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Integration of RENEWABLE ENERGY in Buildings in India

SHORTLISTED TECHNOLOGIES TIPSHEETS

ABOUT SDC IN INDIA

The Swiss Agency for Development and Cooperation (SDC) has been a partner of India for more than 60 years. Since 2011, SDC's engagement focuses specifically on climate change and other environmental issues. The office in India is part of SDC's Global Programme Climate Change and Environment (GPCCE). Other SDC Global Programmes like Food Security and Water also have ongoing activities in India, as part of their regional/global initiatives.

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ABOUT IIEC

The International Institute for Energy Conservation (IIEC) is a not-for-profit, non-governmental organization founded in 1984 to address global issues concerning the use, management, and production of energy. IIEC focuses on increasing access to energy, energy efficiency and electrification rates, and creating livelihoods in the most vulnerable communities. Over the past 36 years, IIEC has established a niche in the global transition to clean energy and climate change – combining international exper tise with local knowledge and integrating policy with direct action. IIEC works with key stakeholders across all sectors to connect international best practices with the unique needs of the communities it serves. IIEC is registered as Section 501(c)(3) organization with headquarters in Breinigsville, PA, USA.

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PROJECT PARTNERS

Basel Agency for Sustainable Energy (BASE)

Basel Agency for Sustainable Energy (BASE), Switzerland Stiftung BASE is a Swiss non-profit foundation and a specialized partner of United Nations Environment. Founded in 2001, our core mission is to develop innovative business models and financing solutions to unlock investments in sustainable energy solutions. BASE's head office is in Basel, Switzerland, and is guided by a strong Foundation Board composed of leading financial experts (Swiss Re), officials from development agencies (UN Environment) as well as investors and entrepreneurs in sustainable energy. The BASE team is made up of sustainable energy (energy efficiency and renewable energy) experts, finance experts and development professionals. BASE has implemented projects in North and South America, Africa, Asia and Europe.

Website: https://energy-base.org/

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Environmental Design Solutions (EDS)

Environmental Design Solutions (EDS) Environmental Design Solutions [EDS] is a sustainability advisory firm focusing on the built environment. Since its inception in 2002, EDS has worked on over 300 green building and energy efficiency projects worldwide. The diverse milieu of its team of experts converges on climate change mitigation policies, energy efficient building design, building code development, energy efficiency policy development, energy efficiency financing, energy simulation, and green building certification.

Website: http://www.edsglobal.com/

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Meghraj Capital Advisors Private Limited (MCAPL)

Meghraj Capital Advisors Private Limited (MCAPL) is an end-to-end advisory services firm offering advisory and execution services in Infrastructure Consulting, Financial Advisory and Investment Banking. MCAPL is part of the British Isles head-quartered Meghraj Group. The firm operates from offices in Mumbai, Delhi and Ahmedabad in India but the firm's credentials and team experience include engagements in South Asia (Bhutan, India, Maldives, Nepal, Pakistan Sri Lanka), South East Asia (Cambodia, Philippines) Middle East (Oman), Africa (Ghana, Benin) and the Caribbean Islands (Saint Lucia, Grenada).

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Integration of Renewable Energy Technologies in buildings (BEEP-RE)

The Global Programme Climate Change and Environment (GPCCE) of the Swiss Agency for Development and Cooperation (SDC) has recognized the urgency of acting in the built environment. The new strategy (2017-2020) focuses on low emission development and has a specific focus on buildings in addition to other core areas of interventions.

In India, there is a growing understanding to make buildings shift from energy consumers to become energy generators by integrating different renewable energy technologies. In order to support this idea, the SDC endeavours to implement a new project component of BEEP in India focusing on the "Integration of Renewable Energy in Buildings". The broad objective of this component is to design, showcase and monitor 2-3 building integrated and innovative renewable energy technologies suitable to and affordable in the local condition and applicable for multi-storey buildings, which are currently given a major push at the government level in India. **"BEEP-RE Program"** will contribute to various global processes in the areas of climate change mitigation, urban development and resources efficiency improvement. The programme will also contribute towards the 2030 Agenda for Sustainable Development, which includes Goal 7: Affordable and Clean Energy, Goal 8: Decent work and Economic growth, Goal 9: Industry innovation and Infrastructure, Goal 11: Sustainable Cities and Communities and Goal 13: Climate Action and, the Paris Agreement.

Program Objectives

- To demonstrate the technological interventions for building integrated renewable energy in India;
- To develop research, monitoring methods and manuals to measure the performance of systems established during the implementation of project;
- To provide capacity building support to government and private sector stakeholder in India; and
- To prepare and disseminate knowledge products for effective implementation of the programme.

Technologies Tipsheets

As part of objective 1 of the program, technologies suitable for building integration in Indian context have been shortlisted. This booklet provides a brief description of each of these technologies.

Contents

01 Solar photovoltaic technology

02 Solar thermal

03 Building Integrated PV solutions

04 Hybrid Solar PVT

05 Building integrated wind turbine

06 Biomass energy

07 Tri-generation

08 Heat pump

09 Energy storage

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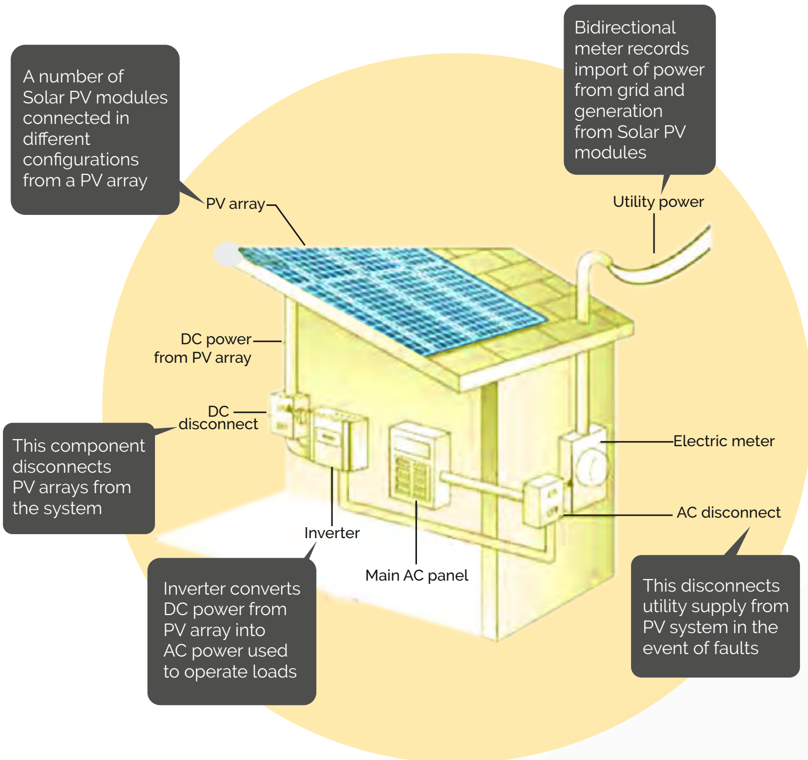
SOLAR Photovoltaic Technology

Photovoltaic (PV) Systems are used to convert energy from the sun into electricity. They are safe and reliable source of solar electricity that produces no on-site pollution or emissions. PV systems incur fewer operating costs and can be installed on any kind of building such as:

Residential | Commercial | Industries | Institutional

PV system falls into two main categories grid-connected and off-grid.



Grid-tied systems

- System is connected with local electricity distribution grid; energy generated is sent into the utility grid.
- A credit for the energy generated is provided generated.
- Grid acts as energy storage unit.

Off-grid systems

- System is independent of the local electricity distribution grid.
- Energy generated is either consumed in real-time or stored in batteries.

Solar PV Application and Potential End Use

Output energy	Application	Suitable Building type	Specific requirement
Electricity	Offset Building electricity consumption & Export to Grid	Suitable for all building types	Shadow free area (rooftop or ground)

Business Models for Rooftop Solar: CapEx, OpEx (RESCO) & Leasing Model

CAPEX (CAPITAL EXPENDITURE MODEL)CAPEX is the most common form of solar power plant business model in India. In this model consumer generally hire a solar EPC company who provide turnkey installation of entire solar power system and hand over assets to consumers.

- Allows residential, industrial and commercial customer to own the system.
- The customer sets up rooftop solar project with the intent to reduce his own power costs.
- The customer bears the entire capital expenditure of the project.
- Customer gets benefit by selling the surplus power generated to the DISCOM.
- The gains from tariff savings accrue to the roof and solar power plant owner.
- Commercial & institutional clients can also claim the accelerated depreciation.
- EPC also performs annual operation and maintained (O&M) of plant on mutually agreed cost per annum.

RESCO (RENEWABLE ENERGY SERVICE COMPANY)

A Renewable Energy Service Company (RESCO) is an ESCO Energy service company which provides energy to the consumers from renewable energy sources, usually solar photovoltaics, wind power or micro hydro. RESCO or BOOT model is about pay as you consume the electricity.

- Solar Power Plant is owned by the RESCO or ENERCO (Energy Company).
- The customer serviced does not own the Solar Power Plant.
- Customer have to sign a Power purchase Agreement (PPA) with actual investor at mutually agreed tariff and tenure.
- Customer only pays for electricity consumed on a per unit price for power basis.
- RESCO developer is responsible for its annual operations & maintenance (O&M).
- The RESCO gets the benefit by selling the surplus power generated to the DISCOM.

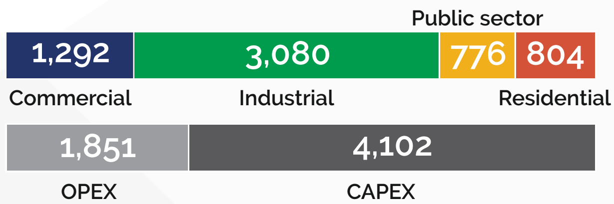
LEASING MODEL

Under the solar leasing business model, usually the leasing company installs and maintains the system on the customer's roof. The homeowner agrees to buy power from the leasing company at a pre-determined rate for a period of around 20-25 years. The rates may come with periodic escalators or maybe fixed in nature. The homeowner requires the right kind of roof and needs to be in a favorable locality. The leasing company would agree to install a system only if these prerequisites are met. At the end of the lease period, the homeowner may purchase the system, renew the lease agreement, or get the panels removed.

India's Solar Capacity in various sectors

Total installed capacity: 5,953 MW

(As on 30 June 2020)



All figures in MW
Source: Bridge to India

SOURA Subsidy Scheme

The Ministry of New and Renewable Energy (MNRE) aims to set up 38 GW of rooftop solar PV projects in the second phase of its ambitious grid-connected rooftop solar photovoltaic programme. In line with the phase II subsidy program of MNRE and with the approval of state government, KSEB initiates a subsidy program for the domestic consumers. In this subsidy initiative, KSEB introduced a special model (Kerala model) apart from the normal subsidy model. The Kerala model are based on the average consumption of the consumer and it aims to give financial support to the weaker section there by making them green energy partner of the state. Since Kerala has been allotted 50 MW under this scheme, the scheme will be closed once 75,000 applications are received.

Model 1 (Kerala Model) & Model 2 (Normal Model Subsidy Model)

Model 1 | Kerala Model

Consumer pays only a part of the total implementation cost of the solar panel. The other part is borne by KSEBL. Consumer will be eligible for a part of the energy generated from the plant based on your investment. Based on your average monthly electricity consumption you can choose from the three options.

Features

Plant Capacity

Solar Power plant should be 2KWp or 3KWp

Maintenance

25 years maintenance of the plant will be done by KSEPL

Economical

The return on investment will always be twice the investment. See table below.

Options Available

Average Monthly consumption (units)	Consumer Contribution (% of cost)	Return (% of plant generation)
Up to 120	12% (Max INR 6200 per KWp)	25%
Up to 150	20% (Max INR 11,000 per KWp)	40%
Up to 200	25% (Max INR 14,000 per KWp)	50%

Application fee: INR 1000 + GST

Eligibility Criteria

All domestic consumers with average monthly consumption up to 200 units are eligible for this project.

Model 2 | Normal Subsidy Model

If consumer wishes to install the plant investing the whole amount less subsidy, they can choose this option. The consumer will be eligible to use entire energy generation from the solar plant. Consumer can claim up to 40 % of the plant cost as subsidy based on the solar plant capacity.

Features

Plant Capacity

Solar Power plant should be 2KWp

Maintenance

5 years maintenance of the plant will be done by KSEPL

Economical

Consumer can claim up to 40 % of the plant cost as subsidy based on the solar plant capacity.

Options Available

Plant Capacity (in Kwp)	Subsidy (% of cost)
Up to 3KWp	40%
4KWp to 10KWp	40% for first 3 KWp 20% for each additional KWp
Above 10 KWP	26% for 10 KWp) & NIL for rest

Application fee: INR 1000 + GST

Eligibility Criteria

All domestic consumers are eligible for this project.

List of rooftop solar installation companies in India ▶

Orb Energy
Vikram Solar
Renew Power

Loom Solar
Tata Power
Solar Mahindra Susten

Sunsure Energy
Fourth Partner Energy
Surya day

SB Energy
CleanMax Solar
Harsha-Abakus Solar

MNRE Subsidy under the Phase II of rooftop solar program

- **Phase I of rooftop capacity deployment had a target of 4200 MW by FY 20 and budget outlay of 5000 Crore**
  - SNA were identified as implementing agencies
  - Had limited success
  - CFA was available for residential and government sector/PSUs
- **Phase-II**
  - Announced in August 2019
  - DISCOMs made the implementing agencies
  - DISCOMs to submit proposal to MNRE for implementation
  - Incentives to the DISCOM, if the installations in financial year are more than 10% of the base year.
  - DISCOMs encouraged to develop utility-led business models for deployment
  - Subsidy available only to residential consumers

Rooftop deployment framework in States

- **Enabling policy framework for solar rooftop**
  - Single window clearance portals
  - Incentives to encourage consumers
  - Net metering regulation framed
  - Rooftop targets defined for states
  - Notified Solar Policy in states
  - Process defined for feasibility check and approvals

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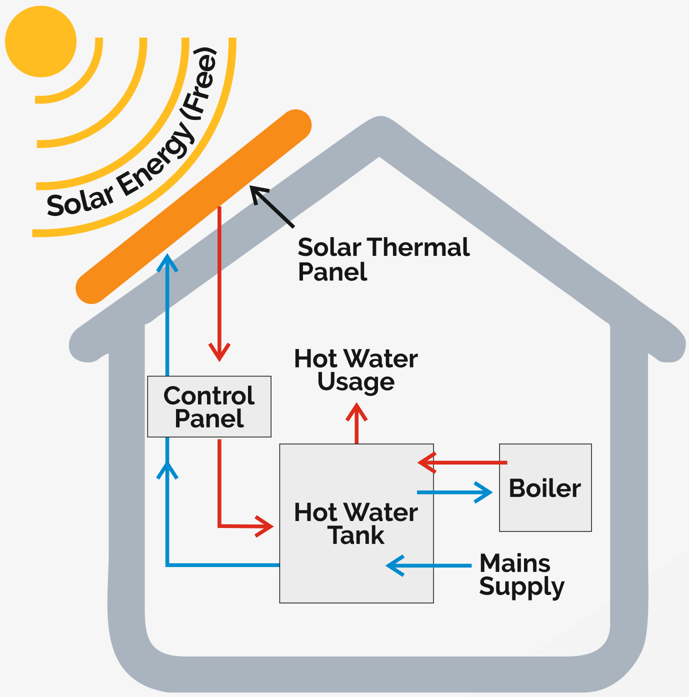
Solar Thermal Technology

A solar thermal system works by harnessing the sun's energy and converting it into heat which is then transferred into home or businesses heating system as hot water or space heating. Solar thermal panels are used in conjunction with a boiler, collector or immersion heater. The solar collector will use the sun's rays to heat a transfer fluid which is a mixture of water and glycol, to prevent the water from freezing in the winter. The heated water from the collectors is pumped to a heat exchanger inside a water cylinder.

After the liquid releases its heat, the water will flow back to the collectors for reheating. A controller will ensure that the fluid will circulate to the collector when there is sufficient heat available. Solar thermal technology is proven, reliable and low maintenance.



Solar Thermal Application and Potential End Use

Output energy	Application	Suitable Building type	Specific requirement
Heat (Hot Water, Low Pressure steam)	Domestic hot water, Cooking, laundry, cleaning, space heating	Residential, Hotel, Hospital, Hostels, institutes	Shadow free rooftop area

Benefits of Solar Thermal

Solar thermal offers compelling benefits to building owners and/or tenants.

(a) **No, or reduced, dependence on fuels that need to be transported to the site:** As an on-site renewable energy technology, solar thermal can replace other fuels normally used for heating purposes, such as oil, natural gas, LPG, coal, biomass and electricity. This can be of special importance, where transportation of fuel is cumbersome and/or costly.

(b) **Applicable everywhere:** Thermosiphon (Thermosiphon (or thermosyphon) is a method of passive heat exchange, based on natural convection, which circulates a fluid without the necessity of a mechanical pump. Thermosiphoning is used for circulation of liquids and volatile gases in heating and cooling applications such as heat pumps, water heaters, boilers and furnaces) systems using natural convection can be deployed even without access to electricity. This makes them especially interesting in off-grid (e.g. rural) regions and where power outages occur frequently. The storage tank of these systems also brings security of water supply at locations with poor water supply.

(c) **Healthier environment:** Local air pollutants from (water) heating systems are a major hazard to health in many countries. By avoiding or reducing the need to burn (fossil) fuels, solar thermal can help create a healthier environment.

(d) **Public support:** In many countries, governments support the installation of solar thermal systems with financial incentives (direct grants, cheap loans, tax incentives etc.). Home owners and developers can benefit from financial support by installing a solar thermal system.

(e) MNRE has been implementing the scheme on 'Off-grid and Decentralized Solar Applications' since May 2014. The scheme was continued as 'Off-Grid and Decentralized Concentrated Solar Thermal (CST) Technologies for Community Cooking, Process Heat, Space Heating & Cooling Applications in Industrial, Institutional and Commercial Establishments' from 2017-18 till 2019-20 for the promotion of CST projects for off-grid solar thermal applications. Ministry was providing Central Financial Assistance (CFA) of 30% of the benchmark cost or the total project cost, whichever is lesser for projects in all states and 60% of the benchmark cost or the total project cost, whichever is lesser for projects in Non-profit making bodies or institutions in special category states. **This was a priority for MNRE however the scheme has been discountinued now.**

Solar Thermal Cooling

Solar thermal energy power stations may also be used for cooling: this refers to either cooling buildings (air conditioning) or industrial processes (refrigeration). Through evaporation and condensation, the solar thermal energy is processed as cold.

There are open and closed systems. Most widely used are closed systems like absorption refrigeration machines and open cooling and dehumidifying processes, such as sorption-supported air conditioning.

Solar Thermal Heating

Solar heating is the utilisation of solar energy to provide process heat, especially in crop drying, water heating, cooking or space heating and cooling.

The technology of solar thermal water heaters is present worldwide and significant deployments occur already in emerging economies and developing countries. Technologies include glazed flat plate collectors, evacuated tube collectors, and lower-temperature swimming-pool heaters made from plastic tubes.

Table below shows Solar Thermal based system installed in India for space cooling

A typical system of 30-ton capacity for commercial complexes and institutions require about 250–300 sq. m. of CST area depending on the type of technology used which may cost around Rs 60–70 lakh. This system should be able to save 18,000–22,000 litre of diesel per year depending on the solar radiation available at the place of installation. It should be able to recover its cost in 5–6 years at the current price of diesel at the rate of Rs 55 per litre.

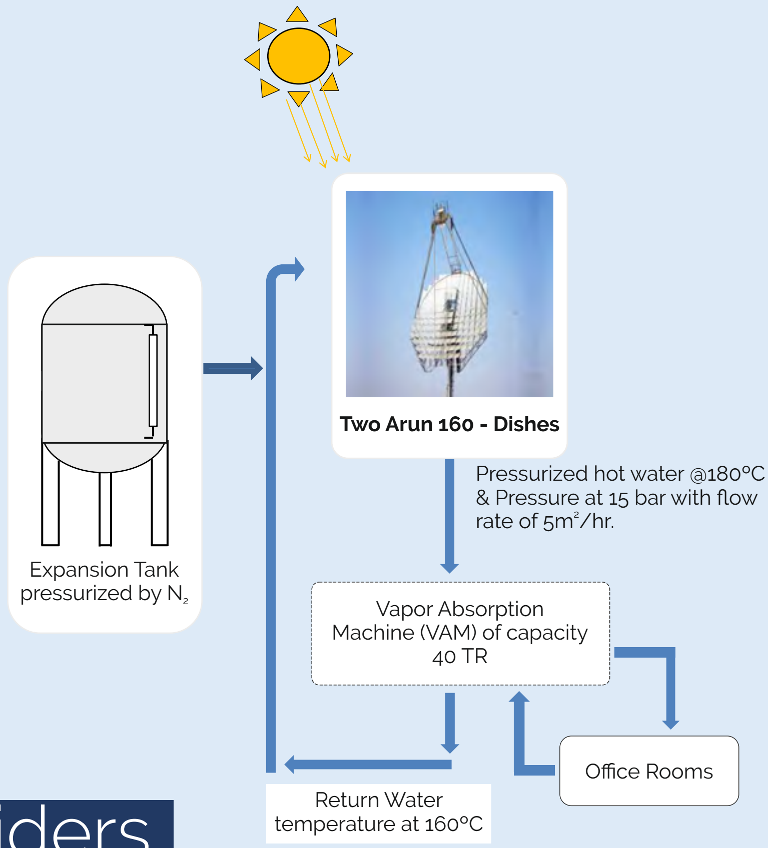
Place	Capacity in TR & type of VAM	Type and size of solar field	Solar heat fed to VAM	Year of installation & Manufacturer	Solar Cost (Rs in Lakhs)
NPCIL, Kota, Rajasthan	100 TR with triple effect VAM	100 nos of PTC, 641 m^2	Pressurized water at 17 bar and 200°C	2013 (Thermal)	245
Honeywell Tech. Hyderabad	100 TR with triple effect VAM	128 nos of PTC, 821 m^2	Pressurized hot water at 17 bar and 165°C	2013 (Thermal)	213
NTPC, Noida, UP	50 TR with 2-day storage and double effect VAM	2 nos of Arun 160,338 m^2	Stream at 15 bar and 170°C	2012 (Clique Solar)	250
Turbo Energy Ltd. Chennai	50 TR with double effect VAM	2 nos of Arun 160,338 m^2	Pressurized water at 15 bar and 180°C	2011 (Clique Solar)	80
Civil Hospital, Thane	212 TR (160 TR with VAM and 52 desiccant cooling) double effect VAM)	150 nos of Scheffler Dishes, 2040 m^2	Stream at 7 bar and 150°C	2011 (Sharda Inv.)	399

Solar Assisted Cooling using Arun Dish

The first cooling system assisted by ARUN solar boiler has been installed at the office building of Turbo Energy Limited (TEL), Paiyanoor, which is about an hour's drive from Chennai. TEL is a leading manufacturer and supplier of turbochargers to many Automobile Manufacturers in India. TEL has successfully installed one ARUN solar boiler system for fulfilling its hot water requirements for operating a Vapor Absorption Machine (VAM) for air-conditioning/comfort cooling for its administrative block. It is in the process of installing another dish for increasing its air-conditioning capacity. The process of hot water generation for operating the Vapor Absorption Machine for air-conditioning with the help of ARUN solar boiler is as explained in the figure on the right.

Description of schematic:

The vapor absorption machine (VAM) installed at TEL, is hot water driven. Pressurized water at 180˚C is required for the machine to operate at an optimal level. The return temperature of the hot water is 160 ˚C. The machine with 40 TR capacity requires 5 m^3/hr of the pressurized hot water which can be catered to by 2 ARUN dishes. The solar circuit is kept pressurized at 15 bar using the nitrogen pressurization system. The nitrogen cylinders are connected to the expansion tank in the circuit for this purpose. The cooling system is used for air conditioning of the administration office at the plant.



Technology Providers in India

- Ascent Solar Thermal Pvt. Ltd.
- Greenergize India
- Solar Power Solutions Pvt. Ltd.

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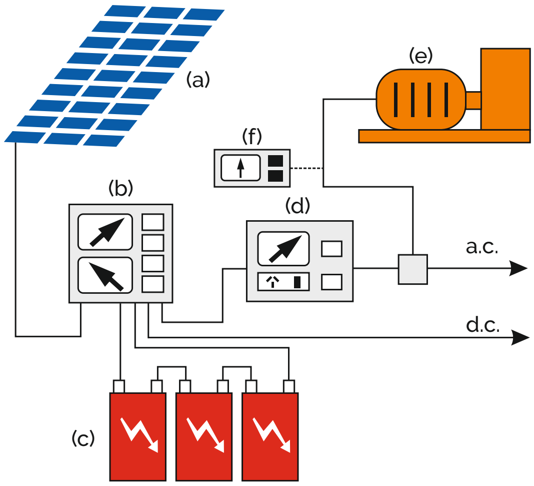
Building Integrated PV Solutions

A Building Integrated Photovoltaics (BIPV) system consists of integrating photovoltaics modules into the building envelope, such as the roof or the facade. By simultaneously serving as building envelope material and power generator, BIPV systems can provide savings in materials and electricity costs, reduce use of fossil fuels and emission of ozone depleting gases, and add architectural interest to the building.

While the majority of BIPV systems are interfaced with the available utility grid, BIPV may also be used in stand-alone, off-grid systems. One of the benefits of grid-tied BIPV systems is that, with a cooperative utility policy, the storage system is essentially free. It is also 100% efficient and unlimited in capacity. Both the building owner and the utility benefit with grid-tied BIPV. The on-site production of solar electricity is typically greatest at or near the time of a building's and the utility's peak loads. The solar contribution reduces energy costs for the building owner while the exported solar electricity helps support the utility grid during the time of its greatest demand.

Components of BIPV



- (a) The PV modules (which might be thin-film or crystalline, transparent, semi-transparent, or opaque)
- (b) A charge controller, to regulate the power into and out of the battery storage bank (in stand-alone systems)
- (c) A power storage system, generally comprised of the utility grid in utility-interactive systems or, a number of batteries in stand-alone systems
- (d) Power conversion equipment including an inverter to convert the PV modules' DC output to AC compatible with the utility grid
- (e) Backup power supplies such as diesel generators (optional-typically employed in stand-alone systems)
- (f) Appropriate support and mounting hardware, wiring, and safety disconnects

Classifications of the BIPV Systems

BIPV systems can be roughly **classified according to the energy supply,** the storage modes, the integrating modes, and the module types. According to the power supply and storage modes, there are two types: the grid-connected type and the stand-alone type. The former is usually connected to a utility grid that serves as a storage component in the BIPV system and ensures the system's stability and reliability. The latter type, on the other hand, employs batteries for surplus power storage. The battery also helps to ensure the stable power supply for the fluctuating power generation. In stand-alone BIPV systems, a supplementary generator is usually necessary for power supply in extreme weather conditions.

According to the integration pattern, BIPV systems could be roughly classified as building-integrated systems and building-applied PV systems. The former is suitable for new buildings by substituting conventional building materials with PV modules, while the latter is easily applied to existing buildings by adding PV modules to some parts of their envelopes.

According to the module shape, BIPV systems can be categorized as rigid-module-based BIPV systems and flexible-module-based BIPV systems. The former is built by rigid BIPV modules, while the latter is built by flexible BIPV modules.

According to their optical properties, BIPV systems can be classified as opaque systems and semi-transparent systems. The former often refers to BIPV systems implemented on opaque building envelopes (roofs or walls), where PV modules are added onto. No sunlight is allowed to pass through the system into the indoor environment. Semi-transparent BIPV systems can be built in see-through building envelope components, such as façades, windows, atriums, skylights, etc.

BIPV Application and Potential End Use

Output energy	Application	Suitable Building type	Specific requirement
Electricity	Offset Building electricity consumption & Export to Grid	High Rise Buildings	Vertical façade exposed to sun without obstructions

Source: Zigzag solar

Applications of BIPV Technologies

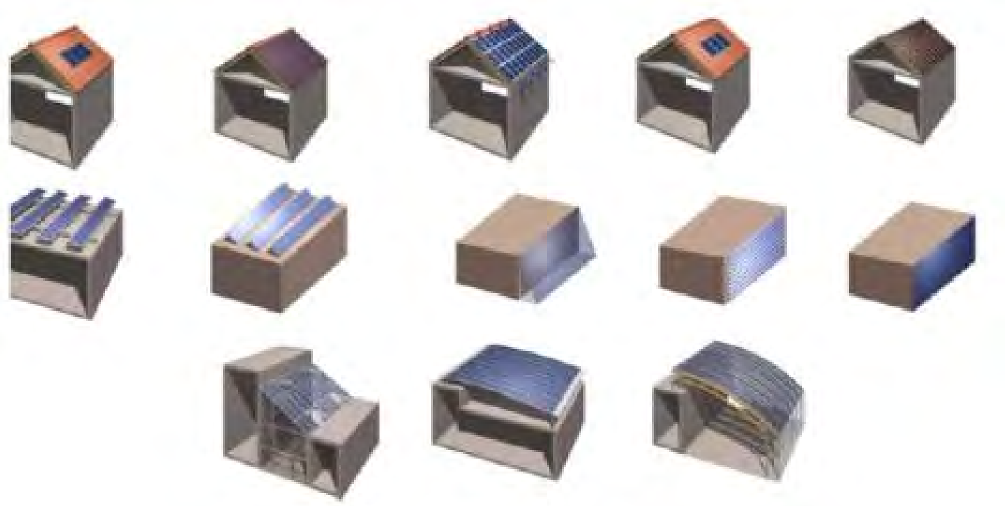
BIPV Technologies

- Conventional or BAPV systems (roofs, canopies)
- Wall integrated semi-transparent glazings
- Clear, uncoloured solar windows and skylights
- Traditional (Si, a-Si, CdTe), or new PV materials (polymers, perovskites,...)
- Luminescent concentrators, or patterned, cell module type

Manufacturer of Building Integrated PV Solutions in India

- Novergy Solar
- U-Solar
- Zig Zag Solar

Typical building applications of BIPV

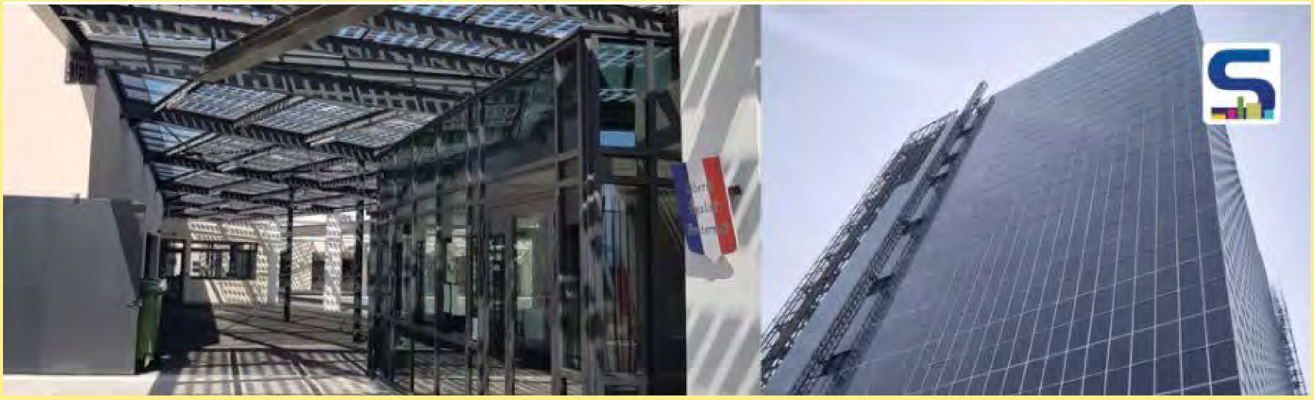


Source: https://firstgreenconsulting.wordpress.com/2013/07/10/bipv-module-mounting-techniques/

Source: Saur energy

Case Study

In 2019, U-Solar Clean Energy Solutions Pvt. Ltd. installed India's largest building integrated vertical solar PV system at a data center in Mumbai. The system, with a capacity of about 1 MW, has been installed by integrating solar panels on all four walls of the facility, covering over 5000 square feet of facade area. It called for the use of custom designed aluminum rails as the module mounting structure. Frameless panels were used on the facade. The panels were connected as they were placed on the structure, and electrical work and construction took place simultaneously for timely delivery. Since the building was already constructed, this was a constraint on the solar energy that could be harnessed. To partially address this issue, power optimizers have been used on each panel. Power optimizers increase energy output from PV systems by constantly tracking the maximum power point (MPPT) of each module individually. They can also monitor the performance of each module. In terms of environmental benefits, U-Solar estimates the solar power system will help provide a CO_2 emissions reduction equivalent to almost 7000 trees per year.



In recent years, BIPV has been developing rapidly due to advances in technology, the cost reduction in PV materials, and an increase in governments' incentive policies for renewable energy technologies.

The biggest advantage of BIPV is that the integration of PV modules brings a high on-site electricity production potential for modern buildings. The electricity generation potential of BIPV in buildings, cities, and countries confirms that promoting BIPV applications would be a great help for the future production and supply of regional electricity demands. BIPV also brings about some by-produced advantages related to architectural aesthetics and energy efficiency aspects compared to conventional buildings, i.e., indoor thermal load reduction and day lighting provision.

Performance of BIPV Systems

In the case of vertical BIPV systems, a reduced output should be expected as all the panels cannot be placed in the optimal direction from a power generation point of view.

The table is on right side shows the output for a small 1 kW system.

Clearly, the power output is reduced to almost half as a result of the orientation. However, BIPV substantially increases the quantum of local energy generation, and a decision on the viability should be done after evaluating the system's return on investment (ROI).

Solar panel's tilt relative to the horizontal	Direction of the solar panel	Annual output for a 1kW DC solar system (kWh/year. in Delhi)	Output relative to highest generation (%)
Vertical	North	391	27
Vertical	East	630	44
Vertical	South	871	60
Vertical	West	795	55
Average of all four Vertical systems		672	47
Horizontal	-	1312	91
Latitude	South	1442	100

Source: U-Solar

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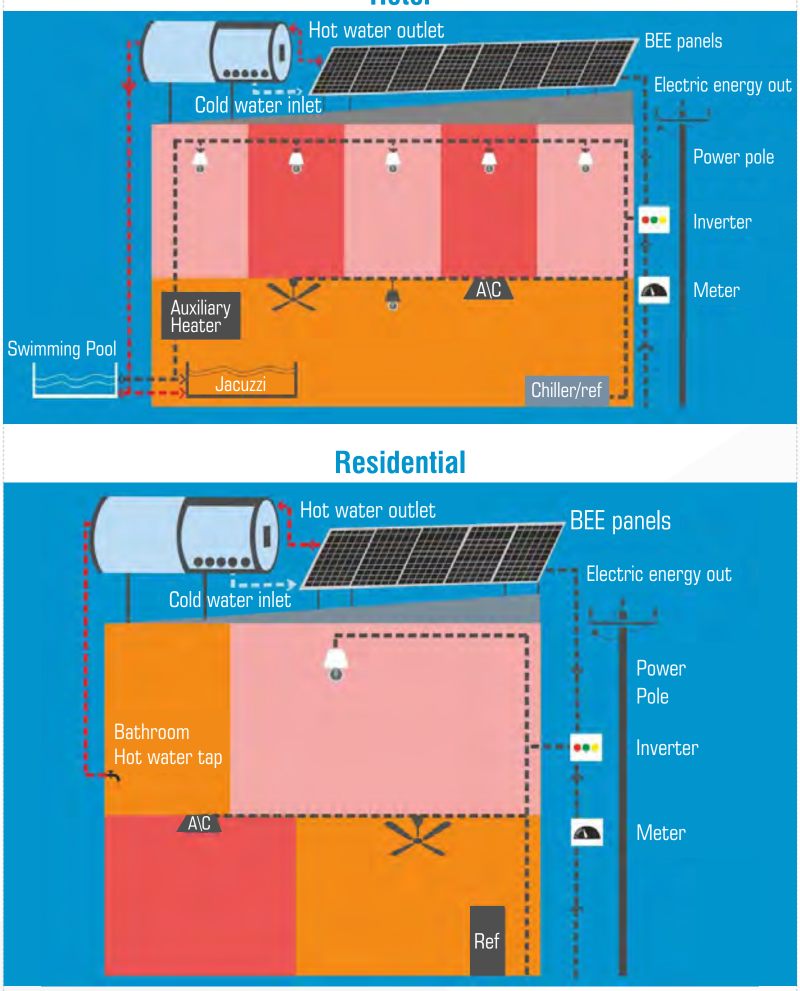
HYBRID SOLAR PHOTOVOLTAIC Thermal Technology (PVT)

Photovoltaic thermal hybrid solar collectors, also known as hybrid PV/T systems or PVT, is a system that converts solar radiation into thermal and electrical energy. These systems combine a photovoltaic cell, which converts electromagnetic radiation (photons) into electricity, with a solar thermal collector, which captures the remaining energy and removes waste heat from the PV module.

PV/T systems overcome the challenges of drop in efficiency of PV cells with the rise in temperature due to increased resistance. Removing the heat from the PV cells thereby cools the cells and thus improves their efficiency by lowering resistance.

A range of methods are available such as the choices of monocrystalline/polycrystalline/amorphous silicon (c-Si/pc-Si/a-Si) or thin-film solar cells, air/liquid/evaporative collectors, flat-plate/concentrator types, glazed/unglazed designs, natural/forced fluid flow, and stand-alone/building-integrated features. Accordingly, the systems are ranging from PVT air and/or water heating system to hot-water supply through PV-integrated heat pump/pipe or combined heating and cooling and to actively cooled PV concentrator through the use of lens/reflectors.

Schematic Representation



Source: *Birds Eye Energy*

PVT Application and its end use

Output energy	Application Suitable	Building type	Specific requirement
Electricity and hot water	Domestic hot water, Cooking, laundry, cleaning, space heating or cooling	Residential, Hotel, Hospital, Hostels, institutes	Shadow free rooftop area

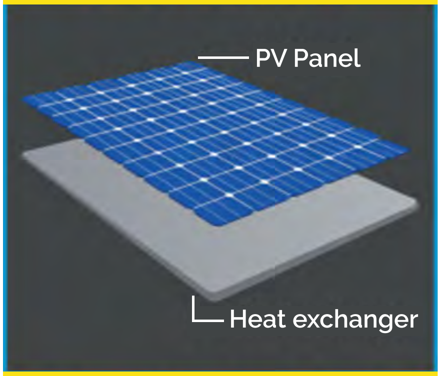
Indian Manufacturer

- Birds Eye Energy

Birds Eye Energy Panel Specifications

- Mono-PERC crystalline cells
- No. of cells: 72
- Panel electric output: 330w
- Panel hot water output: 75 to 100 litres per day
- Panel efficiency: 35% to 40%
- Dimensions: 2017mm X 1032mm X 62mm
- Dry weight of the panel: 53kg
- Fluid volume inside the panel: 3.75 litres
- Design pressure: 8 bar (116 psi)

BIRDS EYE ENERGY PANEL DESIGN



PV panel generates electricity and in addition, transfers heat to heat exchanger

Case Study
Oyo Hotel

Oyo Hotels at Lakdi Ka Pul, Hyderabad was facing a massive challenge of high electricity bills. They were looking for innovative green energy technology to maximize savings from the limited roof top space of 500 sq. ft. The initially installed traditional hot water system had presented durability challenges. Also, traditional solar panels with a limited roof top space could not satisfy the peak energy demand. Thus, they installed "Birds Eye Energy's Duplex panels" which was able to meet the Oyo Hotels needs by installing 15 solar panels that produce 4.5kW of electric power and 1500 litres of hot water per day.

Below table lists the average daily electricity and thermal output generation. In the months of June, July and August, the total daily electricity savings from the 4.5kW + 1500L system installed for OYO hotel was in the range of 45-50 kWh.

Month	Electricity Output		Thermal Output	
	Average Daily Generation (kWh)	Monthly Generation (kWh)	Average Daily Savings (kWh)	Monthly Savings (kWh)
June	15.9	477	34	1020
July	14.1	437	35	1085
August	14.6	453	31	961

In comparison to the traditional systems like hot water panels, PV panels, Heat pumps, the Duplex panels can manage to save upto Rs 28 to 34 lakhs more for a system size of 4.5kW + 1500L.

The system has managed to save about 50 units per day.

Building Integrated Wind Turbine


Source: CTCN

Wind energy technologies can be classified into two categories – macro wind turbines that are installed for large-scale energy generation such as wind farms, and micro wind turbines used for local electricity production. Micro wind turbines are suitable for application at the building scale and are called **'Building-Integrated Wind Turbines' or 'Vertical Axis Wind Turbines.'** The main components of a wind turbine include blades, rotor, gearbox and generator. Small wind turbines were originally designed with a horizontal axis, also known as HAWTs. To reduce the need for a high tower, and aesthetics, vertical axis wind turbines (VAWTs) became increasingly popular for integrated building applications. Furthermore, VAWTs are also quieter (resulting in less noise nuisance) than HAWTs during operation.

Vertical Axis Wind Turbines generators (200 W-10kW) can be used as stand-alone systems or as grid connected systems, and both can be paired with other energy conversion systems, such as photovoltaics. With a height from 2 to 10 meters, small wind turbines can be placed on rooftops, on streets or in gardens, they have relatively little visual impact and are able to produce energy even from modest wind flows. In addition to that, small wind turbines may also be coupled to street lighting systems (smart lighting).

'Building-Integrated Wind Turbines' Players in India

1. Windstream Energy Technologies
2. Spitzen Energy
3. Avant Garde Innovation Pvt. Ltd.

Although vertical axis wind turbines can have different shapes, they can be divided in two main groups: the Savonius turbines (1929) working primarily on the aerodynamic drag principle and the Darrieus turbines (1931) were operating on the principle of lift. On the market there are now innovative models, which take advantages of the features of both. **Savonius Wind Turbine** is a drag type turbine, commonly used when high reliability is required in many things such as ventilation and anemometers. Because they are a drag type turbine, they are less efficient than the common HAWT. Savonius are excellent in areas of turbulent wind and can self-start at low wind speeds (See figure below).

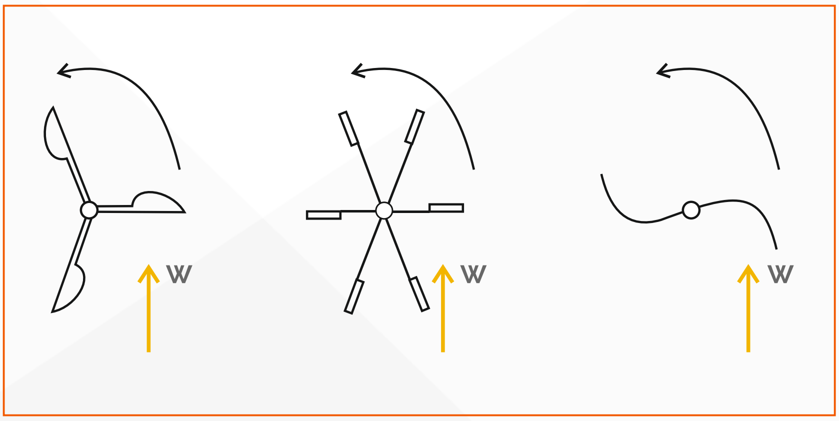


Figure 1: Savonius Wind Turbines

Darrieus wind turbines are commonly called "Eggbeater" turbines, because they look like a giant eggbeater. They have good efficiency but produce large torque ripple and cyclic stress on the shaft, which contributes to poor reliability. They also generally require some external power source, or an additional Savonius rotor, to start turning because of the extremely low starting torque. Torque ripple is reduced by using three or more blades, resulting in a higher solidity of the rotor. Solidity is measured by blade area over the rotor area. Newer Darrieus type turbines are not held up by wires but have an external superstructure connected to the top bearing. Darrieus turbines can either have circular or straight wings (the latter called H-blade Darrieus); a further development has a helicoidal winged design called Gorlov, after its inventor, and it is more efficient (See figure below).

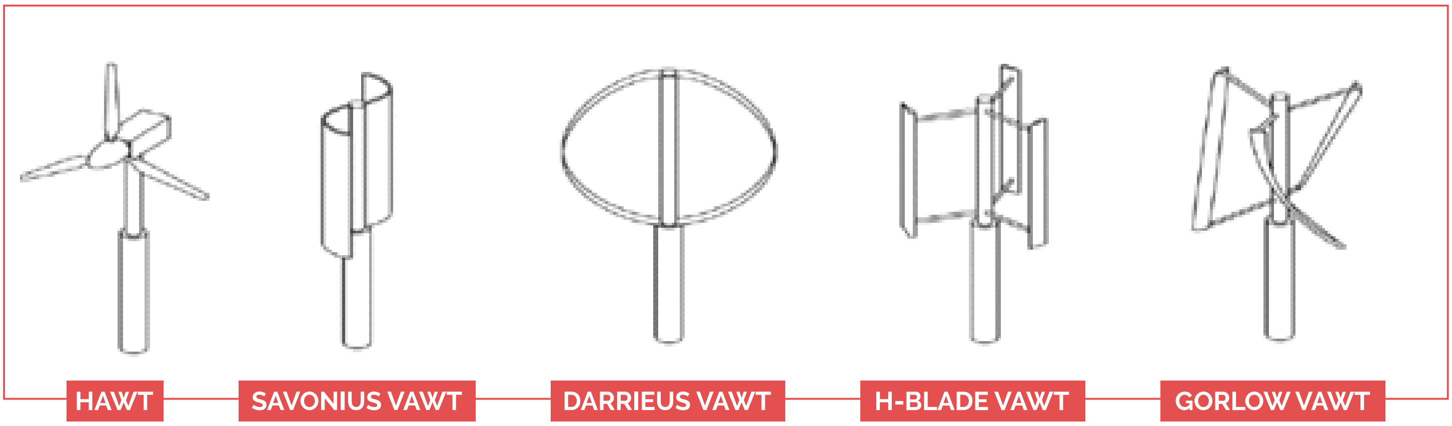


Figure 2: Different types of wind turbine

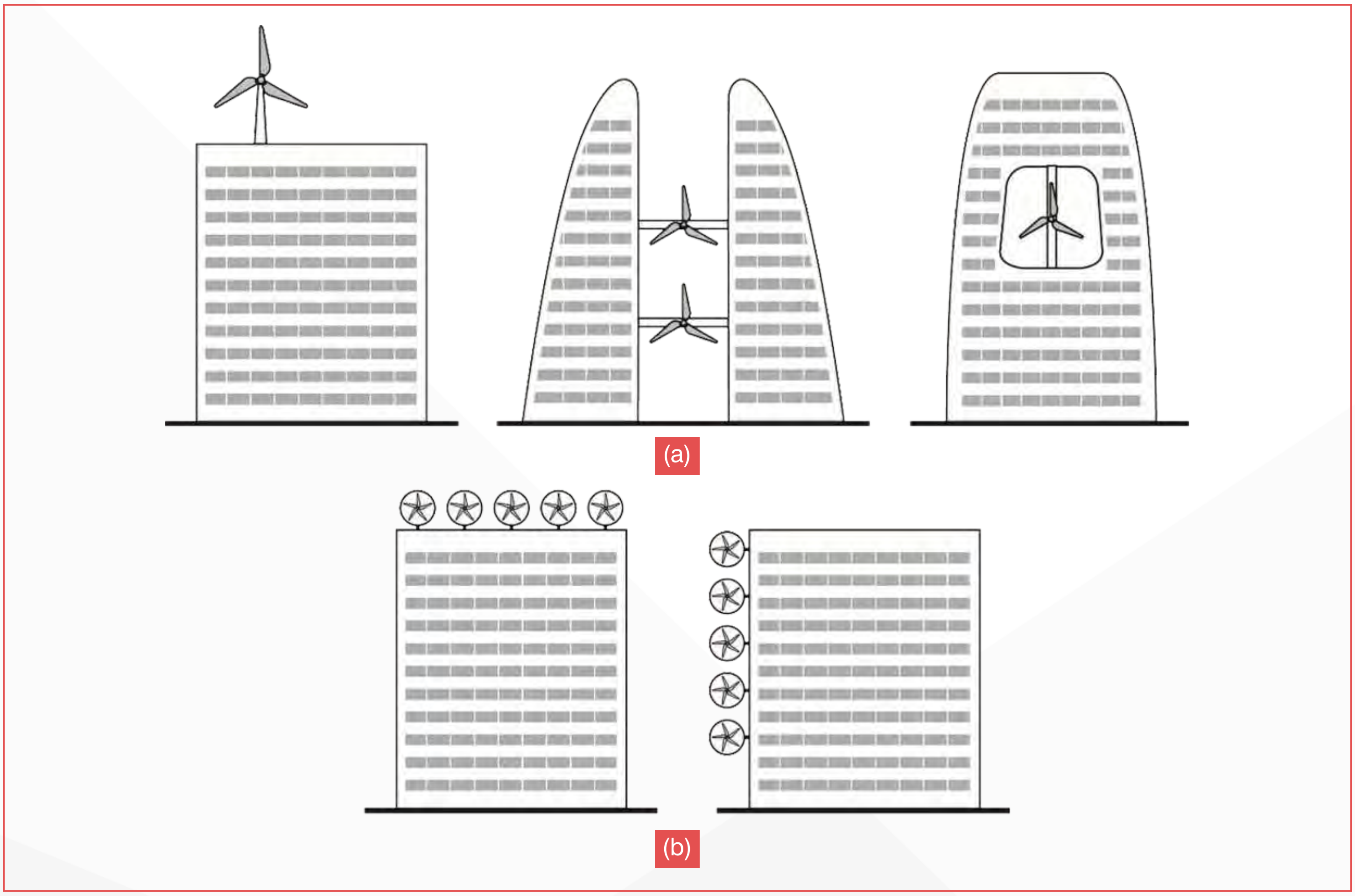


Figure 3: Building-integrated wind turbine system using wind turbines: (a) three possible installation locations of large-size wind turbines; and (b) two possible installation locations of small-size wind turbines.

Financial requirements and costs

Financial requirements for the implementation of building integrated wind turbines include investment and maintenance costs. Investment cost covers not only the products and their installation, but also feasibility studies and system design related activities. One of the most critical activities is to analyse (for existing buildings) and predict (for new buildings during design stage) the wind conditions on and around the building to determine the feasibility and location for installation.

The cost components of wind turbines vary depending on the type, capacity rating, and local availability. Return on investment depends greatly on the actual wind conditions and performance onsite, and partially on the incentive level of feed-in tariff and local electricity pricing.

Building Integrated Wind Turbine Application and Potential End Use

Technology	Output energy	Application	Specific requirement
Building integrated wind turbine	Electricity	Offset Building electricity consumption & Export to Grid	Unobstructed open area (Rooftop or ground)

Source: Saur energy

Advantages of building integrated wind turbine technologies:

- Improving reliability, improving efficiency at low wind speeds, and lowering capital cost.
- Wind turbine blades are now designed with lightweight materials and aerodynamic principles, so that they are sensitive to small air movements. Furthermore, the use of permanent magnet generators, based on rare earth permanent magnets, results in lightweight and compact systems that allow low cut-in wind speeds. In this way, electricity can be generated with wind speeds as low as a few metres per second.
- To be more attractive for integrating into buildings, micro wind turbines are also being designed to be more visually attractive, without compromising their performance.
- Another objective is to reduce/eliminate noise associated with blade rotation and gearbox/ generator noise. This can be achieved by using low-noise blade designs, vibration isolators to reduce sound and sound absorbing materials around the gearbox and generator.
- **Solar-wind hybrid systems combine two of the fastest growing renewable energy technologies.** Such a concept has emerged due to the complementary nature of solar and wind. Solar, due to its dependence on sunlight can produce power only during the day, probably from 8 am – 6 pm. The Wind, on the other hand, starts blowing during late evenings and reaches its peak during the nights. Due to this inherent nature of wind and solar, **power production can be leveled out all throughout the day with a solar-wind hybrid.**
- Lastly, simplifying wind turbine components/ systems also adds to the attractiveness of wind turbine application and reduces maintenance costs. Efforts in this area include the integration of inverters into the nacelle.

Solar Mill

WindStream Technologies, Inc. was established in 2008 with the goal of designing, prototyping and manufacturing affordable and scalable renewable energy technologies for a global marketplace. The Company has developed and tested the first-of-its-kind, integrated, hybrid energy solution and is now marketing and selling SolarMills® to a worldwide customer base.

WindStream Technologies' engineers have designed a unique set of vertical axis wind turbines, added the highest quality solar panels, and a patented system of integrated electronics, to create a hybrid device with the highest energy density in the market.

Hybrid Plant INSTALLATION ON Directorate of Fisheries OFFICE Kavaratti Lakshadweep

Plant Details:

I. System: 20kW (15 kW Solar + 5 kW wind) Off grid
II. Model: (SM 10-48P) with 240V 400Ah T-GEL Battery
III. Load: 14 kW office loads for 8 hours of operation.

These are designed to power the building which requires continuous electricity for storing the collected fish.

The table below gives the information on the amount charged per KWH for various categories.

(20kW) Hybrid Renewable Energy Off-Grid system	
Cost of System in INR	2,715,500.00
Generation per day in kWH	65
Unit rate in INR	22.5
Savings Per Month in INR	36563
Cost Savings per Annum	438750
Return on Investment	6.2 years

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Biomass Energy

Biomass is used for facility heating, electric power generation, and combined heat and power. The term biomass encompasses a large variety of materials, including wood from various sources, agricultural residues, and animal and human waste.

Biomass can be converted into electric power through several methods:

- Direct combustion of biomass material, such as agricultural waste or woody materials.
- Gasification produces a synthesis gas with usable energy content by heating the biomass with insufficient oxygen.
- Pyrolysis yields biooil by rapidly heating the biomass in the absence of oxygen.
- Anaerobic digestion (AD) produces a renewable natural gas when organic matter is decomposed by bacteria in the absence of oxygen.

AD produces biogas, a methane-rich gas that can be used as a fuel and digestate, a source of nutrients that can be used as a fertiliser. Increasingly AD is being used to make the most of out of waste by turning it into renewable energy and has multiple applications for buildings.

Suitability of AD for buildings

- Highly suitable in Indian context, high organic waste content, opportunities for on-site utilization of biogas
- Applicable for commercial and residential buildings

Commercial feasibility

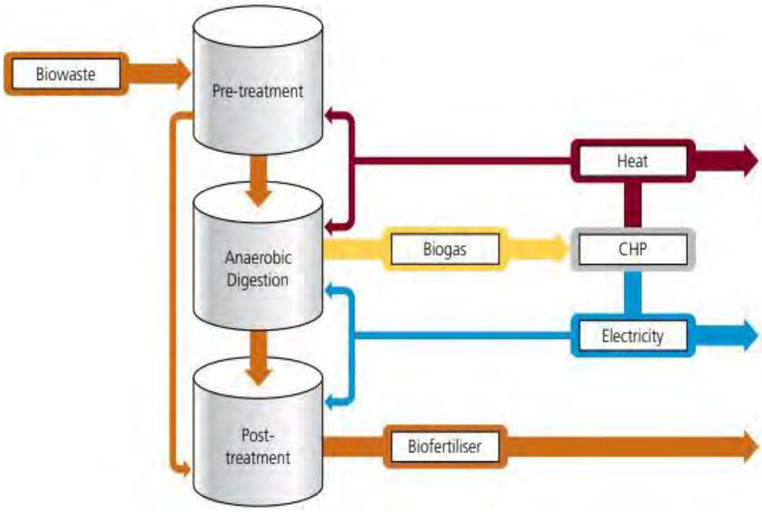
- Commercially viable technologies and multiple players
- High efficiency

How Does the Anaerobic Digestion Process Work?

The process takes place inside an anaerobic digester; a large, sealed tank which is void of oxygen. The air supply is restricted to stimulate 'anaerobic' decomposition (as opposed to composting, which takes place in the presence of air). After 20 to 60 days, depending on the configuration and internal temperature of the digester, a methane-rich 'bio-gas' and a residual co-product, an odour-free 'digestate' is produced.

This gas is commonly used for electricity and heat generation and may also be upgraded for other applications.

The digestate is rich in plant-available N, P and K and may be directly spread on the land as a fertiliser. Alternatively, digestate may be further separated or "dewatered" into a solid fraction (typically 25-35% dry matter, enriched in tP) which can be used as a soil improver, and a liquid biofertiliser containing much of the ammonium and potassium that can be pumped or transported for land-spreading.



Policy and incentives for biogas systems

The Union Ministry of Environment, Forests and Climate Change (MoEF&CC) notified the new **Solid Waste Management Rules (SWM), 2016.** These have replaced the Municipal Solid Wastes (Management and Handling) Rules, 2000. The major highlights of the rules are segregation at source, collection, and disposal of sanitary waste, collect back scheme for packaging waste, waste processing and treatment and promoting use of compost. The rules mandate that all resident welfare, market associations and gated communities with an area of above 5,000 sq m will have to segregate waste at source by the generators or facilitate collection of segregated waste in separate streams and handover recyclable material to either the authorised waste pickers or authorised recyclers. The bio-degradable waste shall be processed, treated, and disposed off through composting or bio-methanation within the premises as far as possible. The residual waste shall be given to the waste collectors or agency as directed by local government body. **A few states are also promoting waste to energy projects.** Thus, the waste can be sent to these plants as these plants generate energy in the form of electricity and/or heat from the primary treatment of waste, or the processing of waste into a fuel source.

Major Players in India

- Founded in 2011, GPS Renewables is a waste-to-energy technology company that is pioneering the development of clean and low-cost technology for waste management solutions. The product is called BioUrja Biomass.
- The Energy and Resource Institute (TERI) product is called TEAMdigestor.

Biomass Application and Potential End Use

Output energy	Application	Suitable Building type	Specific requirement
Gas	Electricity generation & fuel replacement for cooking	Residential societies, Multifamily apartments, Institutes & hotels	Continuous availability of biomass (preferably on site)

Case Study
Green Park Hotel, Hyderabad

The Green Park and Marigold Hotels is a 4-star hotel located at the Urban Hyderabad City. It is a 200-room hotel with one restaurant and a banquet hall. Hotel installed a biodigester for efficient and green processing of food waste while in turn getting Bio CNG as the output thereby replacing a significant portion of their fuel needs. The system layout was customized due to space constraints at the hotel. System components had to be designed and placed at different places in the compound at the back of the hotel and necessary piping had to be carried out to ensure optimal operation. The maximum level of waste addition was **400 kg/day** based on the kitchen's current LPG needs. The waste stream included both food preparation waste (uncut vegetables, etc) and cooked food waste. The energy generated from the BioUrja (name of the system) fuels 2 large burners, which are utilized for cooking. The performance statistics are summarized below. The hotel staff had been trained on O&M procedures. The high level of automation ensures that even unskilled personnel can carry out the basic operation procedure of feeding the waste in about 2-3 hours every day.

Waste Processing Capacity	Max. of 400 kg per day
Water Intake	NIL
Main Reactor	Base Area 6 sq m
Delivery Time	2 months
Operational since	March 2015
Daily Raw Gas Production	56 cu m of biogas
Daily LPG equivalent production	~28 kg per day Annual
Waste Processing Capacity	146 tons
Annual GHG mitigation	More than 170 tons of carbon dioxide equivalent
Operational Cost of generating	1 kg
LPG equivalent Gas	~Rs11
Net Present Value of the Project	>Rs60 lakhs
Rate of Return (IRR)	50%
Payback Period	<2 years

Source: BioEnergy Consult

Source: http://www.greenpowersystems.co.in/case-studies/

Biomass installations in buildings in India

Source: http://www.greenpowersystems.co.in/case-studies/

RE

Assisted and Efficient technologies

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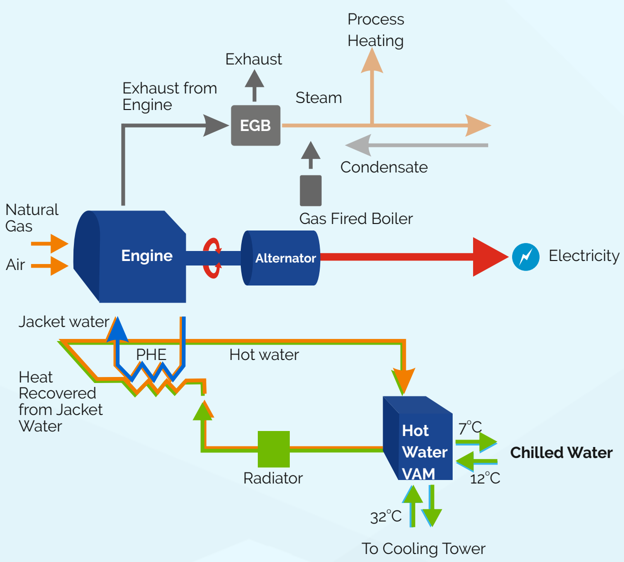
Tri-generation

Tri-generation technology is a technology that can provide simultaneously three forms of output energy: electrical power, heating and cooling. Trigeneration is also known as CCHP (Combined Cooling, Heating and Power) or CHRP (Combined Heating, Refrigeration and Power). In essence, trigeneration systems are CHP (Combined Heat and Power) or co-generation systems, integrated with a thermally driven refrigeration system to provide cooling as well as electrical power and heating. CHP systems consist of a power system which can be an internal combustion engine driven by a fossil fuel or a biofuel, an external combustion engine or other thermally or chemically driven systems coupled to a generator which produces electricity. A heat recovery system recovers heat from the power system and exhaust gases to be used for heating applications. Effective operation of CHP systems requires maximum utilisation of both electrical power and heat. Where there are seasonal variations in heat demand, the utilisation efficiency of CHP systems can be increased if the excess heat is used to power thermally driven refrigeration technologies. Trigeneration systems can have overall efficiencies as high as 90% compared to 33%-35% for electricity generated in central power plants.

Schematic of a tri-generation system



Tri-generation Application and Potential End Use

Output energy	Application	Suitable Building type
Electricity + Heat + Cooling	Electricity and heat generation from gas. Can be used for better utilization of biogas.	Campus, society, shopping complex, large developments with multiple building types.

Advantage of Tri-generation

- Cost Saving
- High operating efficiency
- Reduced electricity consumption
- Environment friendly
- Buffer against increase in electricity cost
- Reliable and good quality uninterrupted supply of power, cooling and heating
- Less dependence on grid power availability or captive power plants

Suitability

- Suitable to local context but requires intense planning.
- Some of the potential consumers of the technology are commercial establishments such as hospitals, hotels, shopping malls and technology parks; industries such as dairy, food and beverage, and pharmaceuticals; and large engineering manufacturing facilities.

Market Feasibility

- Proven technology
- Same equipment can be used to generate cooling, hot water, and electricity in a building

As per Energy Efficiency Services Limited (EESL), trigeneration can reduce the end user's primary energy demand by 60-70 per cent, increase overall energy efficiency by almost 75 per cent, and cut greenhouse gas emissions by up to 30 per cent. The trigeneration system can provide 300 tonnes of refrigeration for every MW of power it generates, saving up to 195 kW of electricity, and eliminating the need for investments in centralised cooling equipment and hot water boilers. Further, by creating a parallel source of electricity through captive generation, trigeneration can protect consumers against surging tariffs.

According to the IEA's Energy Policy Review Report the potential of trigeneration technology in India's energy scenario is estimated at 15 GW, which can be scaled up to 30 GW over the next five years. Tapping into this potential will require an investment of Rs 9 trillion across the building and industry sectors, resulting in an annual emission reduction of 32.2 million tonnes.

A trigeneration system consisting of an internal combustion (IC) engine integrated with biomass gasification may offer a combination for delivering heat, electricity and cooling cleanly and economically. The producer gas generated by the gasifier is used to provide electricity for building use via the IC engine. The waste heat is recovered from the engine cooling system and exhaust gases to supply hot water to space heating, excess heat is also used to drive an absorption cooling system. The proposed system is designed to meet the energy requirements for selected commercial buildings and district heating/cooling applications.

Major suppliers of Tri-generation

- EPSL Trigeneration Pvt. Ltd.
- Clarke Energy India Pvt. Ltd.
- Anama Energies Pvt. Ltd.
- Green Power International (GPI)

Case Study

Case study	Pushpanjali Cross lay Hospital
Location	Ghaziabad, India
Climate Type	Composite
Building Type	Hospital; 400 bed tertiary care
Area	5000 sq. mt.
System Description	Tri generation system 1000 TR air conditioning load. Components to meet the heating and cooling loads include a gas genset (1.7 MW), 600 TR capacity Vapour Absorption Machines (VAM) with heat recovery, and electrical chillers of 400 TR capacity.
System Cost	Total capital cost including DG backup was 9 crore INR. Additional capital investment for the Tri generation system was nearly 3.4 crore INR. Cost of power generated through the Tri generation system (using natural gas) is 3.4 INR/ kW. Net savings of 3.8 INR/ kW or approximately 3 crore INR annually is achieved through this system.
System Performance	The system provides uninterrupted and reliable power supply, without any fluctuations to the hospital. Power supplied by natural gas is more environmentally friendly than the coal-based power supplied through the grid. Operating cost of this system is 1.36 lakhs INR per day compared to 2.25 lakh INR for using electrical chillers running on grid supply.

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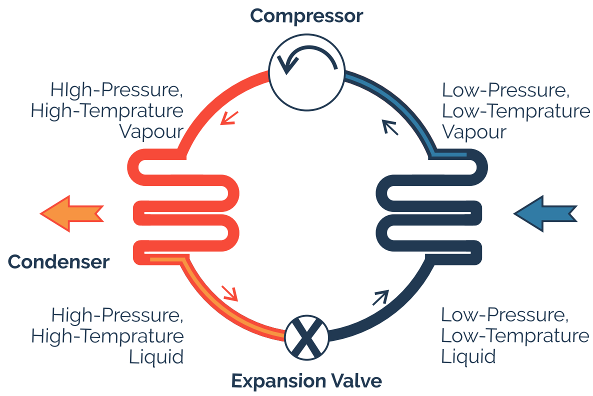
HEAT Pumps

Heat pumps are electrical devices which convert energy from external heat sources (air, water, etc.) to useful heat which can then be used for space heating and/or hot water supply in residential and commercial buildings. They are regarded as one of the most energy efficient and environmentally friendly technologies that enhance the utilisation level and effective integration of intermittent renewable energy sources.



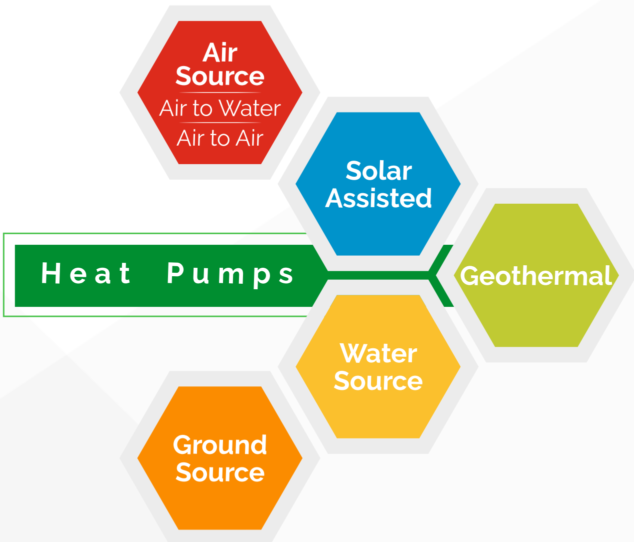
The heat pumping cycle can be divided in three steps:

1. A fluid with a boiling point lower than the heat source temperature serves as a medium for heat transport. It is called the working fluid or refrigerant. As the working fluid extracts the heat from the source through a heat exchanger, its temperature rises and it evaporates.

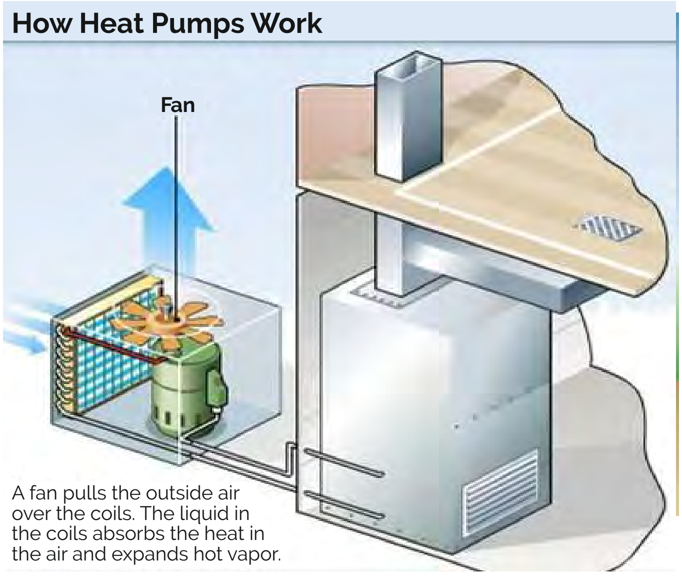
2. Then a compressor compresses the evaporated fluid. Consequently, the pressure and the temperature of the vapour increase. When pumping up a bicycle tyre, you can also observe this phenomenon. The lower side of the pump – where the pressure is highest – is getting very hot.

3. Finally, heat is being transferred from the evaporated fluid to the heat distribution fluid (water or air) in the condenser. As it releases its heat, the working fluid temperature decreases to such a degree that it condenses. After passing through the expansion valve, the fluid regains its initial liquid, low-temperature and low-pressure state. It then flows back to the evaporator where the process starts all over again.

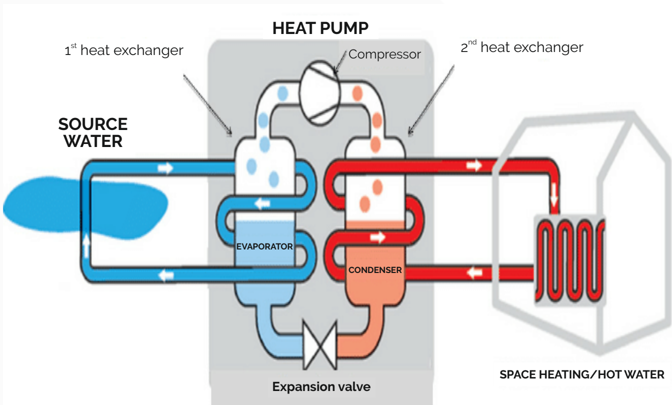
Types of Heat Pumps



An air source heat pump (ASHP) takes low grade heat from the air, and boosts it to high grade that can be used for domestic heating or any other purpose. The pump uses less electricity than the heat it produces. The performance of an ASHP is similar to a refrigerator, but works in a reverse mode. ASHPs find applications in domestic space heating and hot water supply.

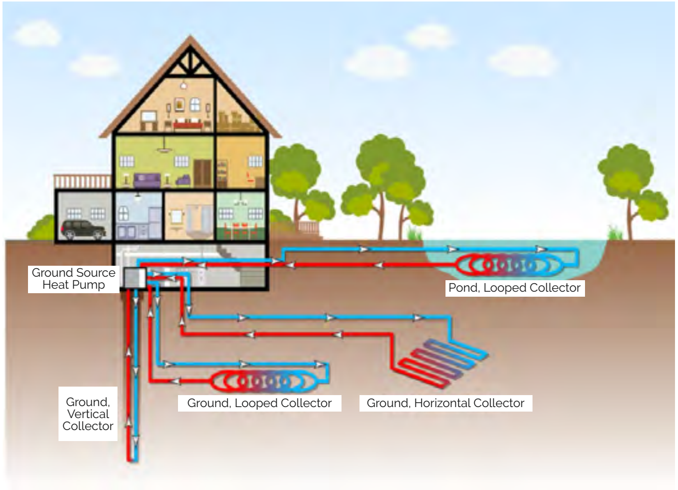


Water source heat pumps (WSHPs) use water bodies such as lakes, ponds, rivers, etc. as a source of heat. They extract low grade heat from water and convert to useful heat. Compared to air-source heat pumps, WSHPs generate less carbon emissions and result in substantial cost savings. As opposed to ASHPs, ambient temperature conditions do not significantly influence the performances of WSHPs. WSHPs are often characterized by high efficiency, but their applications are limited due to the requirement of large waterbodies or storage tanks near dwellings.



Source: *ResearchGate*

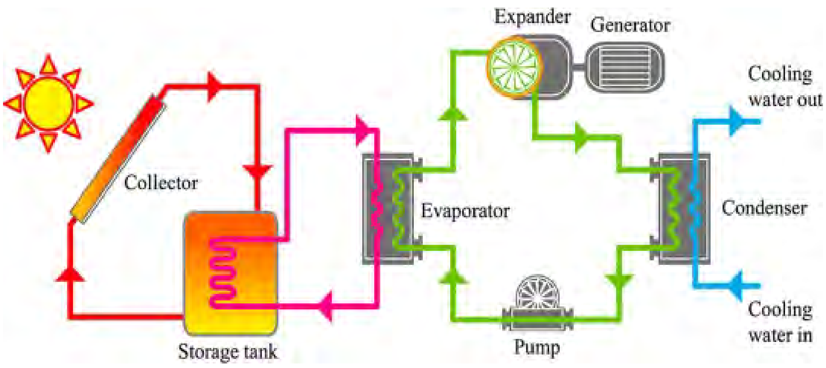
Both ground source heat pumps (GSHPs) and geothermal HPs use heat energy naturally stored in the ground as a source. Sometimes, the terms ground source and geothermal are used interchangeably. However, there are some key differences between both technologies. GSHPs use heat from relatively shallow ground (often between 1.2m and 200m depth), and are usually used for domestic and small commercial applications. Whereas, geothermal HPs use energy from the earth's core from about 500–2500m deep, and are used for large industrial applications.



Source: *Consolidated Electric Cooperative*

GSHP's can be categorized as having closed or open loops and those loops can be installed in three ways: horizontally, vertically, or in a pond/lake, sewage system or other water bodies. In comparison to the traditional air conditioning systems, up to 50% energy savings can be achieved through this innovative technology. In addition, the technology is also 100% water efficient since it rejects heat using conduction, convection and advection and not through evaporation as in traditional A.C system cooling towers which lose approximately 6-8 litres of water per hour to the atmosphere for every ton of air conditioning.

Solar assisted heat pumps are efficient and reliable systems which can meet low temperature heat demand such as domestic space heating and hot water requirements. The intermittency of solar may affect the performance of such heat pumps. This problem can be solved by incorporating dual sources of heat. One example in this case is a solar assisted GSHP, which serves to be cost effective as well as environmentally friendly.



Source: *ScienceDirect*

Heat pumps can also be operated using other sources of heat such as industrial waste heat. Modelling and screening of HP options for exploiting low grade waste heat in process sites suggests that adsorption heat transformer is the best option though its performance may be case specific. Examples of energy savings from power generation include with exergetic efficiencies of up to 70% and 16% savings achieved in coal-fired power plants. Likewise, considerable reductions in primary energy consumption and emissions, associated deployment of heat pumps for heat recovery in sewage treatment plants, can be obtained.

Technology	Installation cost	Average COP	Environmental Impacts	Pros	Cons
Air Source Heat Pump	+	3	Highest environmental impact in cold regions Leakage of refrigerant can cause pollution • Causes noise pollution	• Less or no pollution concerns • Simple operation • Low Maintenance Cost • High COP • Low primary energy consumption	• Frost formation on outer units • COP varies with ambient temperature • Requires more space
Water Source Heat Pump	++	4.3	Can cause water pollution, stratum settlement and trigger geological disasters	Highly efficient • Not affected by ambient conditions • Can utilise waste heat from rivers and lakes	Requires water bodies or storage tanks in vicinity • Needs regulatory permission for installation
Ground Source Heat Pu	+++	3.5	Unchecked heat transfer fluids are hazardous • Surface water can enter borehole • Can perturb groundwater temperature	Highly efficient and shows great energy saving potential • Very reliable source of heat • Can operate in regions with extreme winters	Needs careful assessment of local geology and requirements • COP may decrease over heating season due to saturation of soil temperature

Technology	Installation cost	Average COP	Environmental Impacts	Pros	Cons
Geothermal Heat Pump	++++	4	Reduces emissions with low payback period	• High COP • Utilises vast source of heat • Most suitable for large industrial applications & district heating	May need supplemental heat system for better performance
Solar Assisted Heat Pump	++ to +++++	Higher than individual HP COP	Significant environmental benefits • Can reduce emissions by 50%	Financially and energetically viable solution • Solar helps HPs in achieving higher COP • Lowers grid electricity consumption	• Needs additional control mechanism for optimal operation • Highly location and application specific

Heat pumps are proven technologies that can contribute to the overall efforts of reducing GHG emissions and mitigating climate change. They are seen as some of the most promising solutions for decarbonizing the heating and cooling sectors. Considerable environmental benefits are feasible when HPs replace electric resistive space heating. In some examples, greenhouse gas emissions can be reduced by 50% compared to gas based heating systems.

Indian Manufacturers

- Inficold India Pvt. Ltd
- Thermax Ltd. Pune
- Prototech Energy Pvt Ltd
- Ariston Thermo India Pvt Ltd
- Daikin India
- Blue Star
- Samsung

Source: QUICK'S HVAC, INC.

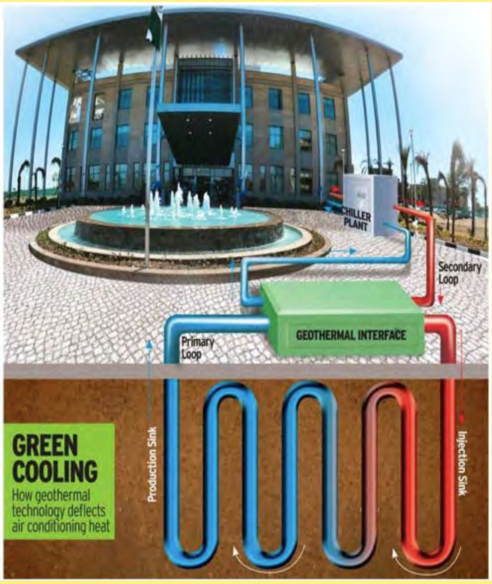
Dholera, Gujarat, India

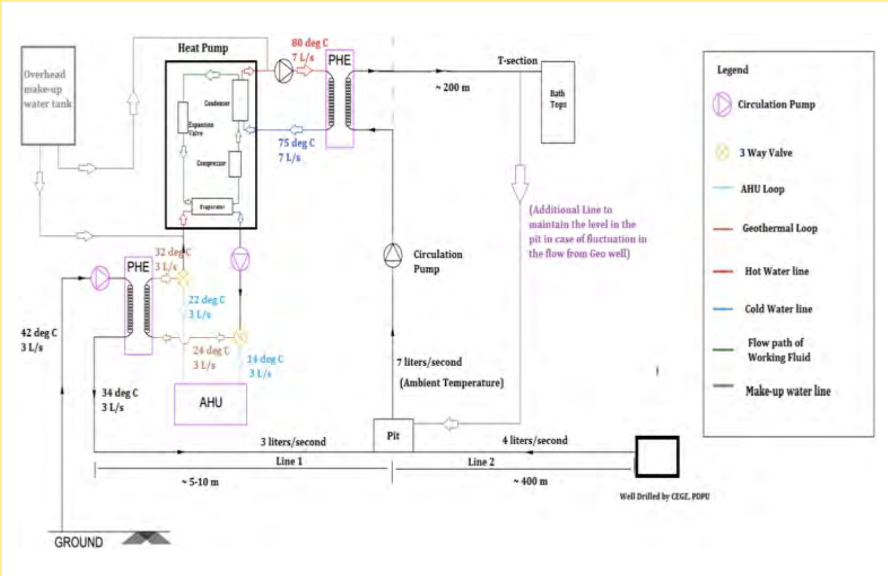
Geothermal Space Heating and Cooling

Geothermal Space Heating and Cooling system at Dholera is based on Ground Source Heat Pump (GSHP) instrument, a first of its kind in India. Centre of Excellence for Geothermal Energy (CEGE), Pandit Deendayal Petroleum University (PDPU) have developed this system in association with Green India Building System and Services (GIBSS).

Two geothermal bore wells were drilled at Dholera of 1000 feet depth. The temperature of the water is 47 to 50 degree Celsius, with a flow rate of seven to eight litters per second. The water is produced from the well without any external energy.

Capacity of system: 32 TR





Sr. No.	Input Type	Units	Geothermal Hot Water	Cooling side temperature
1	Thermal performance of heat pump	Litres/s	3	
2	Cooling water inlet temp	˚C	40	23 ± 10%
3	Cooling water outlet temp	˚C	32	15 ± 10%
4	Geothermal energy used	kW	98	
5	Hot water outlet temp	˚C	80	80 ± 5%
6	Heat capacity	kW	168	168
7	Heat pump COP		2.4	2.1
8	Compressor input power	kW	70	80
9	Cooling provided	kW		88 ± 10%
		TR		25 ± 10%

The system achieves a approximated 40% savings on HVAC costs

India schemes & policies

A. Scale up of Access to Clean Energy for Rural Productive uses.

B. 'Off-Grid and Decentralized Concentrated Solar Thermal (CST) Technologies for Community Cooking, Process Heat and Space Heating & Cooling Applications in Industrial, Institutional and Commercial Establishments' scheme

Schweizerische Eidgenossenschaft
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ENERGY Storage

Source: KIUC

Energy storage technologies include a large set of centralised and distributed designs that are capable of supplying an array of services to the energy system. Storage is one of a number of key technologies that can support decarbonisation. energy storage technologies are categorised by output: electricity and thermal (heat or cold). Technologies in both categories can serve as generators and consumers, giving them the potential to link currently disconnected energy markets (e.g. power, transportation fuels, and local heat markets). Broadly speaking, energy storage is a system integration technology that allows for the improved management of energy supply and demand. In many cases, a single unit of energy storage infrastructure can provide multiple valuable energy and power services.

Energy storage devices can be categorized as mechanical, electrochemical, chemical, electrical, or thermal devices, depending on the storage technology used (Figure below). Mechanical technology, including pumped hydropower generation, is the oldest technology. However, a limitation of this technology is its need for abundant water resources and a different geographic elevation, as well as the construction of power transmission lines to households that consume electricity.

Energy Storage System

*Mechanical, electrochemical, chemical, electrical, or thermal.
Li-ion=lithium-ion, Na-S = sodium-sulfer, Ni-CD = nickel-cadmium, Ni-MH = nickel-metal hydride, SMES=superconducting magnetic energy storage.

Source: Korea Battery Industry Association 2017 "Energy storage system technology and business model"

Energy Storage System (ESS) is fast emerging as an essential part of the evolving clean energy systems of the 21st century. Energy storage represents a huge economic opportunity for India. Ambitious goals, concerted strategies, and a collaborative approach could help India meet its emission reduction targets while avoiding import dependency for battery packs and cells.

India is committed to reducing emission intensity up to 33-35% from the 2005 level by 2030 and set the target of 40% non-fossil fuel-based electricity generation in the energy mix. This requires radical measures to scale up the share of renewable energy (RE) besides the ongoing program of 175 GW RE by 2022. The new targets for RE by 2030 could be in the order of 350 to 500 GW.

With ambitious plans to use renewables – particularly solar PV –to satisfy rapidly increasing electricity demand, India will be the country with the greatest need for additional flexibility in the coming decades, according to IEA analysis.

Table 1: Storage Technologies Comparison Matrix

	Hydro	Flywheel	Lead Acid	Ni–MH	Thermal	Li	Flow	Liquid Metal	Compressed Air	Super-capacitors
Specific energy (kW/kg)	0.3–1.33	5–200	30–50	30–90	10–250	90–250	10–90	100–240	3.2–60	1-30
Energy density (kWh/vol)	0.5–1.33	0.25–424	25–90	38.9–300	25–370	94–500	5.17–70	150–345	0.4–20	NA
Specific power (Wh/kg)	0.001–0.12	400–30,000	25–415	50–1,000	10–30	8–2,000	5.5–166	14.29–260	2.2–24	5
Cycle life (h)	20–50k	Indefinite	200–2k	300–10k	Indefinite	500–10k	10k+ 5k-	10k+ 5k–	20k+	30k
Life cycle	Near universal life with mainte-nance	Near universal life with mainte-nance	Useful life varies by depth of dis-charge and applica-tion, varia-tions by chemis-try	Allows deeper dis-charge and more stable storage, varia-tions by chemis-try	Thermal salts not yet proven. passive storage varies by tech-nology	Useful life varies by depth of dis-charge and other applica-tions, varia-tions by chemis-try	Moving parts require inter-mittent replace-ment	Not yet proven	Near universal life with maintenance	Near universal life with maintenance
Cost per kWh	$1–$291	$200–$150,000	$50–$1,100	$100–$1,000	$1–$137	$200–$4,000	$100–$2,000	$150–$900	$1–$140	$2,400-$6,000
Environ-mental impact	High/Mixed	Low	High	High/Medium	Low	High/Medium	Medium	Low	Low/Medium	Low
Pros	Large power capacity, positive external-ities	Extremely fast response, high specific power, low cost, long life	Mature tech-nology with estab-lished value pro-position	Deep dis-charge capacity, reliable, high energy density	Could pair with waste heat genera-tion, scalable, low cost, large scale	Flexible uses, very fast response and high specific power	Large storage capacity, cheap materials	High capacity, fast response, cheap materials, highly stable, tempera-ture tolerant	Low cost, large scale, mature technology paired with gas turbines	Provide peak power and backup power. Extend battery run time and battery life. Reduce battery size, weight, and cost. Enable low/high temperature operation. Improve load balancing when used in parallel with a battery. Provide energy storage and source balancing when used with energy harvesters.

k = thousand, kg = kilogram, kWh = kilowatt-hour, Li = lithium, Ni–MH = nickel–metal hydride, W = watt.

	Hydro	Flywheel	Lead Acid	Ni–MH	Thermal	Li	Flow	Liquid Metal	Compressed Air	Super-capacitors
Cons	Geo-graphically limited, expensive construc-tion, low energy density and environ-mentally damaging	Low energy density	Low life cycle, toxic materials, flamma-bility risk	Some toxic variations, less specific power than Li, high self-dis-charge, high memory effect	Not fully commer-cialized or not electri-fied	Safety concerns, low depth of corrosion, self-discharge, and efficiency loss over time	Space require-ments, eco-nomic efficiency in multiple applica-tions	Untested in commer-cial use, persis-tent tech-nology issues	Geo-graphically limited, not scalable	They have higher self-discharge rate. This is considerably high compare to battery. Individual cells have low voltages. Hence series connections are required to achieve higher voltages.

Figure 1: Range of Services that can be provided by electricity storage[1]

Bulk energy services	Ancillary services	Transmission infrastructure services	Distribution infrastructure services	Customer energy management services	Off-grid
Electric energy time shift (arbltrage)	Regulation	Transmission upgrade deferral	Distribution upgrade deferral	Power quality	Solar home systems
Electric supply capacity	Spinning, non-spinning and supplemental reserve	Transmission congestion relief	Voltage support	Power reliability	Mini-grids: System stability services
	Voltage support			Retail electric energy time shift	Mini-grids: Facilitating high share of VRE
	Black start			Demand charge management	
				Increased self-consumption of solar PV	

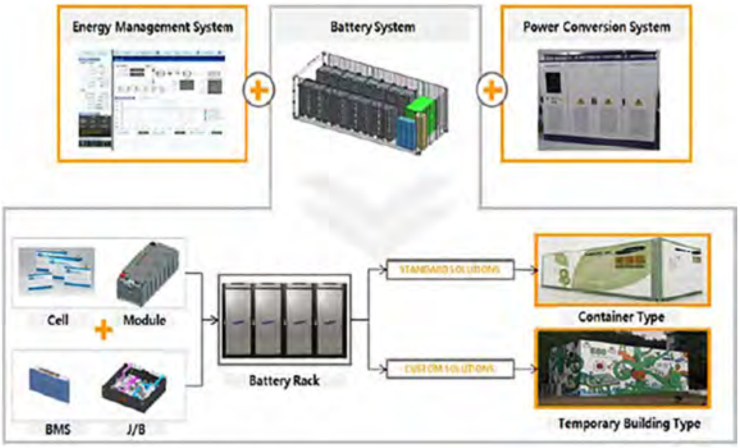
Boxes in red: Energy storage services directly supporting the integration of variable renewable energy

Batteries are ideally suited to meet these rising flexibility needs. Over the next two decades, global growth in batteries is set to outstrip that of any other flexibility option available to electricity systems, according to the World Energy Outlook 2019. Batteries have other advantages, too. They increase the value and competitiveness of solar PV by storing the electricity produced during sunny periods and feeding it back to the grid at another time. Battery storage, coupled with solar PV, also appears to be one of the most cost-effective ways of helping provide affordable electricity to isolated communities.[2]

[1] IRENA report
[2] https://www.leadingedgepower.com/support/help-with-batteries/battery-bank-wiring.html

The various components of a battery energy storage system are shown in the Figure below Schematic.

Figure 2: Schematic of A Battery Energy Storage System



BMS = battery management system, J/B = Junction box.
Source: Korea Battery Industry Association 2017 "Energy storage system technology and business model".

- The battery system consists of the battery pack, which connects multiple cells to appropriate voltage and capacity; the battery management (system BMS); and the battery thermal management system (B-TMS). The BMS protects the cells from harmful operation, in terms of voltage, temperature, and current, to achieve reliable and safe operation, and balances varying cell states-of-charge (SOCs) within a serial connection. The B-TMS controls the temperature of the cells according to their specifications in terms of absolute values and temperature gradients within the pack.

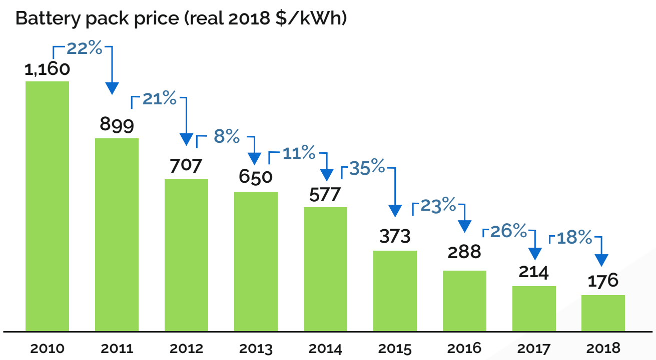
- The components required for the reliable operation of the overall system are system control and monitoring, the energy management system (EMS), and system thermal management. System control and monitoring is general (IT) monitoring, which is partly combined into the overall supervisory control and data acquisition (SCADA) system but may also include fire and distribution. System thermal management controls all functions related to the heating, ventilation, and air-conditioning of the containment system.

- The power electronics can be grouped into the conversion unit, which converts the power flow between the grid and the battery, and the required control and monitoring components—voltage sensing units and thermal management of power electronics components (fan cooling).

Combining Solar and batteries in India

Increasing deployment of variable renewables and changes in electricity demand patterns will double the global need to source power system flexibility, including from batteries. Under stated policies, renewables make up two-thirds of all additions to global power generation capacity through 2040, and solar PV becomes the largest source of installed capacity around 2035. These trends will drive a significant increase in the use of battery storage, led by India, which is projected to account for more than one-third of total deployment by 2040. However, in this scenario, CO2 emissions from the power sector remain stubbornly high around current levels of 13.8 billion tonnes and the sector remains one of the biggest sources of air pollution, especially in Asia.
Due to technological advancements and expected cost reductions, capital costs for battery storage are expected to decline by more than 50% by 2030, thus boosting the amount of storage that is economical to deploy in solar PV projects especially for commercial and big residential societies.

Figure 3: Average global lithium-ion battery pack price declines (Source: BNEF, 2019)



Source: BloombergNEF

Tata Power Collaborates with AES and Mitsubishi Corporation to Power Up South Asia's Largest Grid-Scale Energy Storage System in India

Tata Power, The AES Corporation and Mitsubishi Corporation inaugurated India's first grid-scale battery-based energy storage system in Rohini, Delhi. The 10-Megawatt grid-connected system, owned by AES and Mitsubishi Corporation will pave the path for wider adoption of grid-scale energy storage technology across India. Fluence, a market-leading supplier of energy storage technology jointly owned by Siemens and AES, supplied its state of the art Advancion Technology for the project.

Battery-based energy storage enables electricity to be stored and then delivered within milliseconds, reducing instability of the electric grid, and enabling more energy to be captured and delivered on demand. India has the ambitious vision of installing 225 GW of renewable energy generation by 2022. Battery-based energy storage provides the flexibility and agility to better integrate intermittent solar and wind energy resources into India's electric grid and ensure high-quality power for consumers. This 10 MW project is located at Tata Power Delhi Distribution Ltd.'s (Tata Power-DDL) sub-station in Rohini, Delhi and will provide grid stabilization, better peak load management, add system flexibility, enhance reliability and protect critical facilities for 2 million consumers served by the company.

Players in India

Pluss Advanced Technologies
Exide Industries Ltd, Luminous Power Technologies Pvt Ltd,
Okaya Power Ltd & Greenvision Technologies Pvt Ltd

PCM as thermal mass in building envelope

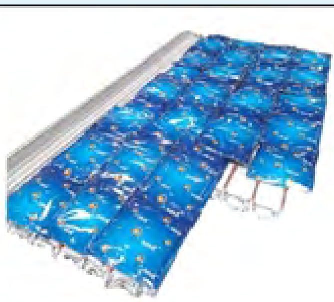
Increasingly, building designers are turning to help deliver sustainable outcomes. Thermal energy system can be applied in various methods; from storage of chilled water (Sensible energy) to ice/phase change materials (PCM) at a designed temperature (Latent energy) delivering results in a range of applications.

In an area that experiences a large diurnal temperature range, PCMs have the potential to be used to store substantial amounts of thermal energy high energy density to volume ratio. The peak daily temperature occurs in the afternoon and similarly, the minimum daily temperature occurs substantially after midnight.

A small change of temperature difference can charge or in other words activate the PCM. For instance, a PCM which has phase change point at +220C would require exposure to an air temperature of +170C. As the human comfort range is from 24 - 260C, the PCM to be used should be in melting range of 22-240C. For instance, PCMs savE® HS22 or savE® HS24 are salt which can change phase between 220C and 240C respectively. By comparison with the same temperature limitations, a conventional sensible heat storage system such as water or concrete would occupy a volume several times greater than latent heat storage. PCM systems can be developed using a wide range of encapsulations, including flexible pouches, HDPE containers as shown in figure next page.


PCM filled thermoTab


thermoTab in ceiling tiles


PCM filled pouches


Pouches in ceiling tiles

To keep a space cold or avoid the temperature increase beyond a certain limit, there are three ways i.e. reduction of heat gain inside the room, reduction in temperature fluctuations and improvement of heat rejection. Implementations of PCMs are the best way to reduce the temperature fluctuations and these can be applied in buildings in either of the two ways: active or passive or a combination of both. The passive way of cooling is easier to implement and use as there is no requirement of mechanical equipment and additional energy. Only natural ventilation helps in charging the PCM by bringing the cold inside the room during the night.

Commercial application(Institutions/Office/Shopping centres)

Sample calculation of PCM required for a space having floor size of 50mtrs x 200 mtrs.

Input Criteria / parameters

- Floor area: 10,000 sq.m;
- PCM: Hs22;
- Density: 1540 kg/m3;
- Thickness: 17 mm;
- Latent heat: 167.6 kJ/kg;
- PCM module, Dimension, PCM weight and encapsulation type - 570 x 157 mm, 1.4Kg, 3-celled pouches
- using nylon multi-layered film.

In a single 60 x 60 cm false ceiling 3 units of such PCM pouches can fit. Hence, the amount of PCM coverage in one false ceiling will be 1.4 kg x 3 modules = 4.2 kg/false ceiling. The surface area of a single false ceiling is 0.37 sq.m. Therefore, the amount of PCM required per sq.m will be 11.35 kg.

- Incorporable weight of PCM in a 10,000 sq.m space - 10000 sq.m x 11.35 kg/sq.m = **1,13,500 kg**
- The total energy storage (PCM) capacity - 1,13,500 x 167.6 = 1,90,22,600 kJ = 5,284.05 Kw-h = **1501.15**

TRH

Reference to data from American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) we have assumed the average HVAC load per sq.mtr as 0.038 TR/sq.mtr(135 Watt/sqr.mtr).
Hence, a building of 10,000 sq.mtr would have an average heat load of 380 TR. Assuming 12 operational hours per day the cumulative cooling capacity would be 4560 TRH. Based on the above scenario the PCM offers opportunity to shift up to 33% of the HVAC load towards free cooling for an average of 4 to 5 months in a year. If accounted for in the beginning of the project the capital equipment such as chillers, AHUs, ducts, pumping system can be downsized.

Selection of the right Phase Change Material

The selection of the right Phase Change Materials (PCM) may vary depending on the average minimum temperature of the region.
Three commonly used temperatures are;
SavE® HS 22 - Requires minimum air temperature of +17˚C
SavE® HS 24 - Requires minimum air temperature of +19˚C
SavE® HS 29 - Requires minimum air temperature of +24˚C

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FUEL Cell


Source: Bloomenergy

"A fuel cell is an electrochemical device that converts the chemical energy of a fuel and an oxidant (pure oxygen or air) directly into electricity without the intermediate step of classical, chemical combustion". Fuels cells can be classified/characterized either based on the type of electrolyte employed or based on the operating temperature range.

Hydrogen or Hydrocarbon fuel + **Oxygen** = **Electricity, Heat and Water**

Fuel cells are classified primarily by the kind of electrolyte they employ. This classification determines the kind of electro-chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development, each with its own advantages, limitations, and potential applications.

Below are the six types of fuel cells which are popular.

FUEL CELL TYPE	DIRECT METHANOL FUEL CELL	PROTON EXCHANGE MEMBRANE FUEL CELL	ALKALINE FUEL CELL	PHOSPHORIC ACID FUEL CELL	MOLTEN CARBONATE FUEL CELL	SOLID OXIDE FUEL CELL
Electrolyte type	Proton Exchange Membrane	Proton Exchange Membrane	Potassium Hydroxide (KOH)	Phosphoric Acid	Molten Mixture of alkali metal carbonates	Oxide ion conducting ceramic
Operating temperature (°C)	20 – 90	30 – 100	50 – 200	~220	~650	500 – 1000
Charge carrier	H^+	H^+	OH^-	H^+	H_3^{2-}	O^{2-}
Power range (W)	1 – 100	1 – 100k	500 – 10k	10k – 1M	100k – 10M+	1k – 10M+
Application	Fuel Cell Vehicles	Fuel cell vehicles, Electrical devices, Backup	Emergency backup, Auxiliary Power Unit (APU)	Stationary power generation	Stationary power generation	Range Extender, APU, Stationary Power generation

Fuel Cell technology offers 24x7 clean, green, reliable & affordable solutions. It can cater to single homes as well as independent buildings, townships in urban & rural areas. The new generation Fuel cell-based power generators can generate 24×7 power and fulfil the electricity, heating & cooling requirements with the use of fuels like piped natural gas (PNG), liquified petroleum gas (LPG), biogas and hydrogen, etc. Hence it is suitable for various kinds of buildings provided it has a gas supply and the output will vary depending on the gas used.

Technology	Output energy	Application	Suitable Building type
Fuel Cell	Electricity + Heat	Storage of excess power from renewable energy sources, electricity generation	All types of buildings

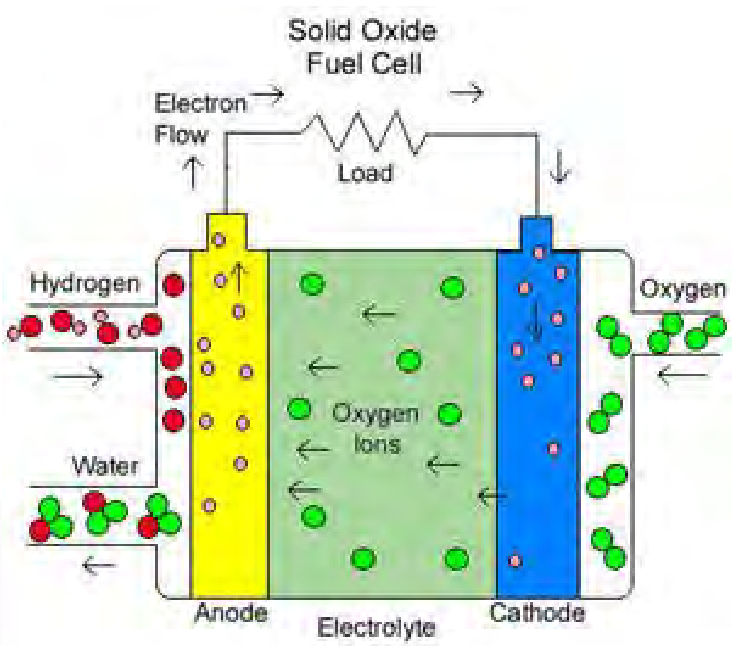
Type of gas	Gas consumption (kg/hour)	Electricity generated per (kWh/kg)	Electricity generated (kWh/kW/day)	Temperature of waste heat (°C)	Amount of heat generated (kWh(thermal)/kWh (electricity))
LPG	0.155	6	24	100-400	1.2
PNG	0.145	7	24	100-400	1.2
Biogas	0.29	3	24	100-400	1.2

However, in the present study/evaluation, only the solid oxide fuel cells (SOFC) are considered owing to their high efficiency in electricity and heat generation.

Solid Oxide Fuel Cells

A solid oxide fuel cell (SOFC) is an energy conversion device that produces electricity by electrochemically combining a fuel and an oxidant across an ionic conducting oxide electrolyte. Solid Oxide fuel cells (SOFC) use a hard, ceramic compound of metal (like calcium or zirconium) oxides (chemically, O2) as electrolyte. Efficiency is about 60 percent, and operating temperatures are about 1,000 ˚C (about 1,800 ˚F). Cells output is up to 100 kW. At such high temperatures a reformer is not required to extract hydrogen from the fuel, and waste heat can be recycled to make additional electricity.

Figure 1: Drawing of a solid oxide cell



SOFCs have a number of advantages due to their solid materials and high operating temperature.

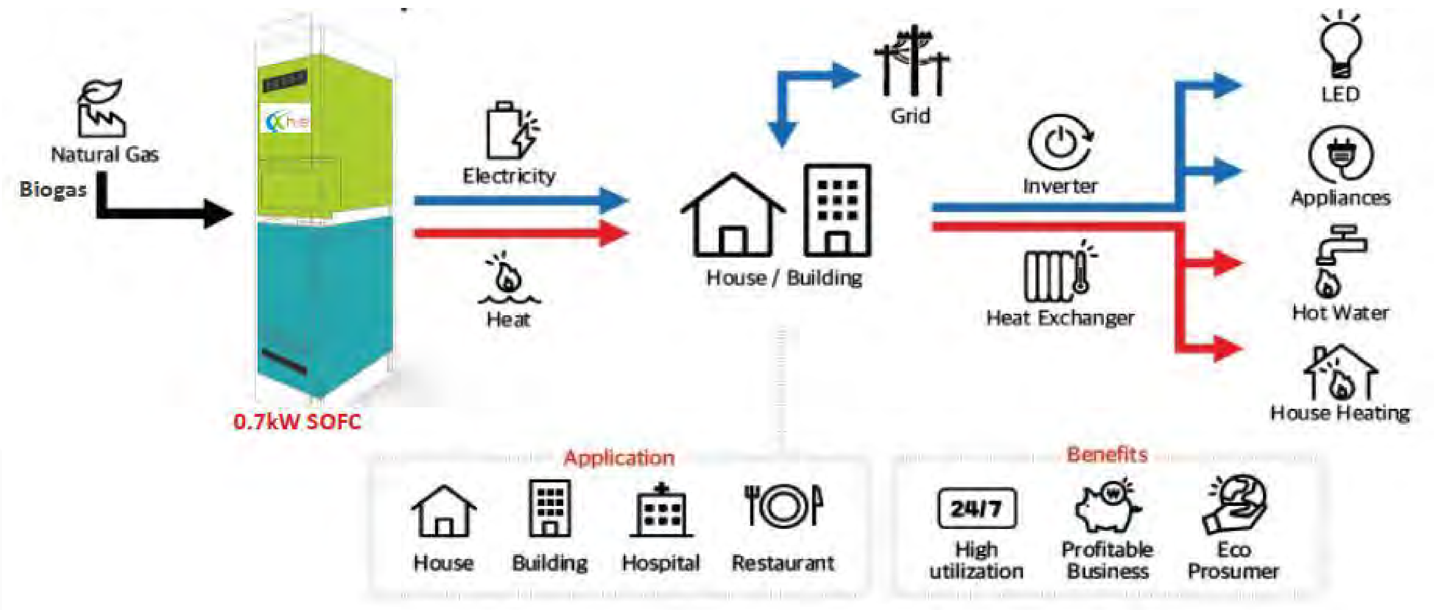
1. Since all the components are solid, as a result, there is no need for electrolyte loss maintenance and also electrode corrosion is eliminated.
2. Since SOFCs are operated at high temperature, expensive catalysts such as platinum or ruthenium are totally avoided.
3. Due to high-temperature operation, the SOFC has a better ability to tolerate the presence of impurities as a result as a result the life of the SOFC increases.
4. Costs are reduced for internal reforming of natural gas.
5. Releasing negligible pollution is also a commendable reason why SOFCs are popular.

However, SOFCs also have some disadvantages.

1. SOFCs operate high temperature, so the materials used as components are thermally challenged.
2. The relatively high cost and complex fabrication are also significant problems that need to be solved.
3. The high temperature limits applications of SOFC units and they tend to be rather large.

Figure Below[1] depicts the schematic of the fuel cell and its integration in buildings.

Figure 2: Fuel cell power generator and its varied applications



The capital cost of SOFC is expected to be ~INR1,75,000/- per kW of installation. Unlike solar PV, the fuel cell owners must bear the operational cost in the form of fuel costs. Hence the payback depends on the cost of gas and capacity utilization. Along with electricity, the thermal energy from the fuel cell power pack can be used for water heating or as a source of heat in a vapour absorption refrigeration machine. Fuel cell power packs are modular, and the solutions are easily scalable and replicable across different locations and types of buildings.

National Status

The last few years has seen considerable research activity in hydrogen fuel cells in India mainly via R&D work sponsored by the MNRE, DST, CSIR etc.

Technology providers from India

The key players operating in the Indian market includes: Thermax Limited and h2e Power.

[1] *Source: H2e Power*

Case Study

Transport for London (TfL) acquired a 20-year lease for the Palestra building in Southwark in 2006 and now occupies eleven of the building's twelve floors. The hydrogen fuel cell unit was manufactured by UTC Power, based in the USA. The unit was supplied to the site by Logan Energy Limited. The hydrogen fuel cell and associated plant cost was USD 3,083,376. Operational cost savings of the fuel cell CCHP have been estimated at USD 115,626 a year when compared against conventional grid supplied electricity and mains–fed gas fired boilers. While the capital cost of a fuel cell plant is high, the savings in fuel and maintenance can result in reduced payback periods where all the heat is utilized for water heating and cooling via absorption chillers. In the Palestra fuel cell, hydrogen is extracted from a mains natural gas supply by a steam reformer. Oxygen is sourced from an ambient air supply to the unit. The fuel cell comprises a phosphoric acid electrolyte sandwiched between two electrodes. Air and hydrogen are respectively passed over the two electrodes and energy released in a chemical reaction is converted into low–voltage DC electricity, with heat and water produced as by products. Individual cells only generate a small amount of power and so several cells are assembled into a stack to provide sufficient power for the Palestra building. Hydrogen fuel cells work continuously, providing a supply of hydrogen and oxygen fuel is maintained. The unit (Pure Cell Model 200) is capable of providing 200 kWe of electricity, in addition to 138 kWth of heat. This, in addition to heat generated by the RECHP, is used to pre–heat the building's domestic hot water supply. The RECHP is capable of supplying of 834 kWe electricity and 987 kWth of heat, giving the combined CCHP system a power capacity of 1034 kWe. the fuel cell had generated 288 MWh of electricity, 332 MWh of heat and had saved around 116 tonnes of CO2 (against an equivalent conventional power supply). The fuel cell is currently operating at approximately 36% efficiency although over time the electrical output is anticipated to reduce, and the heat output will increase. It has been estimated that the hydrogen fuel cell results in carbon dioxide emissions savings of 30% when compared to a building supplied by a conventional gas and electricity supply.

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