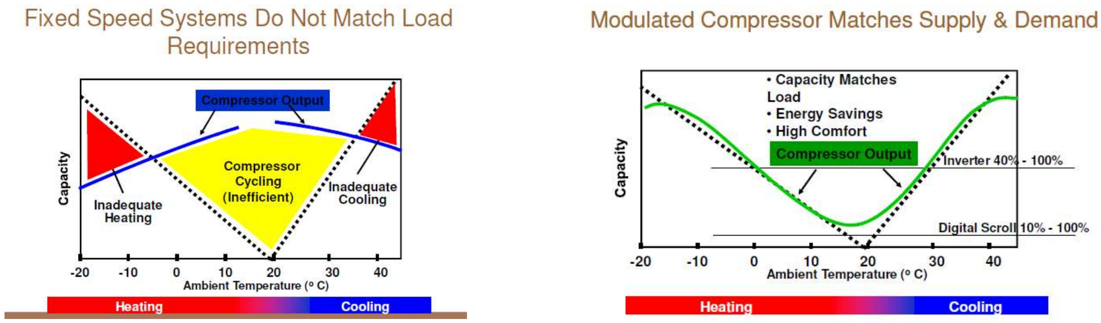


Figure 7 Fixed speed and compressor with variable speed

Case Study:

System Selected	VRV (Capacity 1092 HP, 73 ODU), Daikin
Refrigerant	R-410A
Outdoor Units	Heat pump types
Indoor Units	Ceiling Mounted Multi Flow Cassette : 435 no. High Static Duct : 78 no. Outdoor Air Proc. : 23 no. VAM (HRV) : 29 no.
Control System	Intelligent Manager

Figure 8 Case Study Building

COP at ARI Standard Conditions:

Load %	TC (kW)	PI (kW)	COP
100	45.00	14.20	3.17

75	33.75	9.35	3.61
50	22.50	5.52	4.08

Note: Standard ARI Conditions:

- Outdoor Temperature : 35.0 ºC DBT, 24 ºC WBT
- Indoor Temperature : 27.0 ºC DBT, 19.5 ºC WBT

Case Study:

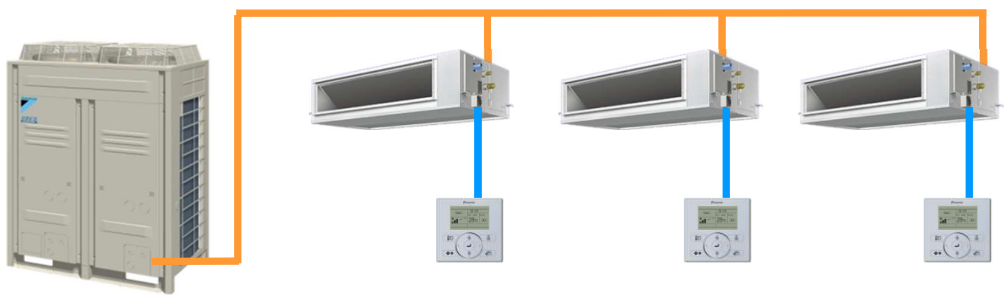


Figure 9 Schematic of VRV system – installed by Daikin

VRV System:

Refrigerant	R-410A
Outdoor Units	Water cooled VRV: 1200 HP ODU Qty : 120 Nos
	Air cooled VRV : 192 HP ODU Qty : 14 Nos
Indoor Units	Ceiling Mounted Cassette Type: 317 Nos.
	Ceiling Mounted Duct type : 41 Nos
	Slim Ductable Type : 286 Nos
	Wall Mounted Type : 35 Nos
Optional Controller	I-Manager
Project achieved 22% energy savings on weekly basis	

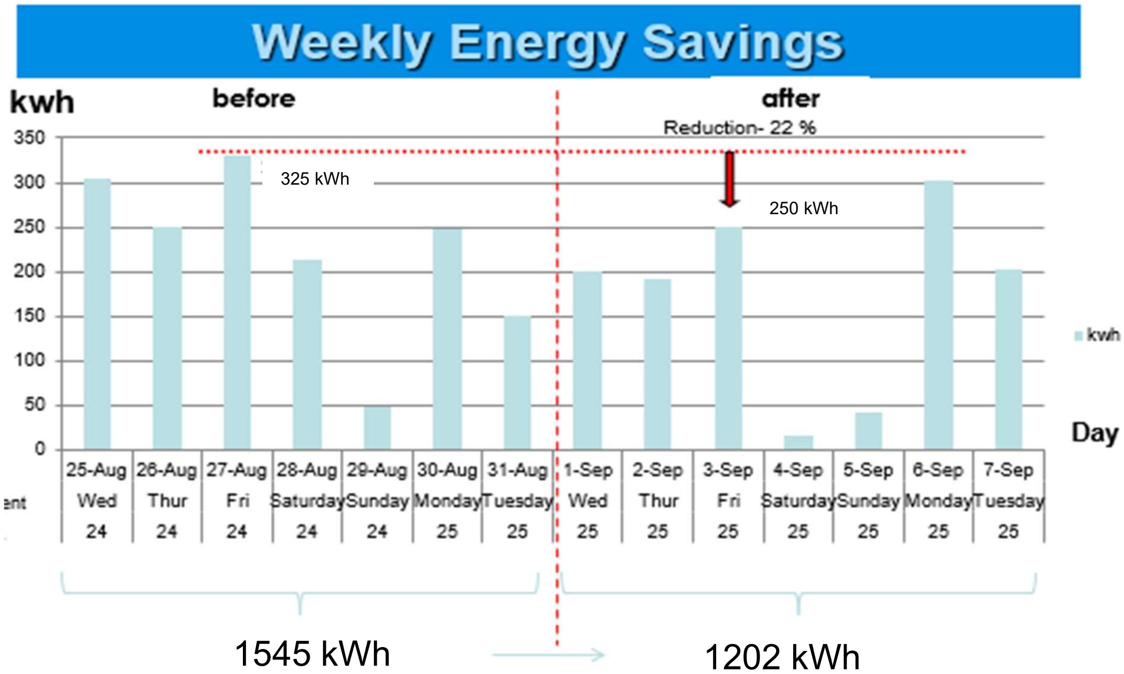


Figure 10 Energy savings before and after retrofitting

Service Providers:

Company Name	Contact Person	Email IDs
Daikin	Mr Vivek Trehan	vivek.trehan@daikinindia.com
Emerson	Mr Manish Begad	Manish.Begad@emerson.com

2.3 Heat Pump

A heat pump is an electrical device that extracts heat from ambient air or waste heat from Industrial application, as power input. The heat pump is not a new technology; it has been used around the world for decades. Refrigerators and air-conditioners are both common example of this technology. Heat pumps transfer heat by circulating a substance called a refrigerant through a cycle of evaporation and condensation. A compressor pumps the refrigerant between two heat exchanger coils. In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed enroute to the other coil, where it condenses at high pressure. At this point, it releases the heat it absorbed earlier in the cycle.

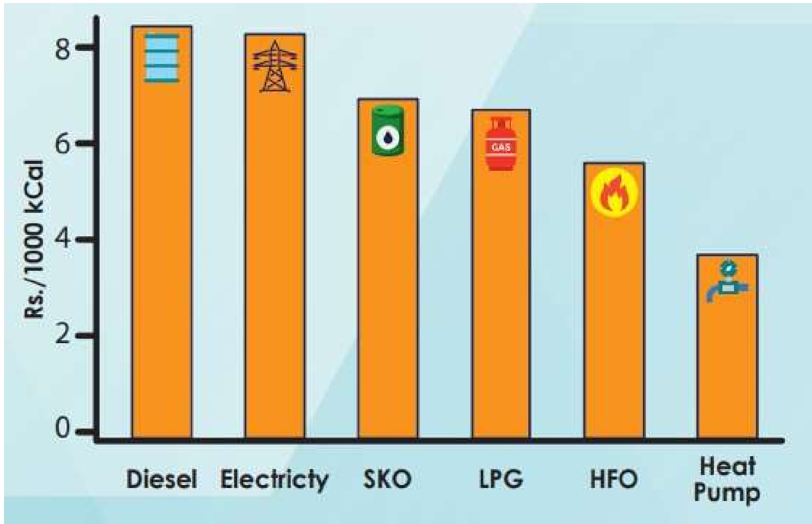


Figure 11 Comparison of heat pump with other technologies/solutions

Advantages of Heat Pump Technology

- Energy saving opportunity 40-60 % over other heating system
- Cost effective and lesser maintenance cost & time
- No danger of compressor failure
- Less control circuits and ease of installation

Case Study:

A leading auto component manufacturer was using SKO fired boiler to meet the heat requirement of pre-treatment tanks in their plating and phosphating plants. Heat pumps were used to replace the SKO boiler and the full system details and their actual performance comparison with the previous systems are tabulated below.

Figure 12 Actual photographs of heat pump system commissioned at project site

Table: System technical details for surface treatment

S No.	Description	Plating Plant	Phosphating Plant
1	Heat Pump Type	3XParallel Coupled Water	2XParallel Coupled Water
2	Total Heating Capacity	111 kW	136 kW
3	Total Cooling Capacity	66 kW	79 kW
4	Power Consumption	41.7 kW	51 kW
5	COP	2.67	2.67
6	Heat Source	Oil cooler return line (25-30 °C)	Oil cooler return line (25-30 °C)
7	Heat Sink	7 Nos of Pre-treatment Tanks (70-75 °C)	4 Nos of Pre-treatment (80-85 °0C)
8	Heating Medium	Water	Water
9	Heat Transfer Method	Indirect Heating - Plate Heat Exchanger	Indirect Heating - Plate Heat Exchanger
10	Refrigerant	R1234ze(E)	R1234ze(E)
11	Compressor Type	High Temperature Scroll	High Temperature Scroll
12	Backup Source	Electrical Heaters	Electrical Heaters

Table: System performance details for plating plant

S No.	Description	Before HP	After HP
1	Primary Energy Source	SKO Fired Boiler	Water Source Heat Pump
2	Backup Energy Source	Standby SKO Fired Boiler	Electrical Heaters
3	Heating Medium	Thermic Oil	Water
4	Heat Transfer Method	Immersion Coil Heat Exchanger	Plate Heat Exchanger
5	Fuel/Energy Consumption per day	385 LPD	1050 kWh
6	Fuel/Energy Cost	Rs. 65 /liter	Rs. 6.3 /kWh
7	Energy Bill per year	Rs. 83,42,000	Rs. 21,73,000

Table System performance details for phosphating plant

S. No.	Description	Before HP	After HP
1	Primary Energy Source	SKO Fired Boiler	Water Source Heat
2	Backup Energy Source	Standby SKO Fired Boiler	Electrical Heaters
3	Heating Medium	Thermic Oil	Water
4	Heat Transfer Method	Immersion Coil Heat Exchanger	Plate Heat Exchanger
5	Fuel/Energy Consumption per day	360 LPD	1244 kWh
6	Fuel/Energy Cost	Rs. 65/liter	Rs. 6.3 /kWh
7	Energy Bill per year	Rs. 78,00,000	Rs. 21,62,000

As a result of this project was able to save around 70% of their cost by achieving the annual savings of around Rs.59 Lakhs replacing the thermic fluid boiler which is equivalent to reduction of 324 Tons of CO_2 emissions annually. Annual cost saving of Rs. 56 Lakhs was achieved with simple payback period of 12 months.

Service Providers:

Company Name	**Contact Person**	**Email IDs**
Emerson	Mr Rahul Pathak Manish Begad	Rahul.Pathak@Emerson.com manish.begad@emerson.com
Mechworld eco	Mr Rohit Singhi	rohit.singhi@mechworldeco.com
Aspiration Energy Private Limited	Mr Logesh Raj	logesh.raj15@gmail.com

2.4 Two Stage Evaporative Cooling System

To achieve Net Zero Energy performance, it is important to reduce air-conditioning load. Traditional air-conditioning system consumes significant energy in providing thermal comfort. While the air cooler consumes quite less energy however, coolers are unable to meet/satisfy the requirement of thermal comfort.

Indirect Evaporative Cooler (IDEC) uses considerably less energy and deliver optimum thermal comfort depending upon the climatic condition and building type. Generally, evaporative coolers are most effective in Hot & Dry climate. It works on evaporative cooling principle, adding water to the hot air and removes the sensible heat from the air and thereby lowering temperature of air.

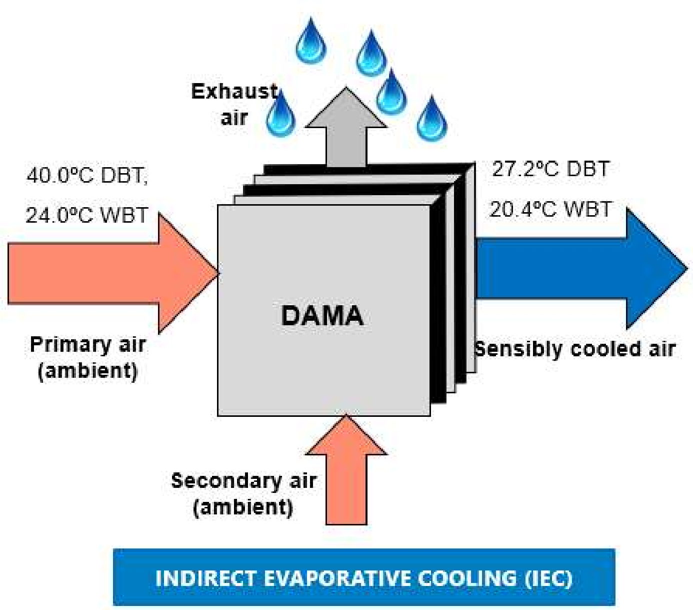


Figure 13 Schematic of IDEC System

Two-stage evaporative cooling systems or Indirect-Direct Evaporative Cooling (IDEC) systems are advance version of IDEC and provide improved thermal comfort. In this technology, both direct and indirect evaporative strategies are used to achieve the lower supply air temperature. The first indirect evaporative cooling systems pre-cools the air by using recirculated water in heat exchanger. Since this is indirect heat exchange and no moisture is added to the ambient air, therefore DBT and WBT of the air become lower.

In the second process, air is cooled with direct evaporative system and the air can be brought down to much cooler temperature while moisture addition into the air is lower as compared to the indirect evaporative coolers. IDEC can offer 30-50% energy savings subjected to the climatic conditions and end use application.

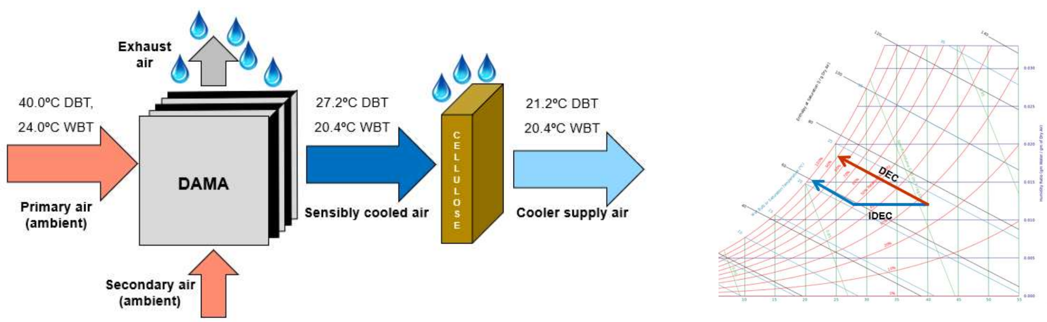


Figure 14 Example of ambient air and supply air temperature conditions

Case Study:

IDEC was installed in one of the malls in Nagpur by HMX having built-up area 300,000 sq.ft. Nagpur falls under composite climatic conditions and the system was installed to provide pre-cooled fresh air through 5 machines (43,000 CFM). This reduced the cooling load on the chiller plant.

This resulted in huge electricity saving equal to 763 MWh as compared to conventional TFA (Treated Fresh Air). Also, it improved the IAQ by providing enhanced fresh air.

Figure 15 Case study building - Nagpur

Service Providers:

Company Name	Contact Person	Email IDs
A.T.E. GROUP (BU: HMX)	Mr Suhas Jadhav	s_s_jadhav@hmx.co.in
Arka clean	Mr Shamkant Mirashi	sales@renotech.in
Toro Cooling	Mr Darshi Dhaliwal	dd@ambiator.com

2.5 Energy Recovery Wheel

Cooling and dehumidification of the fresh air constitutes typically 20-40% of the total energy consumption in hot/humid climate. It can be higher if the requirement of ventilation is high or if 100% FA is required especially in hospitals (ICU/OT etc). The energy consumption of cooling/dehumidification of fresh air can be reduced by using energy recovery wheel. The exhaust air is usually warmer than the conditioned supply air although it is cooler than the outdoor/fresh air, in an air-conditioned building which has continuous supply of fresh air. Hence, heat exchange from exhaust air can provide additional benefit by reducing the load on the air-conditioning system.

Energy recovery system helps exchange/recover heat from the exhaust air so that the supply air can be pre-cooled before reaching to the air-conditioning (AHU) system. The system consists of a unit with fans or blowers and a rotating thermal wheel that transfers heat between two isolated air-streams. The wheel is made of some specific material with high thermal conductivity to enable an efficient heat exchange. It improves the efficiency of the system and reduce the peak cooling/ heating load.

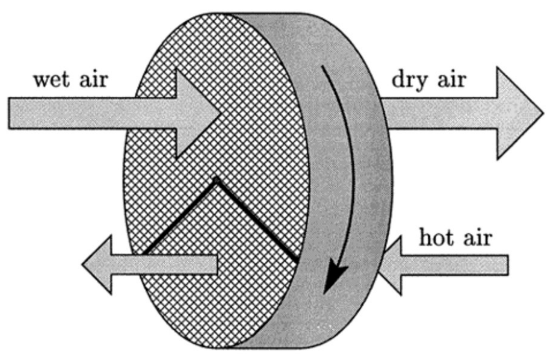


Figure 16: Energy Recovery Wheel.

Dedicated Outdoor Air System (DOAS)

Air Handling Units (AHU) are generally designed for handling both fresh air and the recirculation air from the space. They are selected for sufficient cooling capacity to handle Dry Bulb Temperature which is controlled by thermostat matching the sensible cooling capacity of the coil with the sensible cooling.

It has been observed that, if not designed properly these units have insufficient capacity to handle moisture loads, especially when the ambient moisture content is high (during rainy season). This insufficient capacity leads to increased RH in space, RH in the conditioned space leads to generation of Bacteria and Virus. The conventional solution is to design these AHUs at lower ADP (Apparatus Dew Point) and then reheat using either a heater or hot water coil. These systems are effective but energy guzzlers. Hence in NZEB, these systems are not advisable owing to considerable energy usage.

The cost and energy efficient solution to overcome this problem is to divide the load into the two components i.e. ‘Sensible’ and ‘Latent’ and handle them separately. This approach commonly referred to as the “Divide and Conquer”. Majority of the internal latent load is due to outside air. Hence, it is important that the latent load of the air shall be controlled at the source only. The DOAS approach works on this principle. It removes all the latent load being brought by the outside air at the source and processes the same to a very low dew point thereby enabling it to take care of the rest of the internal latent load too. The internal cooling devices are then limited to sensible cooling only.

Incorporating the Recovery Enthalpy Wheels, EcoFresh, and Passive Desiccant Wheels; this configuration allows the designer to design systems at lower dew points without using a DX system.

Energy Saving with Enthalpy Wheels

The heart of the DOAS is a desiccant coated energy recovery wheel, which slowly rotates between its two sections. In one section, the stale, conditioned air is passed through the wheel, and exhausted in the atmosphere. During this process, the wheel absorbs sensible and latent energy from the conditioned air, which is used to condition (cool/heat) the incoming fresh air in the other section, during the second half of its rotation cycle. Thus, more fresh air can be pumped at lower humidity and lesser energy cost.

RH Control with Passive Desiccant Wheel

The system has a unique configuration and uses a Passive Desiccant Wheels which do not require any active energy to regenerate. The DOAS can provide fresh air up to 10^{o}C Dew Point using chilled water coils.

The DOAS incorporates Total Enthalpy Wheel which preconditions the fresh air, the conventional cooling system and G3MA Passive Desiccant dehumidification wheel ensure supply of perfectly controlled temperature and dew point for a wide range of ambient conditions in different seasons throughout the year at a very low cost of cooperation.

Case study:

Project Type	: Library Block of a prestigious University in North India
City	: Patiala
Product installed	: DOAS - 2 units
Configuration	: HRW, Cooling Coil & Passive Desiccant Wheel
Total air flow	: 14000 cfm
Total energy saving	: 63 TR

Supply Air Conditions : 58 F & 48 gr/#

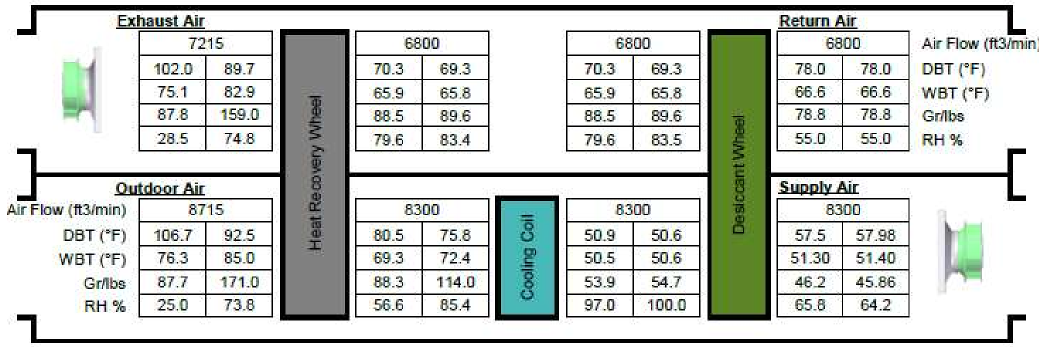


Figure 17 Exhaust and supply air – air flow, DBT, WBT, and RH conditions

Case Study:

Project Type : Office Building in North India

City : Gurgaon

Product Installed : DOAS - 4 units

Configuration : HRW, Cooling Coil, DX Coil, ODU & Passive Desiccant Wheel

Total air flow : 102235 cfm

Total energy saving : 502 TR

Supply air condition : 57 F & 50 gr/#

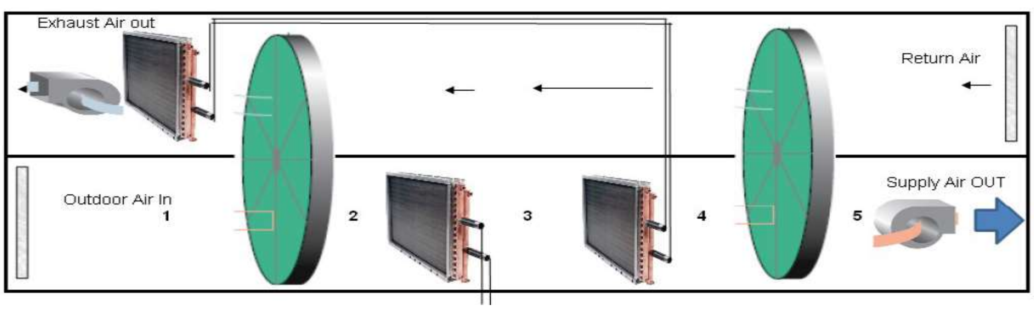


Figure 18 Energy Recovery Wheel – supply air and exhaust air

Case Study:

Heat recovery in air-conditioning system for a process air-conditioning facility, Pune:

The process air-conditioning facility had area of 590 m^2, height 3.6 m and occupancy 27. Outdoor air (OA) conditions in Pune used for air-conditioning load analysis are 40 ºC DBT and 28% RH whereas, the return (room) air-conditions are 23 ºC DBT and 50% RH.

In conventional air-conditioning system, the return air and outdoor air are mixed before the cooling coil. The cooled supply air leaving the cooling coil is further delivered to the room to pick-up the sensible and latent loads in the room. However, by using HRW, the cooled exhaust air is used to cool the supply outdoor air which is generally warm/hot. This results in cooling of outdoor air which then gets mixed with return air.

Annual energy savings achieved:

Effectiveness*	**0.75**	**0.8**	**0.83**	**0.85**	**0.87**	**0.89**
Total energy savings, kWh	16812	17933	18605	19054	19502	19950
Total energy savings, TR-h	4780	5099	5290	5418	5545	5672

*Effectiveness of HRW/ ERW is an important parameter and it is defined as ratio of temperature difference of incoming stream to the maximum temperature difference.

The annual energy savings considering only heat recovery application is significant for Pune city.

Service Providers:

Company Name	Contact Person	Email
Desiccant Rotors International Pvt. Ltd.	Mr Nitish Mathur, Manager Sales TFA & HRW - North	nmathur@pahwa.com Phone: +91 124 4188888 Mobile: +91 8130596692

2.6 Vapor Absorption Chillers

Vapor Absorption Machine is a heat-operated device that uses thermal energy to produce chilled water. The basic difference between the electric chillers and absorption chillers is that an electric chiller uses an electric motor for operating a compressor whereas an absorption chiller uses thermal heat for compressing refrigerant vapours to a high-pressure.

Absorption chillers operate using a concentration–dilution cycle to change the energy level of the refrigerant (water) by using lithium bromide to alternately absorb heat at low temperatures and reject heat at high temperatures. The absorption chillers can be direct fired (using natural gas or oil fuel), or indirect fired. Indirect-fired units may use steam or hot water (from a boiler, a district heating network, an industrial process, or waste heat) as a heat source. A typical absorption chiller includes an evaporator, a concentrator, a condenser, and an absorber.

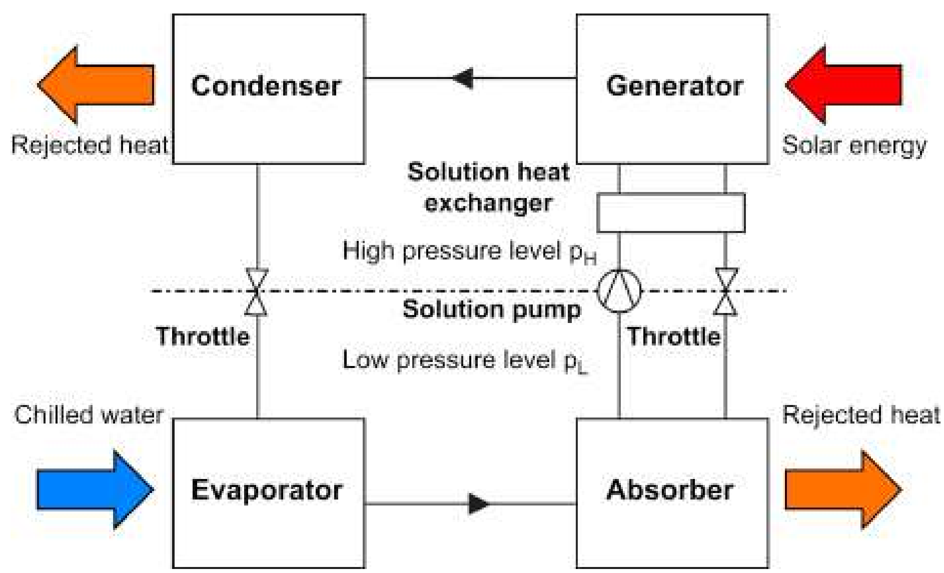


Figure 19 Schematic of VAS system

Case study:

With the increasing demand of potato-based snacks across the globe, large to small scale manufacturers aim to boost their productivity, quality, and sustain their brand credibility. The look-out for sustainable productivity, operational excellence, and profitability are paving the way towards solutions that can answer to the requirements of these industries.

Potato has nearly 70% water content. Upon frying, the water gets converted into low-pressure vapour which is released into the atmosphere using an induced draft fan in the chimney. Thermax's VAM chiller utilizes this vapour to provide air-conditioning in the production area of the facility which would otherwise require a power of about 350 kW using an electric chiller. In addition to this, the condensate from the absorption chiller is used for washing raw potatoes resulting in zero water discharge. This has not only encouraged the manufacturers to make an energy-saving cooling choice but has also shortened the payback period of their investment.

After washing and before the frying process, potatoes go through a series of intermediate processes such as peeling, arranging, blanching, slicing, and dehydrating. Thermax's Ultra Low-Pressure chiller is placed right after the frying process. The low-pressure vapour formed from the frying of potatoes has a temperature of ~115°C and a pressure of about 0.3 kg/cm^2. This low-grade vapour is used as a heat source in chillers to supply chilled water of the desired requirement. The condensate recovered from the chiller is accumulated and is used for cleaning the potatoes thereby saving an enormous quantity of water annually.

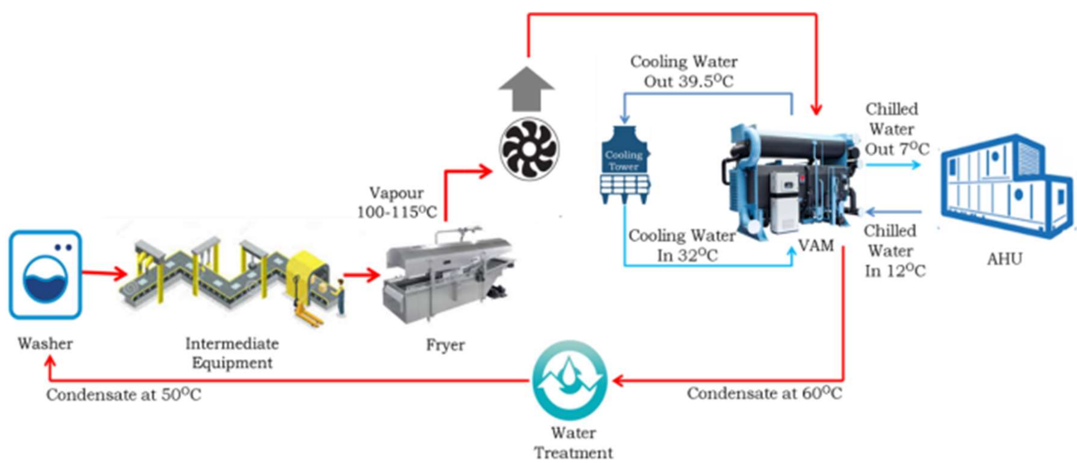


Figure 20 Use of VAM chiller instead of vapour compression system – schematic of VAM in food industry

Key benefits of the VAM chiller in food industry are the following*:

- Power savings : 3 million units annually
- CO_2 reduction : 4000 tons annually
- Water savings : 24000 m3 annually

*Savings are calculated for a typical 600 TR VAM installed at the world's largest potato chips manufacturing unit.

Service Providers:

Company Name	Contact Person	Email IDs
Thermax Ltd	Mr Vaidyanathan KS	Vaidyanathan.KS@Thermaxglobal.com

3 Passive Cooling & Heating Technologies

3.1 Geo-Thermal

Ground Source Heat Pump (GSHP) or geothermal heat pump is a technology which exchanges heat with ground to provide heating/cooling. It works on the principle that the earth temperature remains constant throughout the year and it acts like a source or sink depending upon the outside condition (application). For example, ground temperature is generally lower than the atmospheric temperature in summer, however it is higher in winter. By circulating the working fluid through a ground heat exchanger (GHE), the GSHP system can release heat to the ground for space cooling in summer, and extract heat from the ground for space heating in winter.

This system is more suitable for composite climate as continuous pumping of heat to ground could make the ground saturated. Therefore, during winter heat which is pumped into ground during summer, can be extracted to regenerate the soil as shown in appended figure.

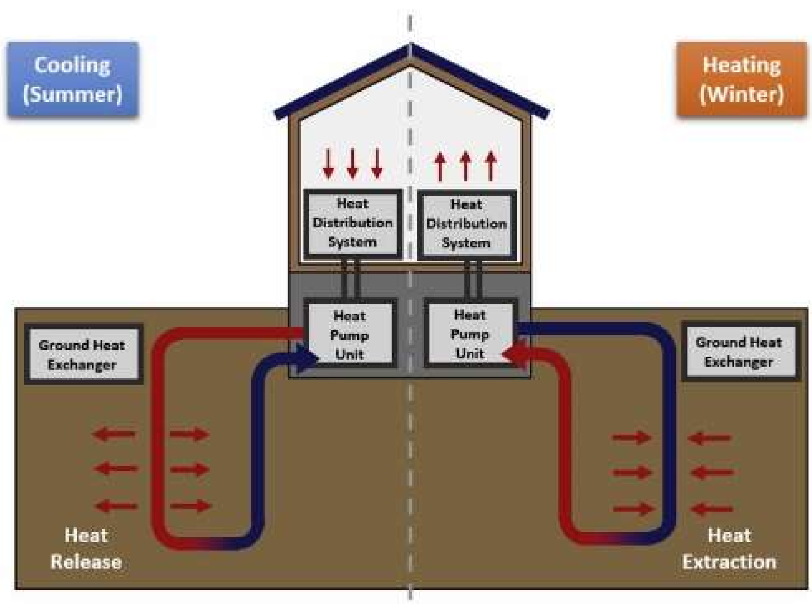


Figure 21: Schematic of ground source heat pump [3]

Case Study:

The building will be heated/ cooled using a hybrid system consisting of a geothermal heat pump (borehole heat exchangers are at a depth of 100m). The water will be cooled to 7°C/heated to 45°C and stored temporarily in a cold/hot water reservoir (buffer tank) with a capacity of 500 litres. The cooling/heating energy will be generated by a hydraulically reversible geothermal heat pump. Heating and cooling energy will be distributed around the building as per requirement by means of a combined hydronic water cassette/FCU (Fan Coil Unit) system which supplies hot or cold water.

Figure 22 Geothermal with borehole heat exchanger at CSIR CBRI Roorkee

Mechanical room is the common place for both primary exchange circuits and secondary distribution circuits. The Geothermal heat pump produces and deposits in a buffer tank from where the distribution to space takes place.

Figure 23 Primary and secondary exchange circuits

DHW =Domestic Hot water	No DHW	No DHW	Geo + Solar
	No Geo No Solar	No Geo No Solar	With DHW
Kilowatts	Standard	Low Energy	Offgrid
Consumption (KW)	9.44	7.73	1.647
Generation	0	0	2.362
Back to grid	0	0	-0.715
No of hours	8	8	8
Total KWh to pay (INR)	75.56	61.82	
Total KWh to be paid (INR)			-5.72

Figure 24 e-Manager for auto switching between Grid and Renewable

With the combination of geothermal and solar energy, the building can be operated without any energy use and (or) surplus power can be exported to the grid.

Service Provider:

Company Name	Contact Person	Email ID
S.A.P. Automations (India) Pvt Ltd	Mr Arijit Ghosh	arijit@sapautomation.in 9971600708

3.2 Radiant Cooling

Radiant cooling works on the principal of mean radiant temperature. In conventional air-conditioning system, cooling is provided by cooled air through convection. To transport the cool air from one location to another location in a building/space requires lot of fan energy. On the other side, in radiant cooling system, cooling is provided by maintaining the building surfaces such as roof, floor and wall at lower temperature to have radiant heat exchange between the surface and heat load (e.g. human body). In this case, transportation of air is not required hence, significant fan energy is being saved. A separate air system is installed to meet the requirement of fresh air or latest heat load such system is called DOAS.

In radiant cooling system, chilled water system operates at elevated temperature therefore chiller efficiency gets improved as compared to the conventional chiller operating at normal conditions (CHW leaving temperature would be around 6-7^{o}C). Due to higher temperature of chilled water, non-compressor-based cooling system which consumes significantly lesser energy as compared to the normal chiller can be used in radiant cooling system.

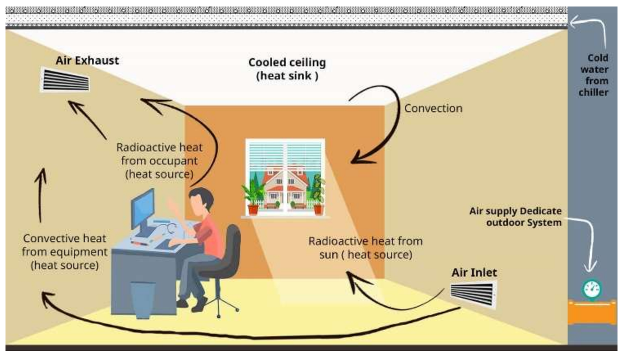


Figure 25: Radiant Cooling System (beepindia.org/technologies-n-tools/radiant-cooling/)

CASE STUDY:

Radiant Cooling & Heating has been installed in the office of M/s KM Trans Logistics (P) Ltd Jaipur. KMT is a logistics and supply chain management company incorporated in 1998 in Jaipur.

Figure 26 Case study building – radiant cooling system

Radiant Floor Cooling/Heating Schematic

Radiant Cooling & Heating was chosen as a key technology for reducing their energy consumption for HVAC. The following figure shows the high level schematic for radiant cooling & heating system.

M/s KMT had chosen radiant cooling system based on financial assessment and pay-back of the system. Using centralized system with radiant cooling allows the total system size to be reduced by taking advantage of load diversity in the building. The operating hours of radiant cooling chillers are lower as thermal mass of the floor screed gives the benefit of storage. EPS insulation (30 mm thick, 32 kg/m3 density) was put on the floor upon which a moisture barrier was laid. PERT (16 mm dia) pipes were installed and then embedded in the floor screed. The entire piping network uses multiple manifolds (shown below) for distribution of cold/hot water depending on whether cooling or heating is needed.

Radiant cooling operates to cater to the base load and FCUs are used for handling peak and latent load. In this case study, initial capital cost with radiant cooling was higher by 7.25 lakh as compared to VRF system. However, owing to efficient operation and the payback (less than a year), radiant cooling system selected.

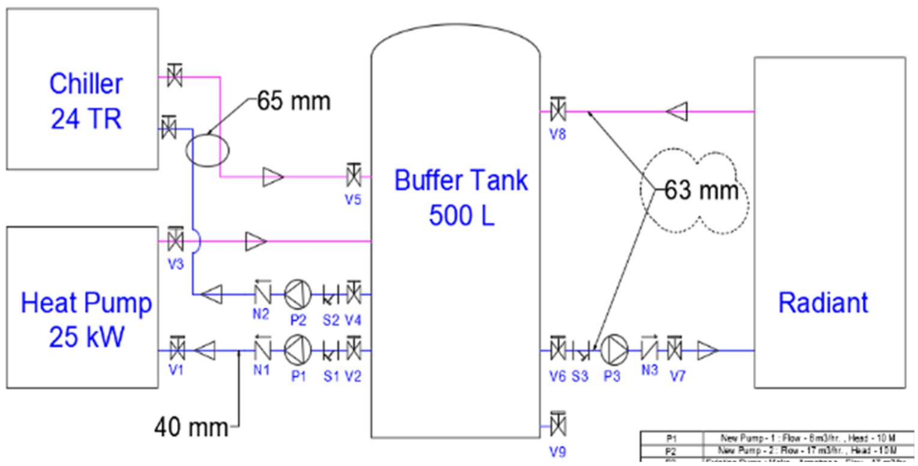


Figure 27 Schematic of radiant heating/cooling system

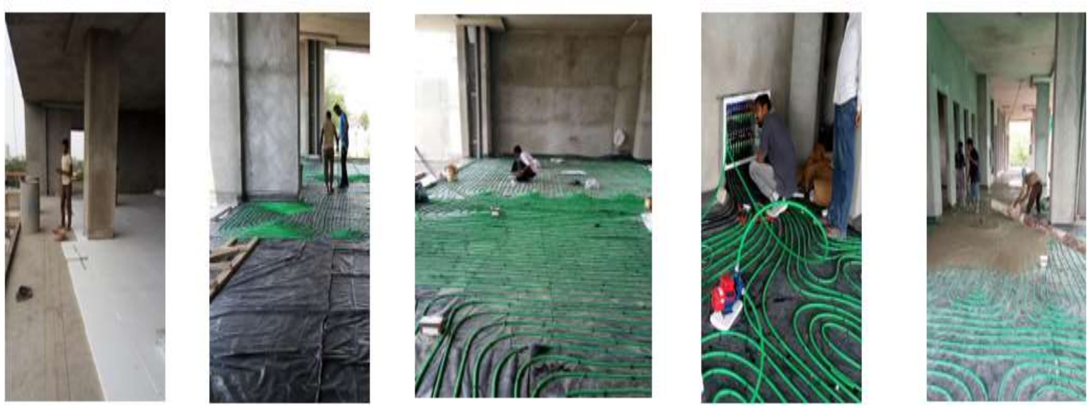


Figure 28 Images from Right to Left show different stages of installation of radiant cooling system at KMT

Plant Room

Chillers and heat pump installed on the terrace. The configuration is as below:

- For Radiant Cooling : 24 TR Chiller
- For Radiant Heating : 25 kW Heat Pump

- For dehumidification & air-conditioning without radiant cooling: 34 TR Chiller

Figure 29 Case study building at Jaipur

Figure 30 Case study building – indoor spaces with radiant cooling

Cloud based monitoring system is being used to further optimise performance of the radiant cooling system.

- Operational data logging
- Chiller operation optimisation
- Automatic scheduled operations
- Varying set points
- Operation based on load, ambient & indoor conditions
- Alerts (system diagnostics)

Service Provider:

Company Name	Contact Person	Email
Oorja Pvt Ltd	Madhusudhan Rao	madhu@oorja.in

3.3 Waste to Chilling

The refrigeration system is powered by biomass or farm waste. The fuel is fed into the hot water generator automatically. The combusted fuel provides thermal energy, which is adsorbed by the water circulated by a hot water circulation pump. The hot water, achieves a temperature of 115-120°C @ 40 LPM, is pumped to the desorber (Tank A), which heats the refrigerant (R717) adsorbed by the adsorbent. The water after exchanging heat with the desorber circulates back to the boiler at 105-110°C. The R717 is circulated using a refrigerant pump at a pressure of 10-15 bar, which is condensed using cooling water from the cooling tower. Roughly, 30-35 kg/hr of liquid R717 is circulated in the system.

The R717 passes through the expansion valve, thereby reducing the pressure and temperature, and changing its form from liquid to gaseous R717. The gaseous R717 exchanges heat with the space to be cooled in the evaporator. This results in the refrigerant to get heated up and returns to the Adsorber (Tank B). The Adsorber, which consists of adsorbent, keeps adsorbing the refrigerant throughout the cycle (20 mins).

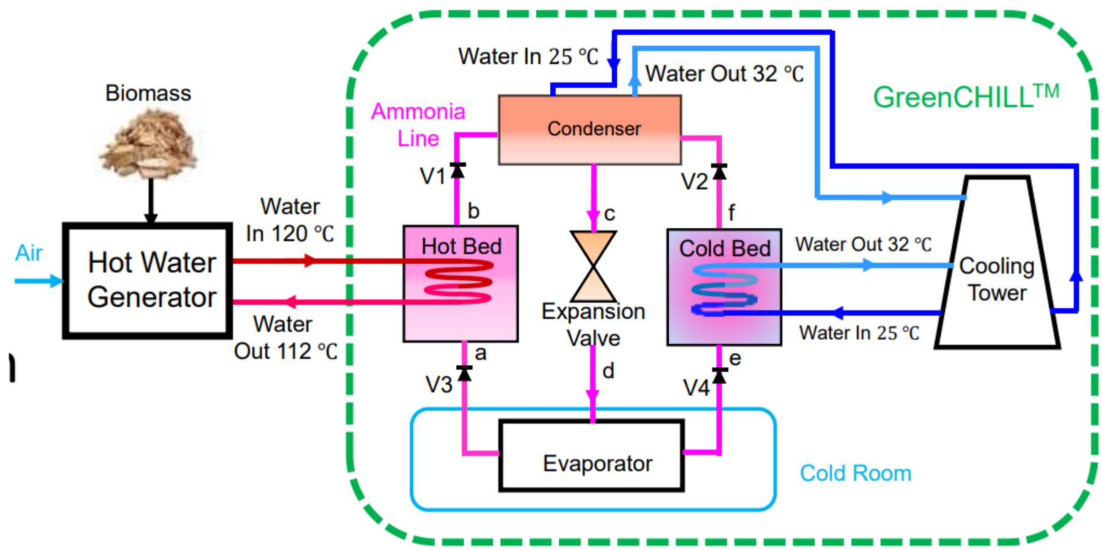


Figure 31 Waste to chilling plant

Once the cycle time (20 mins) is complete, the role of the adsorber and desorber reverses. Now, Tank-A plays the role of Adsorber, and Tank-B plays as the Desorber. The changeover switch ensures that the hot water from the boiler is transferring heat with the Tank-B (presently desorber), which the refrigerant from the evaporator is adsorbed by the Tank-A (presently adsorber). This cycle repeats, ensuring that the adsorbent regenerates automatically, thus ensuring continuity in providing required refrigeration load.

The system automatically maintains the set temperature in the cold room using the PLC panel on Green CHILL. As the cold room reaches the set temperature, Green CHILL automatically switches-off and as the cold room warms up, Green CHILL automatically re-starts. In this manner Green CHILL can work unattended 24 hours a day. The cold room temperatures are also transmitted over the cloud through a Danfoss device so that the cold rooms can be monitored remotely.

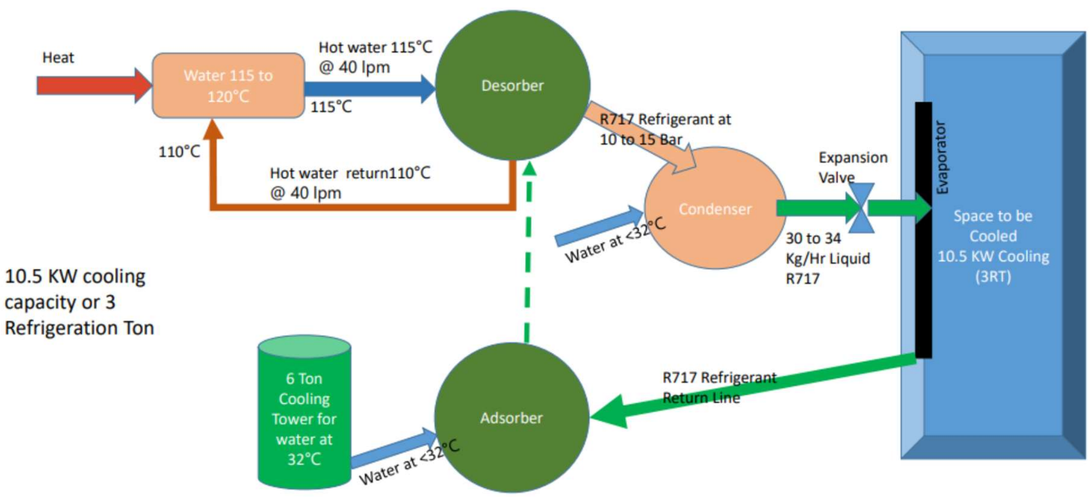


Figure 32 Process flow of waste to chill

Key benefits:

- No/minimal dependency on grid, it can be operated by connecting to Solar PV
- Low specific energy consumption (kW/TR) with respect to conventional refrigeration system
- Multi-purpose applications such as cold storage rooms, pre-cooling chambers, ripening chambers and air-conditioning unit.
- Reduction of post-harvest losses
- Reaches remote locations and powers cold chain infrastructure using biomass and agri-waste

S No	Project Name	Address	Contact Person	Industry type (demonstration)
1	Madhur Fruits Thottiyam Banana Producer Group	Thottiyam, Trichy	Mr Kalayanasundaram	Agriculture / Banana Farming
2	Bigbasket	Bangalore	Mr Ganapathi Subramanyam	Fruit & Vegetable collection & Distribution Centre

Figure 33 Case study building

Figure 34 Green Chill at Bigbasket-DC3

Figure 35 Incinerator

Figure 36 Adsorber and Disorder

Figure 37 NLD system at Bigbasket, Bengaluru

key Benefits:

- Significant reduction in total specific power consumption from 1.35 kW/TR to 0.11 kW/TR
- The agricultural produce can be stored in any remote location, and results in reduced spoilage of fruits and vegetable, thereby improving the shelf life of the products
- System runs with single phase supply hence, more reliable in operating even at remote areas
- The connected load of the system is very less and integration with Solar PV can reduce the dependency on the grid altogether
- Utilization of agri-waste as combustion fuel, results in biogenic emissions and therefore creates a positive impact on the overall GHG emissions
- System uses zero ODP and GWP (refrigerant) hence making it environmentally friendly

Appended table presents the specific energy consumption details and comparison.

Table: Savings estimates for 4MT capacity

S No.	Parameter	Unit	Conventional ACs	NLD System
1	Specific energy consumption of refrigeration load	kW/TR	1.35	0.11
2	Annual electricity Operating Cost	INR Lakhs	4.73	0.40
3	Annual fuel consumption cost	INR Lakhs	-	0.88 – 2.63
4	Annual operating cost	INR Lakhs	4.73	1.28 – 3.03
5	Net cost savings	INR Lakhs	3.45 to 1.70	
6	Net Cost savings	%	73% to 36%	
7	Annual GHG Emissions	MT CO_2	42.38	3.18
8	Net GHG Emission reduction	MT CO_2	39.20	
9	Net GHG Emission reduction	%	92.5%	

Service Provider:

Company Name	Contact Person	Email IDs
New leaf dynamics	Anurag Agarwal	Anurag@NewLeafDynamic.com

3.4 DC Appliances

DC powered appliances consume significantly less energy than the appliances run on AC power. DC system combines distributed generation, energy efficiency, smart grid – iGrid and IOT system.

Figure 38 DC appliances for reduced energy use in buildings

There could be multiple power sources for DC supply such as solar energy, biogas energy, micro wind energy & PICO hydel energy. Appliances are being operated directly from DC sources without any Inverter

<u>Appliances</u>

iChill Split type Room Air-conditioners:

Figure 39 DC Powered AC Units installed at project site

Figure 40 DC Powered AC Units installed in office building

Model	1.5 Ton	1 Ton
Cooling Capacity, W	5275	3500
Input Supply	220-360 V DC	
Input Power, W	1270	900
COP	4.15	3.89
Energy Consumption/hr	0.333	0.250

Comparison of Cooling Appliances: DC versus AC

Appliance	AC 5* W	DC W	AC kWh	DC kWh
Refrigerator 300L	150	40		
Freezer 550 L	200	50		
Aircon 1.5 Ton	1500	variable	1.2/hour	0.33/hour
Milk Chiller 550 L	200	50		
Ceiling Fan 1150 mm	55	20		

An innovative solution for roof top solar systems using DC appliances & smart Nano/Micro Grid:

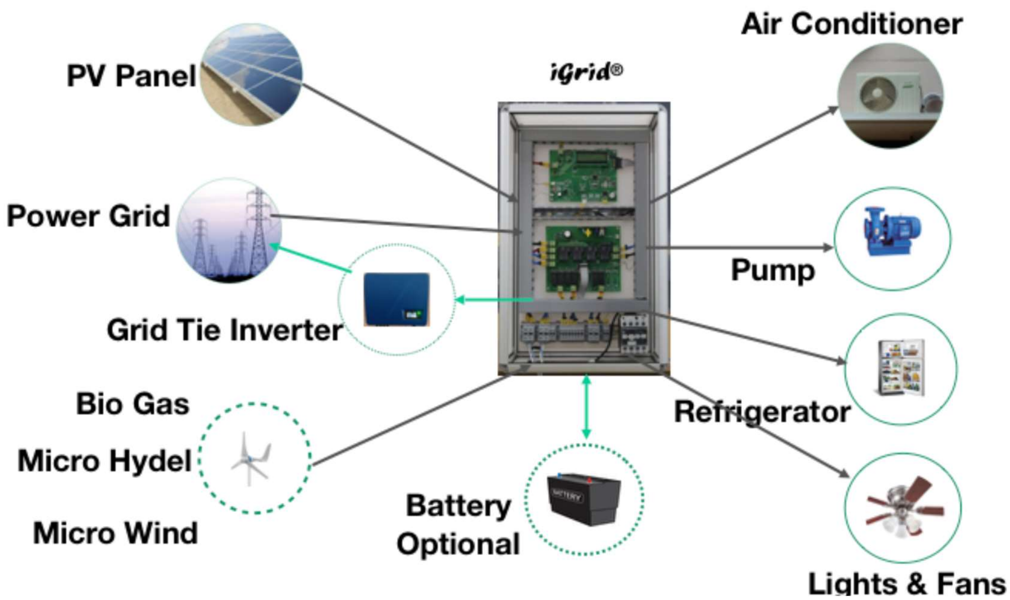


Figure 41 Schematic of DC powered SPV – DC system

The present solutions consists of solar panels, battery with charge controller & inverter for converting the DC from panels to 230V, 50 Hz AC for running the appliances. There are mostly lights and small fans.

Product Solutions:

- Use of permanent magnet brushless DC or synchronous motors with increased efficiency:
    - Elimination of a winding for production of magnetic field by the use of permanent magnets
    - Elimination of carbon brushes and related parts resulting in complete elimination of friction losses, while improving reliability
- As the new motors are of variable speed type, the power/energy consumption is greatly reduced if the load demands are reduced
- The power/energy savings of different appliances are as under:
    - Air Conditioner : at least 50%
    - Refrigerator & Deep Freezer : at least 60%
    - Pumps : at least 40%
    - Ceiling fan : at least 50%
    - LED light : at least 55%
- All the new motors have soft starting, i.e. the in rush starting current is eliminated

- All the new appliances are DC type running directly from PV panels
    - No inverter required
    - Battery is normally not needed except for back-up requirements which can be given as an option
- The system uses the proposed 380 V DC. The rectified AC is also compatible
- The appliances can run from AC grid power by using a AC-DC converter, which rectifies the AC to DC
- Due to the combined effect of the above the solar panel rating is reduced by a factor of at least 60%
- The home/office can run on the following priorities:
    - Use solar energy as far as possible
    - In case the solar power is not sufficient due to bad weather, it will use the available power and the balance is taken from the AC mains
    - In case of total absence of solar power, the appliances will run automatically from AC mains
    - In the absence of both solar and AC mains power, the system will run from battery if back up is available.
- A smart grid controller takes care of the power and load monitoring and automatic enabling use of power from PV panels, battery or AC grid and vice versa
- When the load demand is less than the power generated, the excess power ca be fed back to the power grid through a grid-tie inverter
- The AC and DC circuitry in both grid-tie inverter and AC-DC converters are galvanically isolated
- MPPT (Maximum Power Point Tracking) is incorporated in the AC-DC converter so that at any point of time, the power available in the PV panel is used
- Other sources of renewable energy can be used concurrently like roof top micro wind, PICO hydel, Bio-mass/gas driven generation, etc., depending on the terrain and location
- Thus the building will not use grid power at all when sunshine or renewable power is available
- During night times grid power will be used with the following advantages:
    - The power requirement & consequently the power bill will be halved
    - The power factor will be near unity. This is a great boon for the electricity board and enables a possible increase of connected load by 25% from the same distribution transformers

    - The new appliances will work on a wide range of input supply voltage in both DC and AC
- In case, grid power is not available, battery storage is possible. The battery will be charged by solar panels. The battery capacity is reduced by about 60% due to the improved efficiency and absence of starting current

Readiness of the Solution:

- The solution is already deployed in a many homes & offices in Tamil Nadu.
- The following appliances are available:
    - 1 & 1.5 tonnes ACs; cooling only and cooling & heating models
    - 50, 180 & 300 Litre Refrigerators
    - 250 & 350 L Deep Freezer
    - 1150 mm Sweep Ceiling Fan
    - A range of LED lights including Bulbs, Tubes, Panel lights, street lights and spot/focus lights.
    - RO water purification system with solar operated pumps for water extraction, pumping and RO filter
    - Electric cycle with lithium battery
- Existing wiring of the building has been used with minor changes
- The solution can be customised to individual needs of the home/office subject to a minimum size of 300 W.
- Continuous power & energy monitoring of both DC and AC power is being done through smart meters.

These solutions have been tested thoroughly in the laboratory and in the field.

Company Name	**Contact Person**	**Email IDs**
Basil Energetics Private Limited	Mr R Ramarathnam	rramarathnam@basilenergetics.com

4 Fan & Motors

4.1 BLDC Fans

Brushless DC (BLDC) fan is powered by DC electric source through integrated inverter. These fans have static magnet instead of electromagnets. BLDC motor-based fan consume less energy as compared to the conventional fan. The brushless motors that are attached to the fan blade, have several benefits over conventional motors, like highspeed, high power-to-weight ratio, low maintenance and electronic control.

The regular inefficient ceiling fan utilizes AC induction motor which is inherently inefficient. These motors consume about 75W and consumes one unit of energy in 13 hours. BLDC motor-based ceiling fans, now popularly known as BLDC fans consume (<35 W) less than half the electricity of a regular fan (75-80W) while delivering the same airflow. The challenges in developing a ceiling fan using this motor technology were multi-fold in the form of reliability, longevity, manufacturability, performance to match or surpass the cost of regular fans. Versa Drives solved each of them and made a fan that is better than existing fan in every aspect.

Case study:

Kalasalingam academy of research and education, formerly Arulmigu Kalasalingam College of Engineering and Kalasalingam University is a private deemed to be university located in Krishnankoil near Rajapalayam in Tamil Nadu, India. The campus is close to the ancient temple town of Srivilliputhur.

In 2015, most of our fans were regular ceiling fans which consumes more than 80Watts in classrooms as well as in hostel rooms. In hostels, the fans run almost 16 hours which resulted in huge electricity expenses. All the fans were replaced by BLDC fans and it has significantly reduced the energy cost.

Service Providers:

Company Name	Contact Person	Email ID
Versa Drives	Mr Sathish	sathish@versadrives.com
Can fan	Mr Ajay Sasidharan	ajaysasidharan@canfan.co.in
Atomberg Technologies Pvt Ltd	Ms Roshni Noronha	roshninoronha@atomberg.com

4.2 EC Axial Fan

EC stands for Electronically Commutated System. An EC motor is a brushless, external rotor type of motor. EC Fan is energy efficient technology/ solution to save energy consumption by 40-60%. An electronically commutated (EC) fan design delivers the combined benefits of AC and DC Fans. Electronically Commutated (EC) fan often referred to as a Brushless DC electric motor (BLDC motor) with integrated controller electronics can provide the optimal amount of power to the motor which makes EC or BLDC motors more efficient than AC motors [4].

It is state of the art technology for energy conservation, in conventional AHU system there are no. of equipment's like blower coupled with motor through belt pulley system. Speed of system is controlled by external VFD and there is a requirement to have large electrical panels in the system to operate it. As more components are added in the system, the running efficiency goes down.

In EC technology, very efficient backward curve aerofoil design blowers directly coupled with EC motor, whose efficiency is better than IE 5 motor. This EC motor have inbuilt VFD and harmonic filters. So, there is no need of any additional panel for speed control, power factor improvement and harmonics mitigation. The overall and running efficiency of this system is better than conventional system. There is scope of 35 -50% energy conservation from present level at same air flow.

Figure 42 Photograph of EC axial Fan

Motor Efficiency Comparison

Efficiency of EC motor remain high at very low speed however, in case of induction motor it goes down when motor speed is below 50% of rated speed and it requires external cooling in some cases.

Table: Comparison between Conventional & EC Motors

Performance Parameters	AC Motor	EC Motor
Motor efficiency at varying load	70-80%	90-93%
Motor efficiency at full load	80-90%	> 93%
Power Factor (PF) at drive level	0.6-0.8	Close to unity

Advantages of AECS Technology

- Energy saving opportunity : 35-50 % over conventional system
- Highest running system efficiency : 70-75%
- Space saving system
- Low magnetic noise from motor
- Integrated power electronics for efficient motor speed control
- Integrated motor protections to save motor and power electronics
- Seamless integration possible with PLC, BMS, SCADA & standalone sensors
- Wireless communication with EC116 and EC152 (optional)
- Easy to configure and read-out data

Case Study:

AAD-TECH India Pvt Ltd has retrofitted AHUs with EC Technology in place of conventional AC blower system at one of the ITES buildings. Photographs of the system 'before' and 'after' installation of EC blowers are shown below.

Figure 43 Before & After Retrofit Pictures

Table: Summary of before & after retrofitting

S No.	AHU No	Design				Before Retrofit		After Retrofit		Avg Saving (%)
		CFM	Static in MM	Rating KW	After Rating kW	kW	CFM	kW	CFM	
1	AHU 1	16500	58.5	7.5	10	7.52	17585	4.17	17440	45%
2	AHU 2	16500	58.5	7.5	10	6.92	10548	2.73	10938	61%
3	AHU 3	17500	58.5	7.5	10	6.11	12670	3.63	13020	41%

4	AHU 4	17500	58.5	7.5	10	6.25	10179	3.08	10144	51%
5	AHU 5	17500	58.5	7.5	10	6.52	12907	3.27	12963	50%
6	AHU 6	17500	58.5	7.5	10	6.09	12607	3.52	12763	42%
7	AHU 7	17500	58.5	7.5	10	5.78	10165	2.66	10157	54%
8	AHU 8	17500	58.5	7.5	10	4.83	12617	2.62	12436	46%
9	AHU 9	16500	58.5	7.5	10	7.4	12199	3.61	12440	51%
10	AHU 10	16500	58.5	7.5	10	7.63	13614	3.71	13913	51%
11	AHU 11	20000	58.5	9.3	10.2	8.5	15011	4.46	14877	48%
12	AHU 12	17500	58.5	7.5	10	5.77	9878	2.41	10077	58%
13	AHU 13	20000	58.5	9.3	10.2	7.89	15071	3.49	15131	56%
14	AHU 14	21500	58.5	9.3	10.2	7.49	14812	4.3	15288	43%
15	AHU 15	17500	58.5	7.5	10	8.54	12629	3.28	12941	62%
16	AHU 16	17500	58.5	7.5	10	5.26	6870	2.44	7355	54%
17	AHU 17	15000	58.5	7.5	10	6.72	11788	3.38	11965	50%
18	AHU 18	17500	58.5	7.5	10	6.29	9642	2.51	10492	60%
19	AHU 19	15000	58.5	7.5	10	6.1	11756	2.97	12470	51%
Total						127.61		62.24		51%

From the above table, it can be witnessed that for delivering same air flow average power savings achieved is around **51%** over operational power. AAD Tech has done retrofitting of systems installed at various locations PAN India and summary of savings achieved is tabulated below.

Table: Summary of savings achieved

S No.	Location	Total AHUs Retrofitted	Power Consumption Before Retrofit (kW)	Power Consumption After Retrofit (kW)	Avg Savings Achieved (%)	Total Savings in KWH	Total Savings in INR	Reduction in CO_2 Emission
1	Telangana	61	409.18	196.34	52%	6,38,520	51,08,160	1174.62
2	Maharashtra	46	251.2	125.8	50%	3,76,200	30,09,600	692.06
3	Karnataka	102	750.13	370.91	51%	11,37,660	91,01,280	2092.84
4	Tamil Nadu	149	1152.67	512.36	56%	19,20,930	1,53,67,440	3533.74
Total			2563.18	1205.41	52%	40,73,310	3,25,86,480	7493.26

Project Impact

As a result of this retrofitting, the project was able to save around 1358 kW, 40,73,310 kWh annually which is equivalent to 7493.26 tonne of reduction in CO_2 emission annually. Annual cost saving of 325 lakh was achieved with simple payback period of 18 months.

Service Providers:

Company name	Contact person	Email id
AAD TECH (India) Pvt. Ltd	Mr Manpreet Singh	manpreet@aadtech.in +91 9876724003
Xero Energy	Mr Abdul Muqeeth	muqeeth@xeroenergy.in
EBM Papst	Mr Venkatesh Ravula	venkatesh.j@in.ebmpapst.com

4.3 Motors

In an industrial facility, most of the equipment are motor driven hence, energy efficiency in motors plays an important role for reducing energy consumption. Therefore, relevant National and International Standards have defined different efficiency level such as IE1, IE2, IE3, IE4 and IE5.

The International Electrotechnical Commission (IEC) has developed the International Efficiency (IE) classes for motors. This is an International Standard that stipulates the energy efficiency of low voltage AC motors. IS (Indian Standard) uses same standard to classify the motor efficiency.

Efficiency Class (IE Code)	
Classes	Code
Super Premium Efficiency	IE4
Premium Efficiency	IE3
High Efficiency	IE2
Standard Efficiency	IE1

Industrial Cooling Direct Drive Motor and VSD packages

Cooling tower direct driven motor along with variable speed drives replace the gearbox, driveshaft and induction motor typically used in industrial cooling towers. This combination provides high torque and low speed required for these applications without additional drivetrain components. This results in less parts, only some maintenance, lower noise and reduced risks.

Advantages:

- Reduce maintenance and improve reliability. With this package, gearbox, gearbox cooling system, driveshaft, couplings and bearings etc. can be eliminated. This means no more gearbox maintenance, no oil leaks, no cooling water contamination and no long lead times for replacement parts
- Same technology can be offered in conventional, yet power dense, foot mounted designs that replaces the belt and sheave applications
- Lower vibration and system noise
- Saves energy and eliminates start up current peaks and stresses from across-the-line start up. The drive smoothly accelerates and decelerates the fan to the speed needed, rather than running directly online
- Anti-windmilling technology controls fan blades when the system is not operating
- Simplified fan driven alignment, only need to align the fan to the motor shaft, supported by a global service network that ensures local support, no matter where the motor and drive are installed

Case Study:

15.5 kW 350 rpm Cooling Tower Direct Drive (CTDD) is implemented in JW Marriott, Pune which includes Baldor-Reliance Motors and Variable frequency Drive for air handling unit application. This improves energy efficiency by 35% reduces maintenance costs while delivering quieter operation as compared to the conventional Motor-Gearbox systems.

Figure 44 Case study building

Service Providers:

Company Name	Contact Person	Email IDs
ABB India Ltd.	Mr Madhav Vemuri	madhav.vemuri@in.abb.com
Bharat Bijilee Limited	Mr Anil Naik	Anil.Naik@bharatbijlee.com
Crompton Greaves Limited	Mr Ashok Kulkarni	ashok.kulkarni@cgglobal.com
Kirloskar Electric Company Limited	Mr Ashok Kshirsagar	ashok@pna.vrkec.com
Marathon Electric motors (India) Pvt. Ltd.	Mr Salil Nerukar	salil.nerurkar@marathonelectric.com
Siemens Limited	Mr Prasad Hardikar	prasad.hardikar@siemens.com

5 Lighting System

Lighting is an important measure to save energy consumption in buildings. Incorporating daylight measures reduce energy consumption as well (lighting power density can be reduced by proper introduction of day-light concepts). Provision of daylight through windows, vision glazing, and courtyard enhance daylighting which in fact improves occupant visual comfort and integration between daylighting and lighting fixtures can be controlled to further save energy. Below figure shows windows and vision glazing (which helps in deep penetration of day-light).

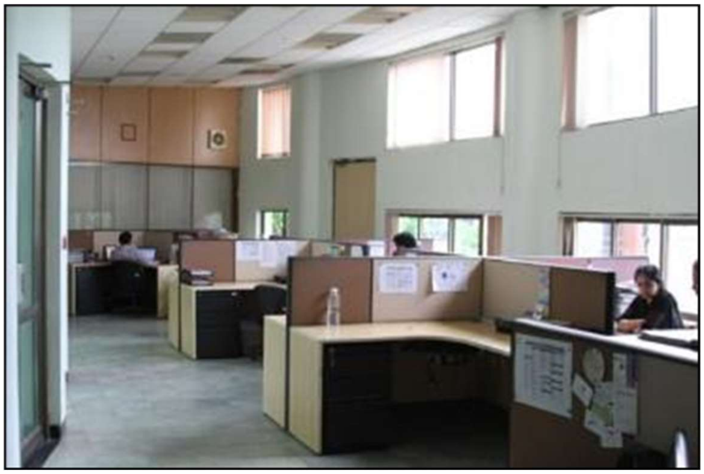


Figure 45 Window and vision glazing – CII GBC Hydrabad – a Net Zero Energy Platinum Building

Daylighting should be holistic in design to offer visual comfort, thermal comfort and shall also reduce the demand of energy. In modern buildings, control measures are provided to harness maximum daylit available throughout the year and to reduce energy usage.

5.1 LED Lighting

LEDs are highly energy efficient lighting systems and enormous energy saving are possible for the facility which have higher lighting energy consumption. Retrofitting of old lighting fixtures by LED based lighting system are easy and the payback is less than a year or so however, it depends on the usage of lighting.

Service Providers:

Company Name	Contact Person	Email IDs
Avni Energy Solutions Pvt Ltd (ESCO model available)	Mr Sandip Pandey	sales@avnienergy.com
Eview Global PVt Ltd	Mr Rajiv Gupta	rajiv@eviewglobal.com
EESL	Mr Chandra Shekar	ybchandrashekar34@gmail.com
FortuneArt Lighting (ESCO model available)	Mr Prasad	arvlines@gmail.com

Havells India Ltd	Mr Sunil Sikka	sunil.sikka@havells.com
OSRAM Lighting Pvt. Ltd.	Mr Nitin Saxena	N.saxena@osram.com

5.2 Light Pipes

Light pipe is a technology to transmit the natural light from an outdoor to inside space, hence reducing the use of artificial lighting. Light pipes not only can reduce electricity consumption in buildings, but also improve the indoor environment quality. Light pipe generally consists of three components; outdoor light collector (usually installed on the roof), a diffuser (installed inside) and a pipe with inside reflective coating to transmit the light. Sunlight collector of light pipe captures light and is transferred through conduits into building by light diffusers. Optically designed, large sunlight collectors unlike ordinary domes are vital element for very high light output of light pipes. Ultra-high specular reflective conduits are critical to reduce light transmission losses. A light pipe can deliver light to a basement/cellar reaching 15.0 m (50 feet) distance.

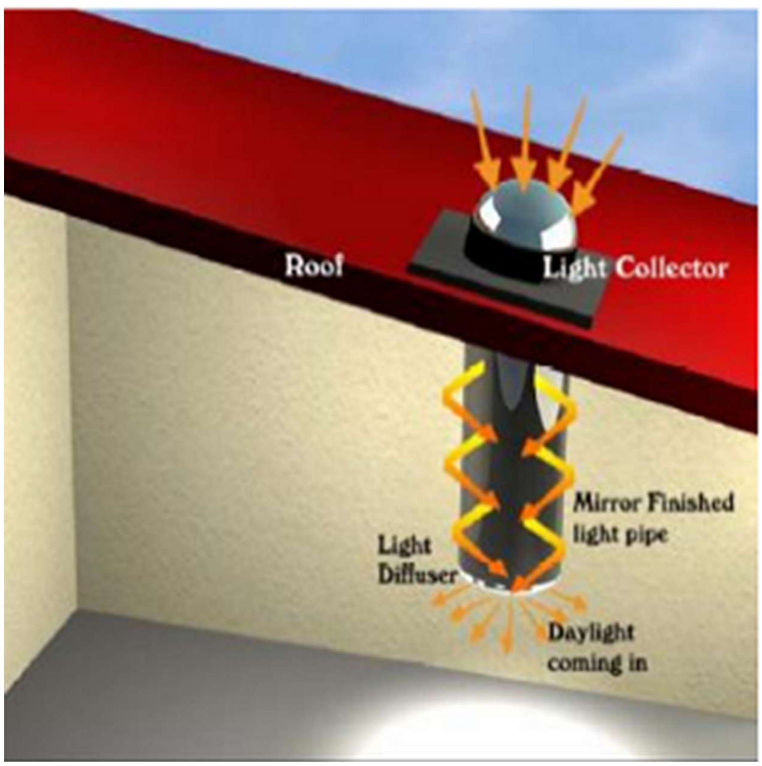


Figure 46 Photograph and schematic of a light pipe

Case Study:

In Silvassa Dets, there are three plants i.e., Bar Plant, Powder Plant and Unit-2. In Bar Plant packing hall, there are in total 60 nos High Pressure Mercury Vapor Fittings each 250 Watts, summing up to 360 kWh energy requirement per day. As per the USLP, it is essential to cut off the energy consumption wherever possible. Hence, it is very essential to use natural resources to meet the day-to-day lighting requirements.

To completely stop the HPMV lights in the packing hall, 30 nos Skylight pipes are installed. In 2021, 12 and 15 nos Sky Light Pipes have been installed, which has led elimination of 30 nos. HPMV lights during day time (average 10hrs), saving 75 kWh per day (27375 kWh per year).

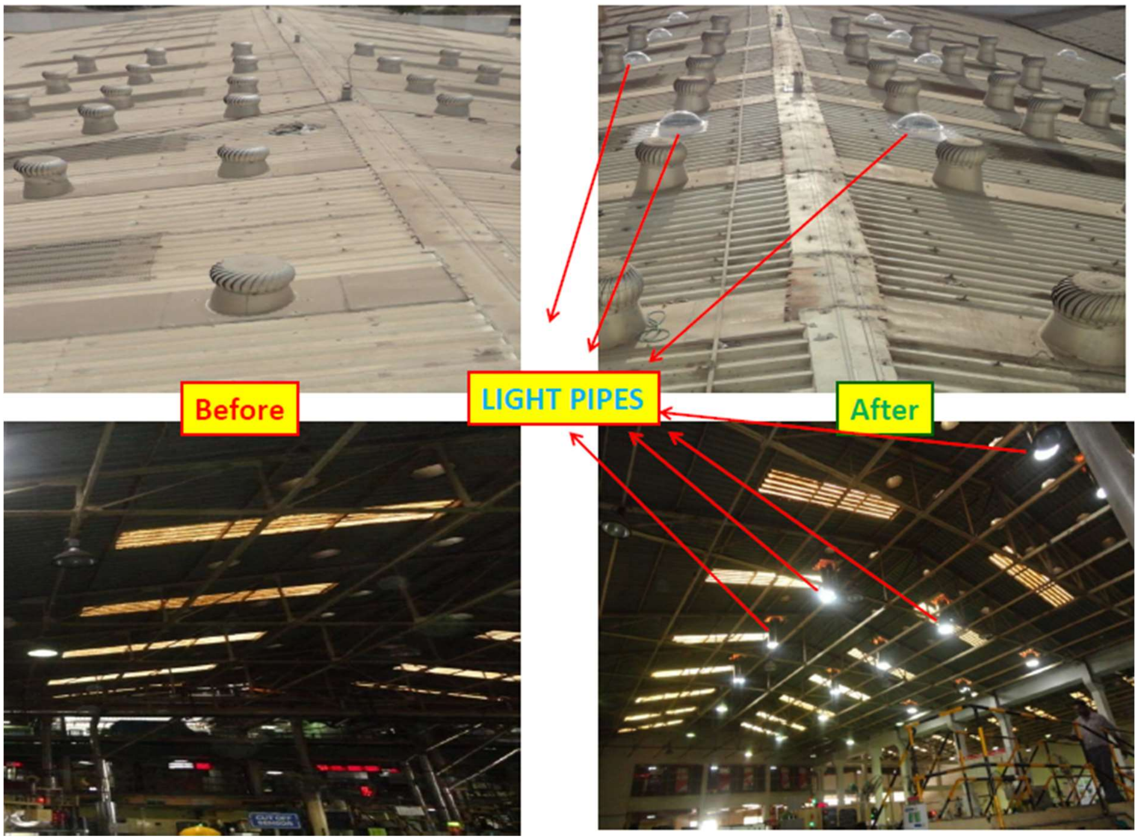


Figure 47 Installation of lighting pipes in a factory building

Service Providers:

Company Name	**Contact Person**	**Email IDs**
E-View Global Pvt Ltd	Mr Rajiv Gupta	rajiv@eviewglobal.com
Sky Shade	Mr Paresh Kumar	paresh@skyshade.in

6 Control System

6.1 Building Management System (BMS)

Building Management System (BMS) is a digital interface, state of art technology to operate building equipment at optimum for maximum energy savings. It includes a group of interlinked networks and devices (hardware & software), which optimizes building operation mainly emphasising on energy use through fine tuning operation of air-conditioning and other electromechanical components. Generally, 8-10% or even more energy can be saved by using BMS in commercial buildings. BMS automates operations such as scheduling lights, HVAC and equipment based on building usage.

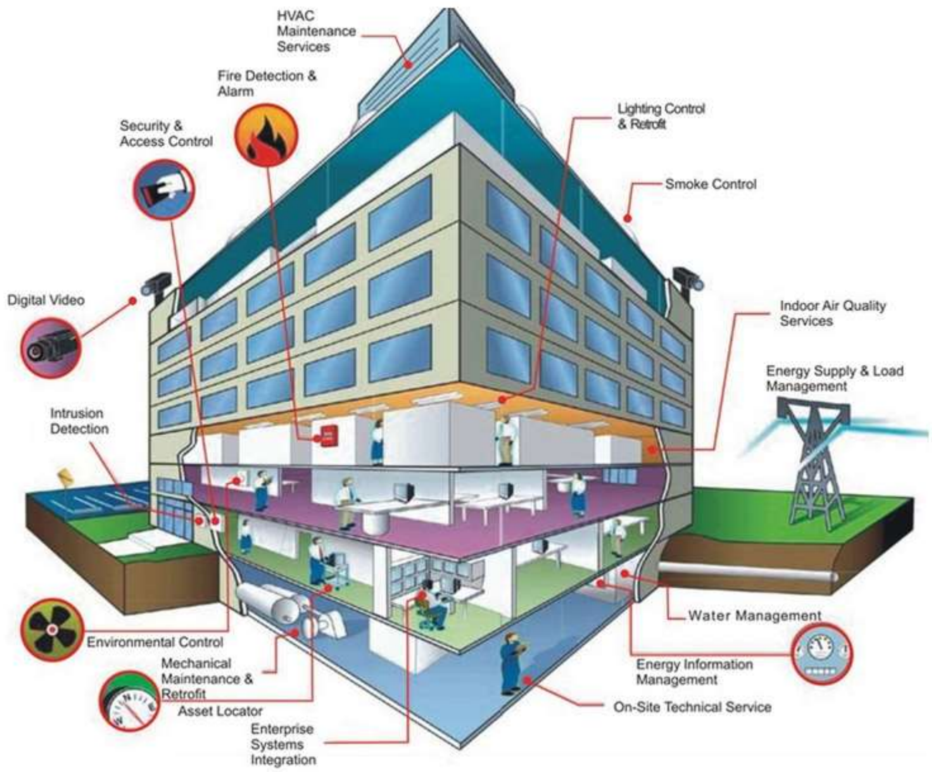
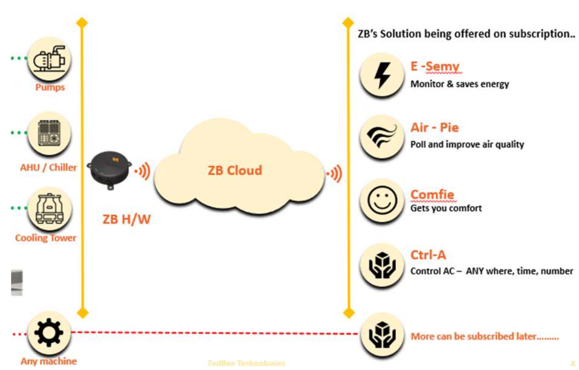


Figure 48 Components for BMS system integration

Case Study:



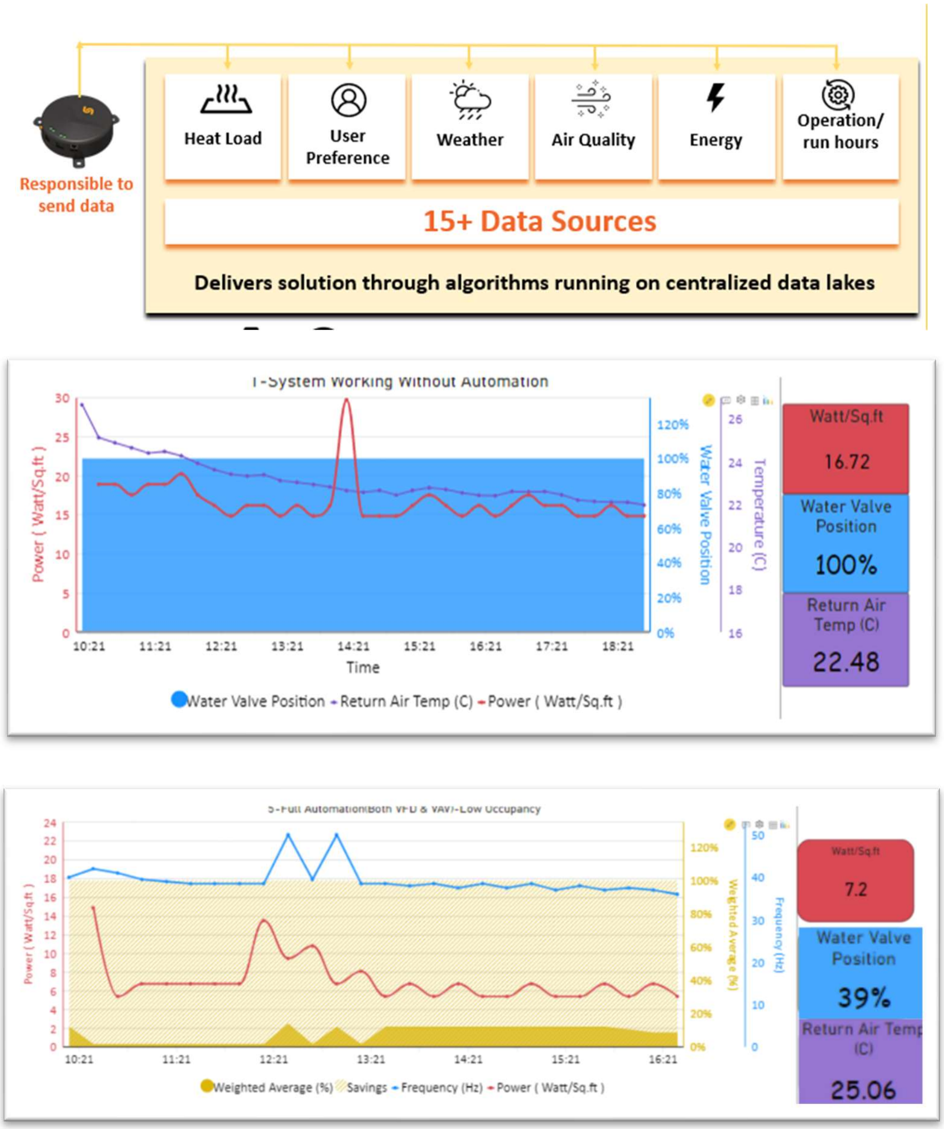


Figure 49 BMS system installation and equipment performance at IITM Research Park

<u>Benefits of Esemy:</u>

- 35% energy savings with improved comfort by 30%
- Savings of 17 tons air-conditioning
- Pre automation bills : ₹ 60,000
- Post automation bills : ₹ 43,000
- Total investment : ₹ 1,80,000
- ROI of 11 Months

Service Providers:

Company Name	Contact Person	Email IDs
Siemens Ltd	Mr Raakesh Manoharan	raakesh.m@siemens.com
Renata Envirocom Pvt. Ltd.	Mr Anil Sagar	anil.sagar@envirocom.in
Zedbee	Mr Sreejith	sreejith@zedbee.in

6.2 Variable Frequency Drive

Variable Frequency Drive (VSD) is an electronic device that controls the rotational speed of a motor-driven equipment (i.e. a blower, compressor, fan, or pump). Speed control is obtained by adjusting the frequency of the voltage applied to the motor. These motors are used in most heating, ventilation and air-conditioning (HVAC) systems and account for a significant portion of the total HVAC energy consumption. Efficient operation of motors using VFDs can result in significant energy savings.

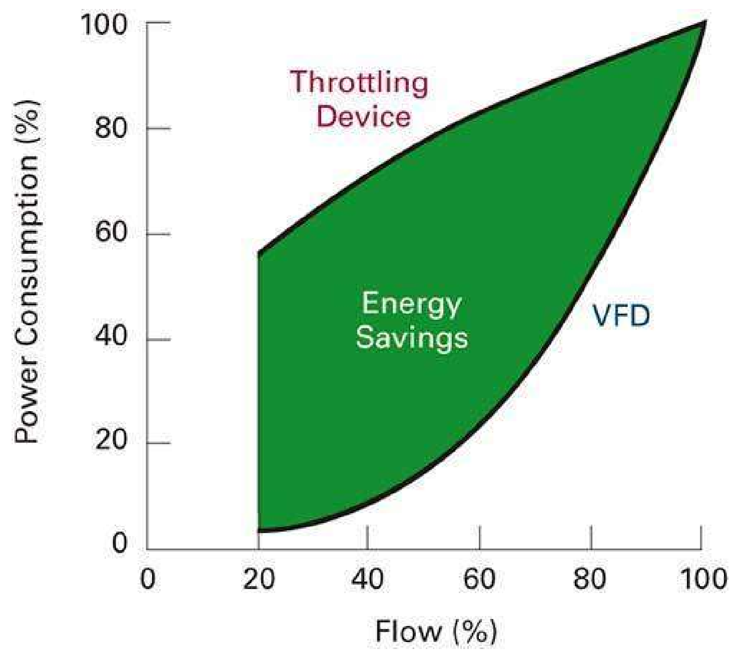


Figure 50 Relation between Flow and power consumption – effect of VFD

A VFD provides the amount of energy needed to handle the instantaneous load of the heating or cooling system. Without a VFD, air flow of an HVAC is system is controlled by throttling an inlet vane or braking an outlet damper. However, the best way to control the airflow is to use VFD, that continuously regulates motor speed. When the requirement of air is low, the motor will use less energy by reducing the speed.

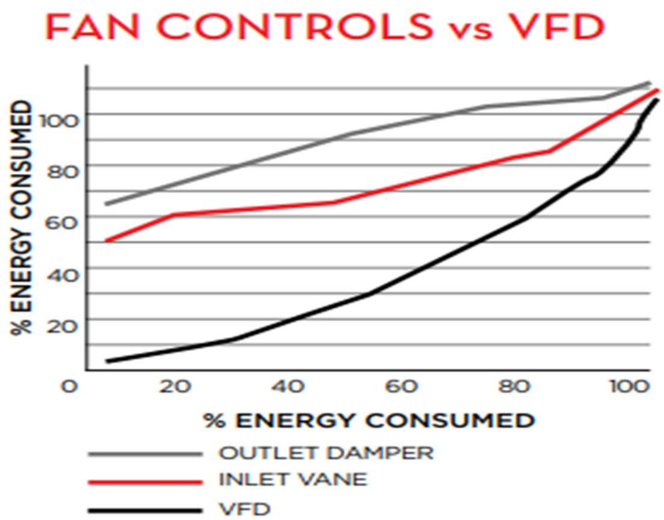


Figure 51 Effect of VFD – Outlet damper ad inlet valve

For example: When an HVAC system requires 50% airflow, the VFD uses 21% of full airflow energy, whereas an inlet vane control will use 65% of full airflow energy and an outlet damper control will use 87% of full airflow energy. VFDs reduce maintenance costs and extend operating life, allowing motors to run at less than their fully rated speed. VFDs also allow more precise control of airflow, which helps to increase the comfort level in buildings.

Case Study:

Operational cost reduction with highly efficient retrofit solutions in Hablis Hotel Chennai.

If chillers are retrofitted with VFD, considerable power saving could be achieved when the hotel ran the chillers under partial load conditions. Trane has recently completed a retrofit project for The Hablis Hotel, a luxurious first-class business hotel located at the centre of Chennai, India. The existing Trane water-cooled chiller RTHD retrofitted with VFD. It is estimated that the operational savings for the hotel would be more than USD 20,000 per year. The retrofitting has also reduced the manpower effort significantly and helped in improving the internal team's working efficiency while significantly reducing operation cost.

Two chillers in the project working efficiently depending upon the loading condition however, when the load reduced to 40-50%, efficiency of chiller is reduced. During site observation, it was found that the ageing chillers running under partial load conditions had high power consumption. After further investigation, it has found that the operators at the hotel running these machines at 25 percent load in an attempt to reduce operational cost, which had resulted in frequent visits by technicians with high maintenance costs.

After rounds of data analysis and mutual discussions, Trane's consulting engineers proposed VFD solution to the customer and convinced them that if the chillers were retrofitted with VFD, the considerable power saving could be achieved when the hotel ran the chillers under partial load conditions.

Figure 52 Case study building – Hotel Hablis Chennai, chiller equipped with VFD for maximum energy savings

Service Providers:

Company Name	**Contact Person**	**Email IDs**
Trane	Mr Vivek Sivaramakrishnan	Vivek.Sivaramakrishnan@trane.com
ABB India Ltd	Mr Madhav Vemuri	madhav.vemuri@in.abb.com
Amtech Electronics	Ms Bhavana Thakkar	sales@amtechelectronics.com
Danfoss	Mr Ramesh Reddy	Ramesh_reddy@danfoss.com
Hitachi HirelPower Electronics Pvt. Ltd.	Mr Dhiren Shah	dhiren_shah@hitachi-hirel.com
Rockwell Automation India Pvt. Ltd. (Allen-Bradley India Ltd.)	Ms Ruchi Mathur	rmathur@ra.rockwell.com
Schneider Electric	Mr Amresh Deshpande	Amresh.Deshpande@ schneider-electric.com

Section II: Renewable Energy System

Renewable energy sources commonly used in buildings are Solar Photovoltaic (SPV) system, wind, geothermal, and biomass. Examples of renewable energy technologies that can be incorporated are the following:

- Solar Photovoltaic (SPV) system
- Building Integrated Photovoltaic (BIPV)
- Wind turbines
- Hybrid system (SPV+Wind)

1 Solar Photovoltaic System

Solar Photovoltaic (SPV) is a technology that converts sunlight (solar radiation) into electricity by using Photovoltaic (PV) cell. Silicon-based PV technologies can be grouped into three types,

- Single-crystal or monocrystalline silicon

Since these are made from pure monocrystalline silicon, this type of PV cell offers better efficiency as compared to others PV cells. For monocrystalline cells, the efficiency ranges between 16% and 24%.

- Polycrystalline silicon

These PV cells are fabricated from ingot of multi-crystalline silicon and easy to manufacture. These PV cells are cheaper however less effective. The efficiency of polycrystalline cells varies from 14%to 18%.

- Thin film amorphous silicon.

Amorphous System – in amorphous silicon PV cells, a thin un-crystallized layer silicon is attached onto a substrate, which rides the cell relatively thin and offers efficiency around 4-10%.

The major challenge with solar PV technologies is ensuring appropriate siting for maximum electricity production. An ideal solar PV installation would be placed in an unshaded, south-facing location with an optimum tilt angle, and would supply electricity to a site where there is a demand for the electricity.

1.1 Single Facing

Generally solar PV modules generates power from one side, these panels are known as single phase solar PV. These are conventional solar panels which have lesser efficiency as compared to bifacial solar panel.

1.2 Bi-Facial

In bifacial solar panel, electricity is produced by both sides of panel. They're often more durable because both sides are UV resistant, and potential-induced degradation (PID) concerns are reduced when the bifacial module is frameless. Balance of system (BOS) costs are also reduced when more power can be generated from bifacial modules in a smaller array footprint.

Case Study:

Since inception, 2003, CII-GBC has been promoting the use of renewable energy sources. Earlier, the SPV capacity was 24 kWp that off-set grid energy use by 21%. For a Net Zero Energy Building, it is mandatory to off-set 100% grid energy use by renewable energy. Hence, it was decided to opt new technology that can enhance RE generation from the roof-top (1175 sq.m). Initially, a site assessment was carried out and potential RE technologies are studied. Bifacial Solar PV technology adopted which had promising efficiency (high electricity generation).

Figure 53 Case study building – Bi-facial SPV system

Bifacial solar PV is a transparent and frameless module and unlike regular solar modules that come with a singular face for absorption of light. Bifacial solar modules are equipped to allow passage of light from both the sides of solar cell and generate electricity from both sides (front and rear face of the module).

Figure 54 Horizontal and vertical installation of Bi-facial SPV system

This helps in increasing the efficiency per cell, resulting in an increase in the total energy generation along with reduced construction costs. In fact, to increase the yield on the backside, roof surfaces are coated with high SRI (more than 110) paint that reflects the radiation on back side of the module. The SPV system installed at 1.5 m height from the roof, so that diffused radiation will fall on back side of the SPV modules. Total 130 kWp (efficiency of module is 23% which is higher than the conventional module). The total SPV system capacity is 138 kWp.

Service Providers:

Company Name	**Contact Person**	**Email IDs**
PPAM SOLKRAFT	Andreas Molin	andreas.molin@ppamsolkraft.se
Bosch Ltd.	Mr Niranjan Naik	NiranjanN.Naik@uk.bosch.com
Megawatt Solutions Pvt Ltd	Mr Siddharth Malik	smalik@megawattsolutions.in
Oriano Solar	Mr K G Vijayvargiya	kg.vijay@orianosolar.com
Waaree Solar	Mr Ajay Mishra	ajaymishra@waaree.com
Swelect Energy Systems Limited	Mr VC Raghunath	vcr@swelectes.com

1.3 Building Integrated Photovoltaic System (BIPV):

Availability of space for power generation is one of the major challenges for net zero energy buildings. Hence, Building Integrated Photovoltaic (BIPV) system can be integrated to the building façade/roof to generate power although their efficiency is lesser than the conventional SPV system. BIPV systems can be explored in a new building (as part of design) as well as these kinds of systems can be installed during retrofitting in existing buildings. BIPV also reduces glare and heat load as well in buildings. Below figure shows installation of BIPV system in a green building project.

Delta Power, Rudrapur

Figure 55 Installation of BIPV System

1.4 Solar Boot Model

RESCO (Renewable Energy Service Company) or BOOT Model (Build Own Operate Transfer) is referring to a single concept of buying solar power under a long-term agreement from another company that oswns a solar project. In this model investment is done by the solar generator and supplies the power to consumer under a long-term agreement on prescribed tariff. In this model, all risk of non-performance of the project is to the account of solar power generator and the consumer pays as per actual generation and consumption[5].

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[5] https://www.uniquesunpower.com/boot-model-for-solar-rooftop/

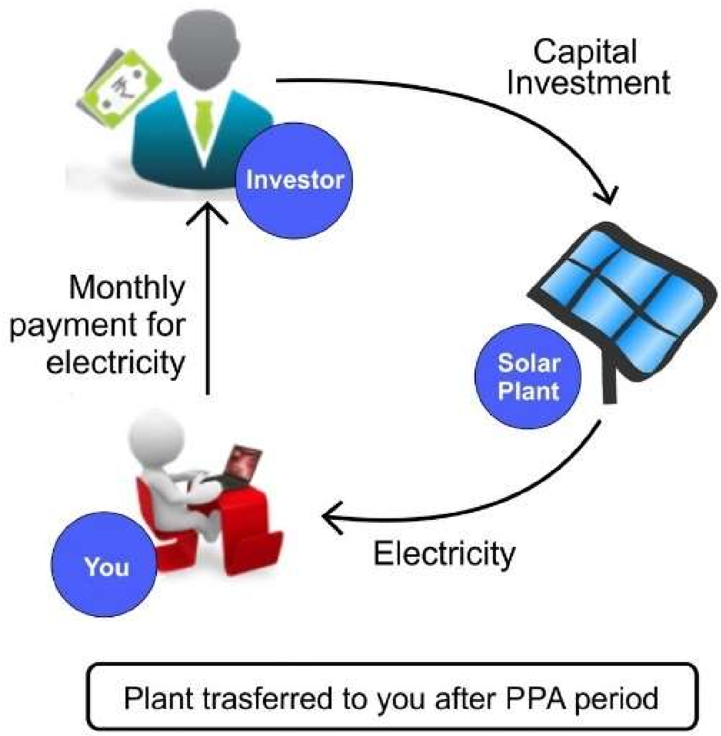

Figure 56 Solar Boot Model for NZEB

Case Study:

A Leading Textile company at Bhilwara, Rajasthan, India involved in spinning, weaving and finishing of textiles, having a huge facility in Bhilwara, Rajasthan has opted for BOOT model. Solar Power Plants installed over rooftops (industrial sheds and RCC roofs) and on land generate 15 GWh of electricity every year to serve the facility load.

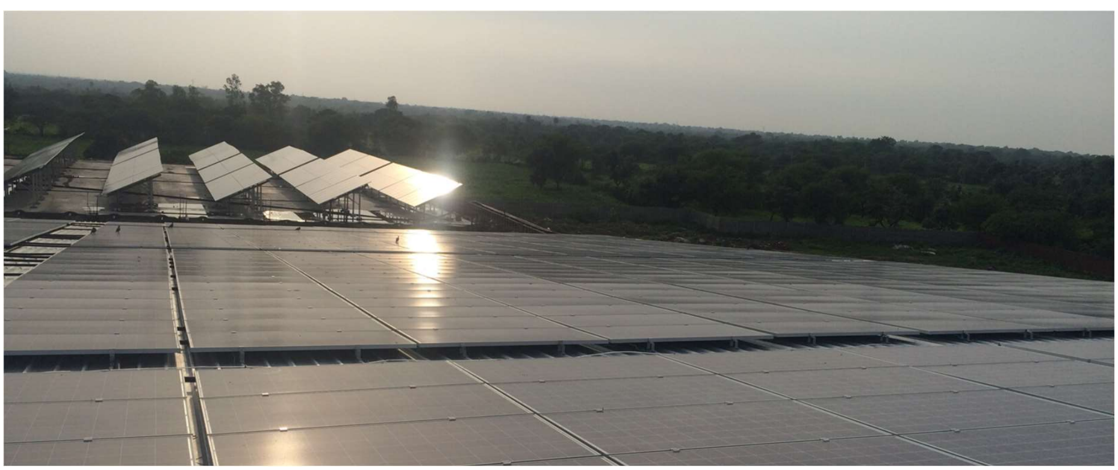

Figure 57 Case study building

Technical Specifications:	
Solar Panel	**Area**

• Technology: Poly-crystalline • Size - 320 Wp, 325 Wp & 330 Wp • Make - Trina Solar & Vikram Solar **Inverters** • Type - String • Size - 50 kW, 60 kW • Make – Sungrow	• Ground Mount : 94,106 sq. m • Rooftop : 47,550 sq.m **Project Size** • 10.3 MW (connected at 415 V) **Project Type** • Ground Mount + Rooftop
Benefits: • CO_2 offset/ year: 13980 MT • Annual energy output: 15.2 million kWh	

Service Providers:

Company Name	Contact Person	Email
SunSource Pvt. Ltd.	Mr Adarsh Das	contact@sunsource-energy.com
Amplus Solar	Ms Ritu Lal	ritu.lal@amplussolar.com
Jakson Power	Mr Vaibhav Singhal	vaibhav.singhal@jakson.com
Cleanmax Solar	Mr Vikram Salvekar	vikram_salvekar@cleanmaxsolar.com

1.5 **Wind Turbine**

Generally, wind turbines are installed at macro level for large scale energy generating such as wind farm. Of late, market has adopting micro wind turbine for generating electricity at building level. This technology is known as building integrated wind turbines. Small wind turbines are originally designed with a horizontal axis, also known as HAWTs. To reduce the need for a high tower, and for aesthetic reasons, vertical axis wind turbines (VAWTs) become increasingly popular for integrated building applications. Furthermore, VAWTs are also quieter (resulting in less noise nuisance) than HAWTs during operation [5].

Figure 58 Integrating micro wind turbines to the built environment

Service Providers:

Company Name	Contact Person	Email IDs
Integrum Energy	Mr K G Vijayvargiya	vijay@integrumenergy.in

2 Solar Thermal

In solar thermal system, solar energy is converted into thermal energy with the help of solar collectors and receivers known as solar thermal devices. Solar water heating can be a cost-competitive way to generate hot water or air and eliminate both the cost of electricity and fossil fuel as well as the associated environmental impacts.

Solar Hot Water System

Solar hot water systems use collectors to absorb and transfer heat from sun's radiation to water, which is stored in a tank until needed. Solar energy collectors in general are special kind of heat exchangers that transform solar radiation energy into internal energy of the transport fluid. Solar water Systems (SWH) are categorized by the temperature at which heat is most efficiently delivered and the collector type that is best suited for the delivered temperature, mid-temperature (flat-plate collectors), and high-temperature (evacuated tube collectors).

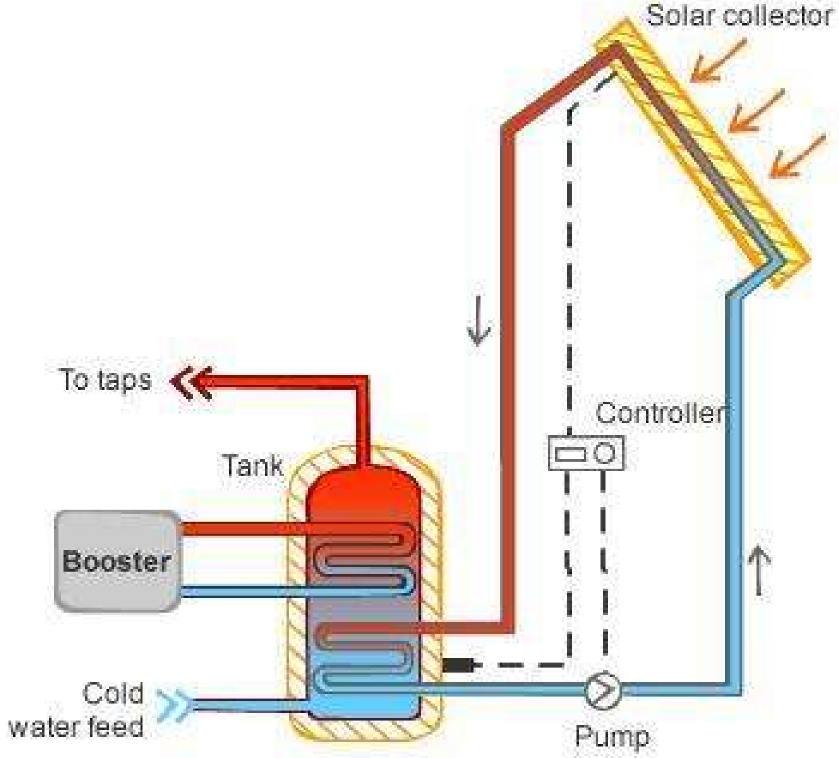

Figure 59 Solar Hot Water System

Case Study:

Solar Thermal System for Diesel Generator Engine Block Heating

Figure 60 Solar Water Heating system

TVS Motor, Hosur (TVSM)[6] plant uses Diesel Generator as a backup power source during the time of power failures. To reduce the start-up time of the diesel generator the engine head must be maintained at constant temperature, and this is done with the help of forced circulation electrical heating system. Because of this continuous requirement to maintain constant temperature in the engine block, the electrical heaters consume about 1200 kWh per day.

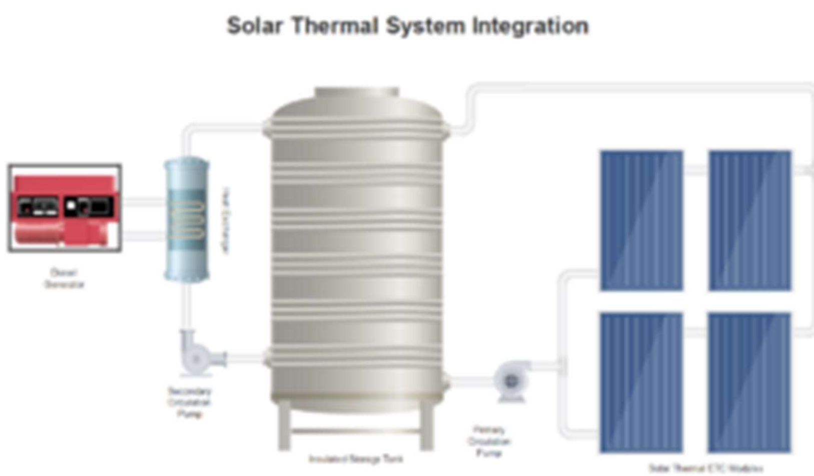

Figure 61 Solar Water Heating system

After detailed study and analysis on the energy consumption pattern for the electrical heaters, Aspiration Energy came up with a highly efficient solar thermal system design

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[6] https://aspirationenergy.com/case-study-solar-thermal-system-for-diesel-generator-engine-block-heating/

with energy accumulator to serve the heat requirement for 24-hour operation of engine head block heating.

The designed capacity of total system is 225 kW and consists of 50 modules of 4.5 kW each. The solar thermal systems are designed in such a way that even at the winter season, the system will deliver the required heat output to maintain the engine block temperature at 55 °C. The system is designed with butterfly-shaped Evacuated Glass Tube Collectors (ETC). Each ETC module is rated at 4.5 kW thermal capacity with 7.7 m^2 aperture area. The system was installed with 2 modules in series connection and 25 pairs of modules in parallel connection with reverse return header.

The primary circulation of the system was driven by a multistage centrifugal pump which circulates water from storage tank to solar thermal modules and back to storage tank. When solar direct radiation falls on ETC glass tubes, the water flowing through the tubes heats up and returns to storage tank. After multiple passes through the modules, the water can be heated up to 95 °C at maximum solar radiation. The hot water stored in the tank is pumped by secondary circulation pump and delivers it to the plate heat exchangers installed for each generator. The plate heat exchangers are integrated in such a way that the existing heater element is connected parallel to the plate heat exchanger – so that the electrical heater acts as the main heating element when solar thermal is idle in adverse weather conditions.

The engine heads are heated up by indirect heat transfer between the solar water and jacket water with the use of plate heat exchanger. The hot water from solar thermal modules flows in hot side while the jacket water from engine from engine circulation flows through the cold side. After successfully installing the system, the average savings per day is 1031 kWh and the average heater energy consumption per day is 169 kWh for the given solar radiation in the month under observation.

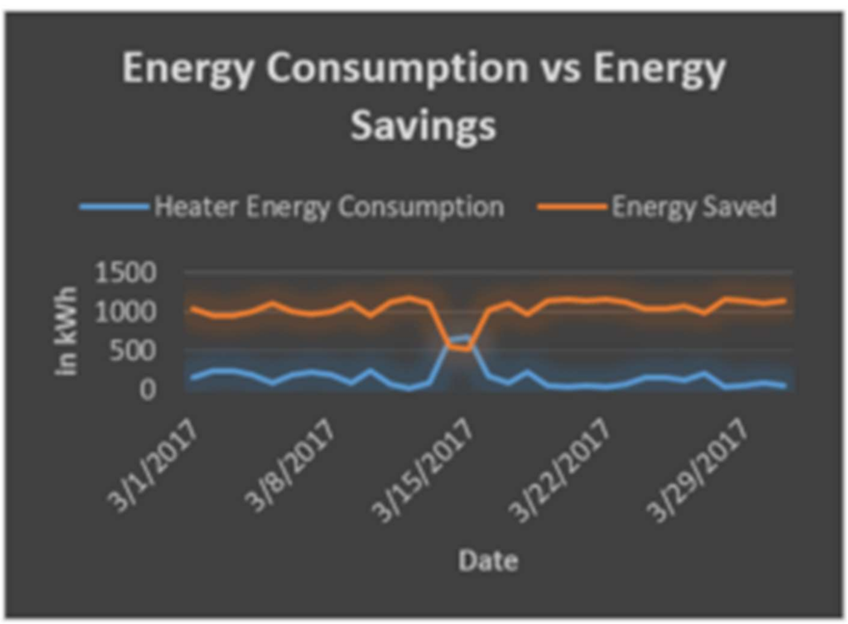


Figure 62 Performance of Solar Water Heating system and energy savings

Date	Heater Energy Consumption	Energy Savings (kWh)	Cost Savings (%)
03-01-17	158	1042	86.83
03-02-17	243	957	79.75
03-03-17	255	945	78.75
03-04-17	207	993	82.75
03-05-17	99	1101	91.75
03-06-17	196	1004	83.67
03-07-17	238	962	80.17
03-08-17	202	998	83.17

Case study:

A parabolic solar concentrator comprises of sturdy Fibre Reinforced Plastic (FRP) shell lined with Stainless Steel (SS) reflector foil or aluminised polyester film. It can accommodate a cooking vessel at its focal point. This cooker is designed to direct the solar heat to a secondary reflector inside the kitchen, which focuses the heat to the bottom of a cooking pot. It is also possible to actually fry, bake and roast food.

Positioning of solar panels or collectors can greatly influence the system output, efficiency and payback. Tilting mechanisms provided to the collectors need to be adjusted according to seasons (summer & winter) to maximise the collector efficiency. Four to 5 hrs in late morning and early afternoon (between 9 am to 3pm) is commonly called the "Solar Window". During this time, 80% of the total collectable energy for the day falls on a solar collector. Therefore, the collector should be free from shade during this solar window throughout the year (shading may arise from buildings or trees towards south of the installation).

Figure 63 Parabolic concentrating solar cooker

Service Providers:

Company Name	Contact Person	Email
Absolicon Solar Collector AB	Mr Joakim Bystrm	joakim@absolicon.com
Aspiration Energy Private Limited	Mr Logesh Raj, Mr Kiran	Karthik.s@aspirationenergy.com

3 Biomass Energy

Biomass is a renewable source of energy derived from the carbonaceous waste of human and natural activities. It is derived from numerous sources including the by-products from the wood industry, agricultural crops, raw material from the forest, household wastes etc.

Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Main advantage of bioenergy is that it can be used to generate electricity with the same equipment which is now being used for burning fossil fuels. Biomass is an important source of energy and the most important fuel worldwide after coal, oil and natural gas. Bioenergy, in the form of biogas, which is derived from biomass is expected to become one of the key energy resources for global sustainable development. Biomass offers higher energy efficiency through Biogas than by burning it directly.

Service Providers:

Company Name	Contact Person	Email IDs
Ahuja Engineering Services Pvt Ltd	Dr Disha Ahuja	dishaahuja@aesplindia.com
Aruna Green Ventures Pvt Ltd	Mr Kumar	dishaahuja@aesplindia.com

Section III Net Zero Energy Buildings

IGBC is spearheading net zero energy building movement in the country. IGBC's NZEB rating enables reduction in energy consumption and encourage to use renewable energy sources to off-set grid energy use.

As on date, more than 16 projects have adopted Net Zero Buildings rating programme. 8 projects have already Net Zero Energy Certified (Office, ITES, Factory, Warehouse, independent residential home). Discussions are ongoing with over 70 projects for Net Zero Energy.

Plant-13, Godrej & Boyce Mumbai | **Globicon Terminals Mumbai** | **ICICI-RSETI Jodhpur**

Capgemini EPIP Campus, Bangalore | **CII-Godrej GBC Hdyerabad**

Shairu Gems Surat | **Mahindra Eden, Bangalore** | **Bhawar House, Chennai**

- IGBC Net Zero Energy rating has emphasized more on Energy Efficiency. Hence, all the projects have given significant importance in reducing energy use by deploying Energy Conservation Measures. Projects have explored several innovative measures in RE Technologies such as – Bifacial Solar Modules to enhance RE penetration in their total energy consumption.

- IGBC's HQ in Hyderabad is Net Zero Energy Platinum. On daily basis, the building is generating more than 600 kWh, demonstrating Net Zero Energy Performance.

1 CII-GBC Hyderabad

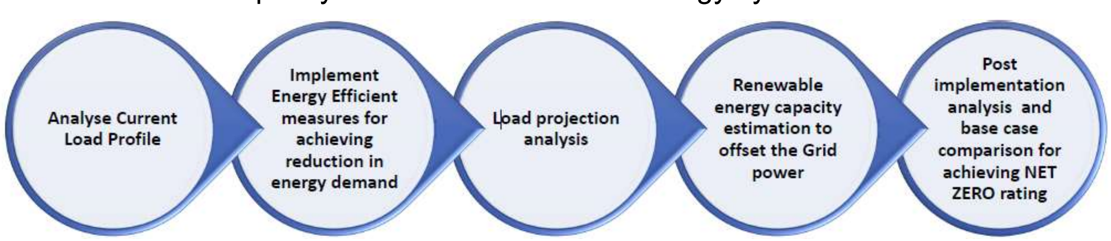
The built-up area of IGBC HQ is 1858 sq.m, out of which 1115 sq.m is fully air-conditioned (centralized cooling system). The building is designed for day-time, around 100 occupancy. Building envelope (wall, roof and glazing) is energy efficient and designed for maximum daylighting for all regularly occupied spaces. Glass has been installed considering right orientation; more glass has been provided in north – harnessing daylight without heat.

Measure	ECBC 2017	IGBC HQ
Glass U-value (W/m^2 °K)	3.0	1.7
SHGC (Solar Heat Gain Coefficient)	0.27	0.25
Roof (W/m^2 °K)	0.33	0.30
Wall (W/m^2 °K)	0.40	0.57

Strategies for Achieving Net Zero Energy Status

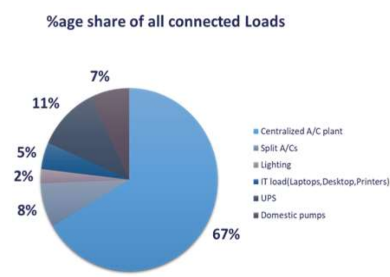
Energy efficiency has paramount importance for achieving NZE performance. IGBC's HQ has been designed with energy efficient measures and has demonstrated more than 20% energy savings over the baseline ECBC2017. Retrofitting strategy developed to further reduce energy demand and to increase use of renewable energy, following measures are implemented.

- Retrofitting of lighting (interior and exterior) system
- Replacement of air-conditioning system (complete chiller plant)
- Commissioning of advanced BMS system for optimised performance
- Increased capacity of on-site Renewable Energy system

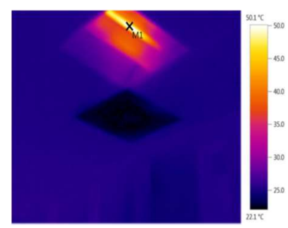


Energy end-use summary and load profile recorded, and deep analysis performed to understand hourly energy use. The peak load is 100 kW. Maximum demand occurs during the daytime, cooling system (chiller and air handling unit) are main energy guzzlers.

Retrofitting of Lighting system:



Completely automated CFL based (with dimming control, integrated with daylight and occupancy sensor) lighting fixtures installed in 2003. Globally, lighting has found complete transformation owing to introduction of LED based lighting system which in fact has reduced lighting load in buildings, drastically. Lighting system retrofitted in 2018 and it has cut down the load from 16.5 kW to 3.5 kW. LPD (Lighting Power Density) is less than 0.4 W/sq.ft). Thorough analysis (thermography) performed before retrofitting the lighting system. Temperature of lighting fixture recorded as 51^{o}C in case of CFL based lighting whereas, the temperature of LED lighting fixture was 29^{o}C, LED has reduced cooling load by 4%. Photographs show lighting fixtures before and after retrofitting.



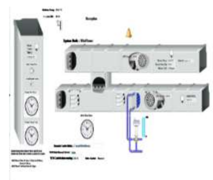
Retrofitting of Cooling system

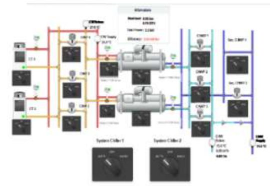
The whole chiller plant retrofitted including chillers, pumps and cooling tower with the most advanced and energy efficient system. The system is integrated with the wind towers (passive cooling) that constantly supply pre-cooled fresh air. Two water-cooled screw chillers (2x49TR, COP of chiller is 4.85, ikW/TR is 0.725 at 100% loading). Since, most of the time, building operates at part load hence, chillers selected giving more emphasis on part load performance (IPLV is 6.58 and ikW/TR at part load is 0.534). High efficiency pumps (IE4 motor) are installed for chillers and cooling towers, integrated with VFD to optimize the performance.

Before retrofitting

After Retrofitting

Retrofitting of BMS system





A sophisticated integrated Building Management System (iBMS) system commissioned (replace old BMS) to optimize and track energy performance. It is estimated that an integrated BMS system can save 8-10% energy in commercial buildings. Chiller plant, AHUs and indoor & outdoor environmental variables are continuous being monitored, then, the recorded data are used to analyse the performance. Time to time, feedback of iBMS is studied.

Increased on-site Renewable Energy Capacity:

Since inception, 2003, IGBC's HQ has been promoting the use of renewable energy sources. Earlier, the SPV capacity was 24 kWp that off-set grid energy use by 21%. For a Net Zero Energy Building, it is mandatory to off-set 100% grid energy use by RE sources. Hence, it was decided to opt new technology that can enhance RE generation from the roof-top (1175 sq.m). Initially, a site assessment was carried out and potential RE technologies are studied. Bifacial Solar PV technology opted which had promising efficiency (high electricity generation).

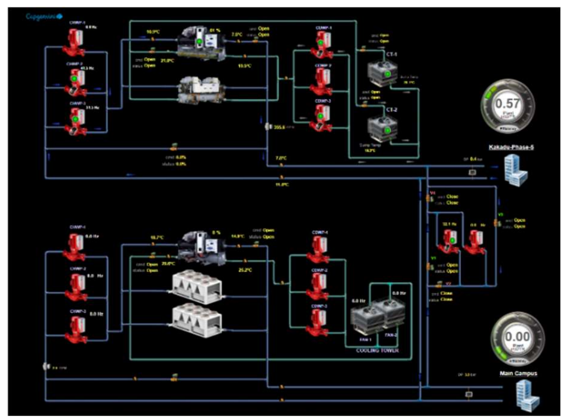
Bifacial solar PV is a transparent and frameless module and unlike regular solar modules that come with a singular face for absorption of light. Bifacial solar modules are equipped to allow passage of light from both the sides of solar cell and generate electricity from both sides (front and rear face of the module).

This helps in increasing the efficiency per cell, resulting in an increase in the total energy generation along with reduced construction costs. In fact, to increase the yield on the backside, roof surfaces are coated with high SRI (more than 110) paint that reflects the radiation on back side of the module. The SPV system installed at 1.5 m height from the roof, so that diffused radiation falls on rear façade of bi-facial modules. Total 130 kWp (efficiency of module is 22.3% which is higher than the conventional module) capacity of onsite bifacial SPV installed (over roof-top and wind towers) and 8 kWp of old SPV system retained (now installed on utility rom). The total SPV system capacity is 138 kWp. At present, the HQ of IGBC operates on NZE performance on operational basis. For improving performance on continuous basis, recorded data are documented, and deep analysis carried out on regular basis to optimize the energy usage.

2 Capgemini EPIP Campus Bangalore

India's First Net Zero Energy Platinum (Operational) Campus in India

Capgemini's, EPIP Campus in Bengaluru is the first IT/ITES campus in India to achieve the Net Zero Energy – Platinum (Operation) certification from IGBC. The project team headed by Mr R Vishwanathan extensively worked for almost 3 years to explore new & innovative measures for energy efficiency and retrofitting of old equipment to industry benchmarked high performing equipment /systems. After having required infrastructure in place for the efficient use of energy, the project team focused on generating /sourcing renewable energy. Today, the project produces on-site RE (over 20%) and wheels remaining power to off-set 100% grid energy use by Renewable. This has been possible after taking serious steps such as:



- Retrofitting of old equipment to the most energy efficient equipment (water cooled chillers, inline primary pumps integrated with VFD, AHUs fitted with EC motors and ESP filters along with UVGI Lamps, all LEDs lighting fixtures, plug loads, integrated Solar lighting fixtures for exterior illumination, street lighting, etc).
- Significant increase in on-site RE generation (1.35 MWp)
- Source about 78-80% green power through Purchase Power Agreement (PPA)
- Installation of 100% Solar based street lighting
- Use of solar powered chiller for maximum cut down in energy demand
- Reduction in Data Center energy consumption by retro-commissioning, retrofitting, managing hot & cold aisle containment and sophisticated control of cool air
- Rigorous metering and monitoring of energy at end-use. Monitoring of each equipment on real-time basis (15 min internal) and diagnose performance with respect to rated capacity/energy consumption
- Inferred decisions from online management system (central command center to map out energy usage/benchmarking and create alarms as when performance deviate from the design goals)

All these implementations bring down the energy use of the facility by 16%. The project team has analysed energy efficiency achieved by all ECMs using whole building energy performance simulation and compared it with Energy Conservation Building

Code (ECBC) 2017. The Energy Performance Index Ratio (EPI ratio) of the campus is 0.73.

Offsetting Grid Energy Use by Renewable Energy Sources

After deploying the infrastructure related to energy efficiency and ensuring energy efficiency by 16% over the existing case (before ECMs), the project team focused on RE generation at the site and procured green power to meet the remaining energy use. The project team has commissioned 1.35 MWp of on-site SPV that offsets at least 20% of the total annual energy use while considering the anticipated energy savings from ECMs. For such a large IT/ITES campus, it is not possible to generate 100% of RE at site itself, therefore, the project entered into a long-term agreement for the procurement of Green Power, around 78-80% power is wheeled.

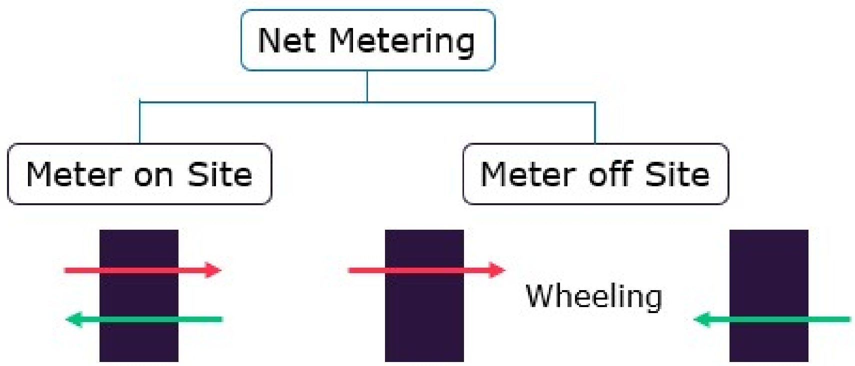


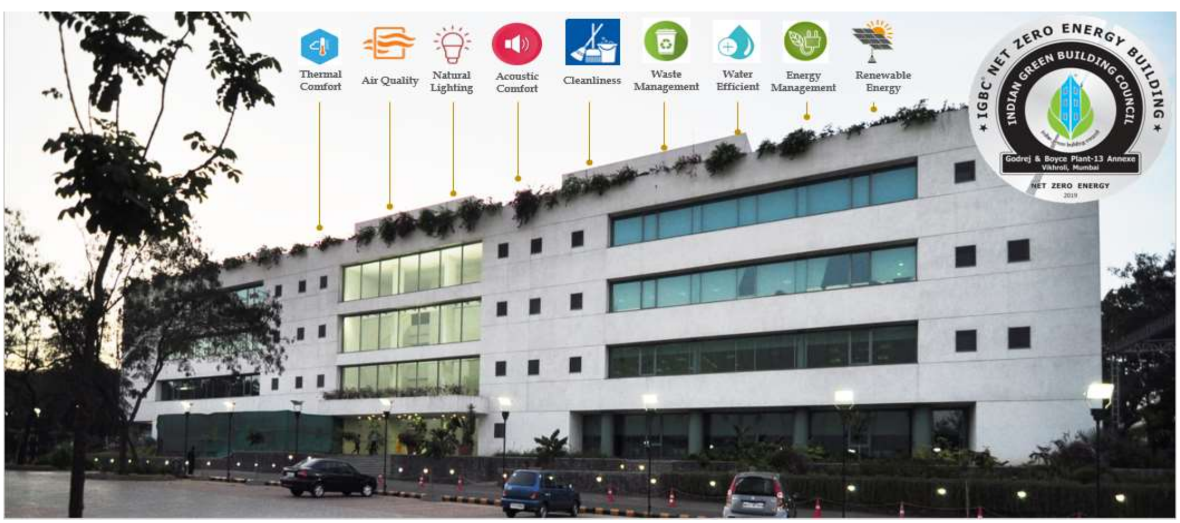
Figure 64 Schematic of Net Metering for meeting Net Zero Energy target

3 Plant-13 of Godrej & Boyce Mumbai

First Office Building to Achieve Net Zero

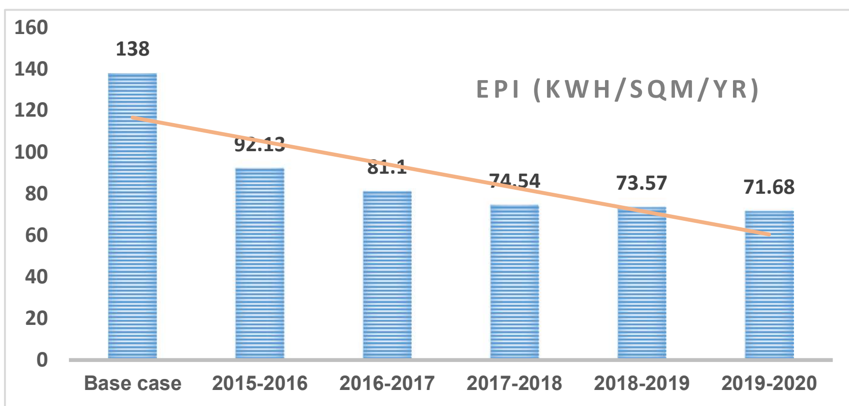
Godrej & Boyce became the first organisation to successfully adopt and achieve IGBC Net Zero Energy Building Certification for “PL-13 Annexe Building” located at their Mumbai campus. G&B’s “Good & Green Vision” strives to integrate sustainability with regular business practices. It aims to ensure 40% reduction in energy consumption, achieve zero waste, and carbon neutrality, and generate one-third of its portfolio revenues from green products and services.

Plant-13 Annexe Building of Godrej & Boyce is a multi-use office located in Mumbai. Built in the year 2010, this building is equipped with facilities like Offices, Conference, Meeting rooms, Training rooms, Auditorium, Banquet, Cafeteria, Food court and 24x7 kitchen facilities. The building is constructed over a site area of 4 acres and has G+4 floors with area of 250,000 sq.ft. The building is occupied by around 400 employees/staff and common facilities like cafeteria, conference and meeting rooms etc. are shared by over 2000 staff members.



The building was designed with measures like Optimized Window to Wall (WWR) ratio, North-South Orientation, Punched windows, and Light wells for daylight. Additionally building used efficient glass (Double Glass with low heat 25% & high light transmission values 40%), walls with AAC blocks & roof with Insulation and green vegetation to reduce heat ingress and also to mitigate UHI (Urban Heat Island). These strategies enabled to significantly reduce the loads at the design stage and optimize the size of equipment.

The building has central air-conditioning system (chilled water system comprising of water-cooled chillers). High COP screw chillers were installed as it offers higher part load performance. Chillers were rated to deliver COP of 5.9 at full load, however at part loads the COP achieved was much higher (8 to 9 at 50% load). Furthermore, instead of having equally sized equipment, distributed sizing was chosen i.e. total TR was split into 2x250 TR (with twin compressors) and 2x125 TR. Distributed sizing provided operational flexibility and enabled optimized utilization (fit to the load conditions). Cooling towers were provided with VFD. VFDs were programmed to adjust the speed depending upon the condenser water temperature. Chilled water pumping system comprised of secondary pumps integrated with VFD. VFDs were tuned to operate as per the load requirement depending upon the DP (differential pressure) on chilled water lines. Similarly, AHUs (Air Handling Unit) connected with VFD to operate based on the return air temperature. The entire CHW (Chilled Water) system was monitored & operated through Building Management System (BMS).



As a part of commitment towards increasing share of renewable energy, 120 kWp Solar PV has been installed on atop which replaces total 8% of the annual energy by renewable. In addition to on-site resources, G&B entered into tri-party Power Purchase Agreement (PPA) with third party vendor and wheeled solar power approximately 1200 kWp from the solar plant located at Sangli, Maharashtra against open access permission obtained from State Electricity Utility Company (MSETCL). Thus, with combination of 120 kWp on-site and 1200 kWp off-site, Plant-13 Annexe Building is able to meet the Net Zero Energy targets.

4 ICICI-RSETI Jodhpur

ICICI Rural Self Employment Training Institute (RSETI) is established under the aegis of Ministry of Rural Development, Government of India with the support of State Government to identify, orient, motivate, train and assist young people to take up self-employment through promotion of Micro, Small and Medium Enterprises by providing them short term training programmes. ICICI-RSETI, Jodhpur is run and managed by ICICI Foundation.

Some of the Illustrative features of this building includes the following:

- Use of local sandstone from Jodhpur called ‘Chittar Patthar’ which is least affected by air, sunshine and extreme weather conditions
- The building has thick walls, stone grills and open corridors for cooling effect
- Setting up LED-based lighting and standalone solar street lights for lighting the premise
- Usage of cool roof tiles to reduce heat ingress inside the building
- Deployment of star-rated appliances, energy-efficient DC fans and an energy monitoring system to ensure optimal utilization of energy
- Phytoremediation installed which does not use any amount of energy for treating the waste water generated
- A highly efficient 35 kWp SPV plant is installed to off-set grid energy use.

The building has net metering mechanism which allows the institute to supply excess power to the grid.

5 Bhawar Residence Chennai

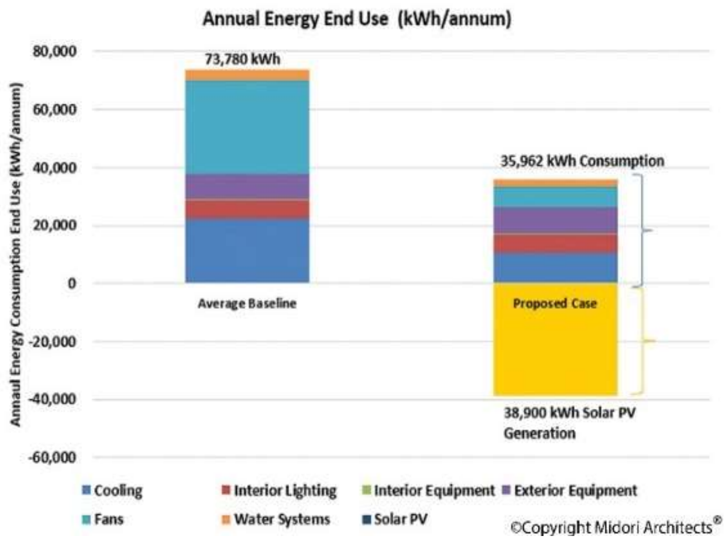
Commercial & Industrial (C&I) consumers adopt NZEB practices as they may have several environment commitments and significant operation gain. Mostly residential buildings do not have such obligations. Now, architects and design firms are quite interested to showcase their projects as Net Zero Energy or carbon neutral, as many owners wish to have their homes climate responsible.

Bhawar House is designed to fully cover their energy requirements by RE, without inducing any damage to environment. Natural cooling/ventilation system are integrated into the design. Bhawar House is designed to house 3 generations across 3 floors, the design comprises of an elegant form that is derived from passive strategies and biophilic design concept ad its core drivers. Sustainable features are an integral part of this design and have been considered in all aspects of this modern home.

Passive design strategies like natural ventilation, shading, buffering were employed to facilitate air flow through the building. To improve the aerodynamics of the building, the sharp corners of the structure were curved with a radius of 500mm to allow smooth movement of wind and provide better ventilation which are then validated by the Wind flow analysis performed. The lobby that is created by breaking the monotony of the straight wall and wedging out the center becomes a bridge connecting the two sides of the house is used to ventilate the two parts. Screens with vegetation are introduced on all 4 façades of the building to improve the light quality inside, to block-off glare, and to reduce solar insolation.

This creates a reverse venturi effect, as an increase in the air velocity is noticed after it passes through the screen. The rounded corners along with the swivel of the floor plates allows the wind to enter the lobby and maintain a constant air flow of 0.625 m/s even if the outdoor wind velocity is as low as 0.7m/s from the North. This wind speed is categorized as ‘Light Breeze’ which is the optimum level of physiological cooling to occur for human comfort.

Estimated baseline annual energy use (following ECBC 2017) is around 73 MWh whereas, after introducing energy efficiency measures, the annual energy use is 35 MWh. A 28 kWp system has been installed to off-set 100% fossil-fuel based energy to Renewable.



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Confederation of Indian Industry

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Confederation of Indian Industry (CII)

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the growth of industry in India, partnering industry and government alike through advisory and consultative processes. CII is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, India's premier business association has over 7200 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 100,000 enterprises from around 242 national and regional sectoral industry bodies. CII charts change by working closely with Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialized services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

CII Sohrabji Godrej Green Business Centre (CII Godrej GBC) is a joint initiative of Government of Andhra Pradesh, Godrej & Boyce Mfg Co and CII with the technical support of USAID – a unique model of public-private partnership. The Green Business Centre was established in 2004. CII Godrej GBC is the CII "Centre of Excellence" for energy, environment & recycling, green buildings, renewable energy and climate change activities in India. CII Godrej GBC strives to promote Green initiatives through creation of "Islands of Excellence" and then spread the results and learnings.

Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation (Shakti) seeks to facilitate India's transition to a cleaner energy future by aiding the design and implementation of policies that promote clean power, energy efficiency, sustainable urban transport and climate action. Working collaboratively with policy makers, civil society, industry, think tanks and academia, Shakti seeks to catalyze transformative solutions to meet India's energy needs in clean and sustainable ways.

The energy choices that India makes in the coming years will be of profound importance. Meaningful policy action on India's energy challenges will strengthen national energy security, create jobs and keep our environment clean.

IGBC

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For any information and support on net zero, please feel free to contact:

CII - Sohrabji Godrej Green Business Centre
Survey # 64, Kothaguda Post
R R District, Hyderabad – 500084, India
Tel: +91 40-44185157/155 Fax : +91 40 23112837

S Karthikeyan
Principal Counsellor, CII GBC
Mail: s.karthikeyan@cii.in