About MNRE

Akshay urja se desh vikas
Ghar ghar bijli, gaon gaon prakash

In 1982, the Government of India set up the DNES (Department of Non-conventional Energy Sources). This was upgraded to the MNES (Ministry of Non-conventional Energy Sources) in 1992, and is now known as the MNRE (Ministry of New and Renewable Energy). The MNRE is the nodal ministry for all matters relating to the development and promotion of new and renewable energy in the country.

About TERI

TERI, established in 1974, is a not-for-profit, non-government research organization deeply committed to every aspect of sustainable development. Over the years, TERI has been working with governments, multilateral organizations, and corporate entities in providing comprehensive support on aspects such as policy issues, project evaluation, and technology.

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Ministry of
New and Renewable Energy
Government of India

Energy Efficient

Solar Homes/Buildings

teri
The Energy and Resources Institute

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CONTENTS

Homes/ buildings that incorporate concepts of solar passive design and utilize energy-efficient equipment and devices, which run on renewable energy, are called energy-efficient solar homes/ buildings. Such homes/ buildings provide comfortable living and working conditions, both in winter and in summer, with minimal consumption of electricity. Energy efficient homes/ buildings can save over 30% to 40% of electricity used for lighting, cooling or heating.

ENERGY EFFICIENT SOLAR HOMES/BUILDINGS

Design aspects

The design of energy efficient solar homes/buildings depends on climate, solar path and intensity, humidity, wind flow, and ambient temperature of a particular place. Design parameters of homes/buildings, therefore, vary with different climatic zones of the country.

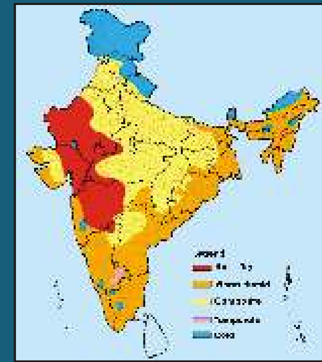
Integrated PV panels generate electricity while looking like a part of the building design

Efficient solar homes/ buildings have been constructed in a few states as initiatives of the MNRE (Ministry of New and Renewable Energy). The governments of Himachal Pradesh, Punjab, Haryana, and Nagaland have made it mandatory to construct all buildings using passive design features. The following are the three fundamental strategies that can be adopted to reduce energy consumption in homes/buildings.

- Incorporating solar passive techniques in a building design and enhancing building material specifications for minimizing the load on conventional systems (heating, cooling, ventilation, and lighting). Passive techniques vary with climate, and simple techniques that are useful for new homes/buildings in different climates of India are listed in booklet.
- Designing energy-efficient lighting and HVAC (heating, ventilating, and air conditioning) systems in homes/buildings.

Climatic zones

The country can be divided into five climatic zones. Some cities that fall in these zones are:



Zones	Cities
Hot and dry	Jodhpur and Ahmedabad
Warm and humid	Chennai and Kolkata
Moderate	Bangalore
Cold	Leh, Shillong, and Shimla
Composite	Bhopal and Delhi

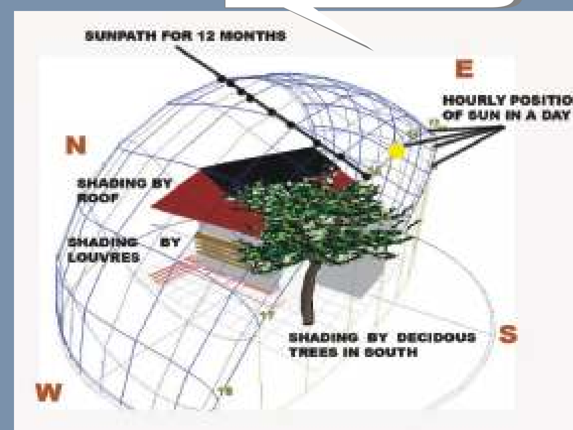
- Integrating renewable energy systems, such as solar photovoltaic systems and solar water heating systems, with buildings to meet part of their load.

PASSIVE DESIGN FEATURES AND THEIR ADVANTAGES

Orientation of building

We all know that the sun travels daily from the east to the west. Its movement from the north to the south and the south to north results in seasonal changes during the year. The orientation of a building in a particular direction, therefore, can heat or cool the building depending on the climatic zone in which it is constructed. Proper orientation can help increase or decrease the heat load by 5%. For example, if the long sides of the building in the composite climatic zone face north and south and the short sides face east and west, the heat load can be reduced.

The orientation of a building determines the total amount of energy required to heat or cool it.



Sunshades reduce the direct solar radiation entering the house.

Sunshades

These are installed at the top of windows/doors to obstruct sunrays that enter the building during summers but allow them to enter during winters. This helps protect the building from over heating during summers and keeps it warm during winters, thereby reducing electricity consumption which otherwise, would increase due to heavier use of room coolers/heaters.

Window design

Windows in a building allow light, heat, and air to come in. While day light and air are welcome in buildings in all climatic zones, heat may or may not be required, depending on the climatic zone in which the building is constructed. Therefore, decision regarding location of windows should be based on the requirement of heat in the building. The sizes of windows and their shades also depend on the climatic zone.

The sizes of windows and their shades also depend on the climatic zone.

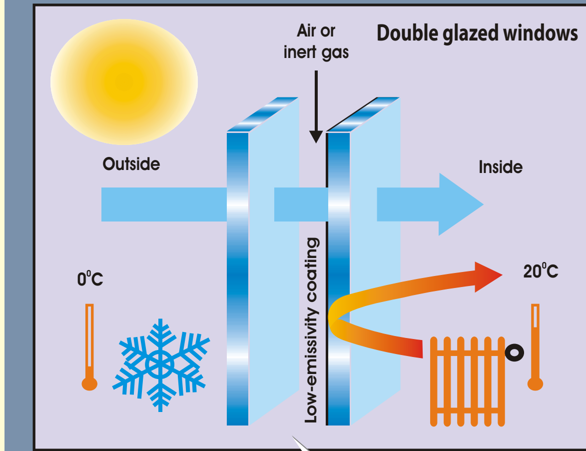
Window design

Double glazed windows

Insulation helps reduce heat gain into, and heat loss from, a building. Double glazed windows with air gaps can act as good insulation. The insulating air gap lowers the heat gain of the building. It should be used for air-conditioned spaces. BEE (Bureau of Energy Efficiency) has recommended specifications for glazing in air-conditioned spaces, in the Energy Conservation Building Code 2007 (www.bee-nic.in)

Building insulation

Insulation can be added to walls or roofs to reduce heat transfer. It also helps in moderating indoor thermal comfort and is effective in reducing temperature fluctuations in non air-conditioned spaces. Some commonly used insulation materials are mineral wool, extruded/expanded polystyrene, PUF (polyurethane foam), and vermiculite, among others. Since roofs receive maximum solar radiation, it is advisable to insulate them using any of the above materials. Cavity walls are an effective method of insulation. Fly ash-based aerated concrete blocks and cellular concrete blocks have good insulating properties and can be used for wall insulation. Suitable specifications can be provided by an architect depending on the climatic zone where the building is to be constructed.



How a double glazed window works

Construction details(L to R) for insulation, waterproofing, air-conditioning ducts, service ducts underside the shading elements, window frames and electrical box protection

Insulate the roof with materials such as rock wool, mineral wool, EPS, XPS, vermiculite, and so on.

Roof treatment

Some simple roof treatments, other than roof insulation, for reducing the summer heat gain in buildings, are as follows.

- White washing the roof before the onset of the summer.
- Spraying water on the roof. Sprinkling water at regular intervals can reduce heat gain through roof.
- Using shining and reflecting material for the rooftop.

Evaporative cooling

Water moderates harsh ambient conditions around the building

When water stored in a water body evaporates into the surrounding air, it lowers the ambient temperature. This phenomenon is known as evaporative cooling. The presence of a water body such as a pond, lake or sea near the building or even a fountain in the courtyard can provide the cooling effect. The most commonly used system is a desert cooler, which comprises water, evaporating pads, a fan, and a pump. External cooling through humidification can also be achieved by keeping surfaces of roofs moist using sprays or lawn sprinklers. Evaporative cooling is very effective in the hot and dry climatic zone, where humidity is low.

Landscaping

Trees reduce ambient air temperatures and cool the surrounding areas.

Landscaping provides a buffer against heat, sun, noise, traffic, and airflow. It is also effective in diverting airflow or exchanging heat in a solar-passive design. Deciduous trees, such as *amaltas*, *champa*, and similar varieties, provide shade in the summer and sunlight in the winter when their leaves fall. So planting such trees to the west and south-west of a building is a natural solar passive strategy. Evergreen trees provide shade and wind control round the year. They are best placed to the north and north-west of a building. Natural cooling, without air-conditioning, can also be enhanced by planting trees to channel south-easterly summer breezes in tropical climates. Hard surfaces and dark coloured pavings such as concrete pavements or cement concrete pathways around a house should be avoided because it may increase the surrounding temperature. Increased temperature would result in thermal discomfort inside the house and increase air-conditioning bills. Instead, soft surfaces such as organic paving or vegetated areas should be used.

Surface to volume ratio

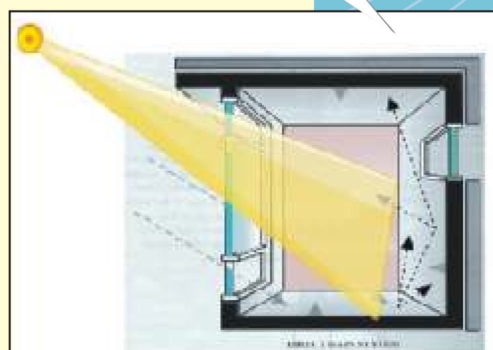
A compact building gains less heat during daytime and loses less heat at night. The compactness of the building is the ratio of its surface area to its volume, that is, Compactness = S/V (surface area/volume). In hot-dry climates the S/V ratio should be as low as possible to minimize heat gain. In warm humid climates the prime concern is creating airy spaces. This would require a higher S/V ratio.

Passive heating

In places in cold climatic zones, for example Shimla, where temperatures outside are lower than they are inside, heat flows away from buildings through their external envelopes and due to air exchange. In such climates, passive heating measures are adopted to provide thermal comfort and also to reduce the demand for conventional heating. Two methods are popular for passive heating of buildings.

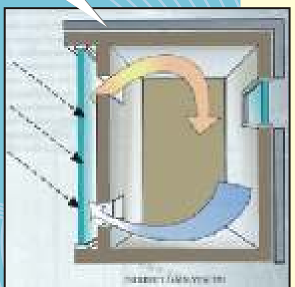
Direct gain method It is the simplest, cheapest, most common, yet effective approach for heating the interiors of a building. Sunlight is permitted into habitable spaces through an opening, which allows it to directly strike and heat the floor, walls or other internal objects. These, in turn, heat the air within the room. Double glazed windows face the south (in the northern

Direct gain method

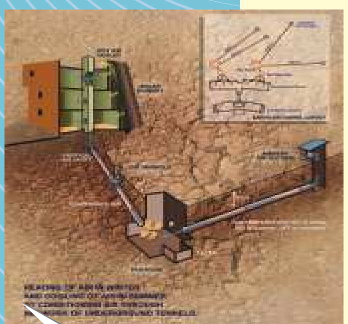


hemisphere) to receive maximum sunlight in winter. During the night, these windows act as insulating curtains and prevent heat loss. In addition, during the day, when areas of the building exposed directly to sunlight tend to over-heat, high thermal mass absorbs and stores heat in bare massive walls or floors and arrests the increase in room temperature. Heat stored in the mass is then released into the interior during the night, when the temperature falls, keeping the room suitably warm. Some examples of thermal storage materials are concrete, bricks, stone, and water, which are usually located in internal or external walls, floors and other built-in structures that receive sunlight directly.

Indirect gain method



Indirect gain method In this strategy, a thermal storage wall is placed between the glazing and habitable space. This prevents solar radiation from directly entering the living space. It is absorbed, stored, and then, indirectly transferred to the habitable space. A trombe wall is a thick solid wall with vents at its lower and upper ends. It is usually painted black or a dark colour to increase its heat absorption capacity. This wall is placed directly behind the glazing with an air gap in between. The vents act as inlets of warm air into the room and as outlets for flushing out cool air from the room. The air in the space between the glazing gets heated and enters the habitable room through the upper vents.



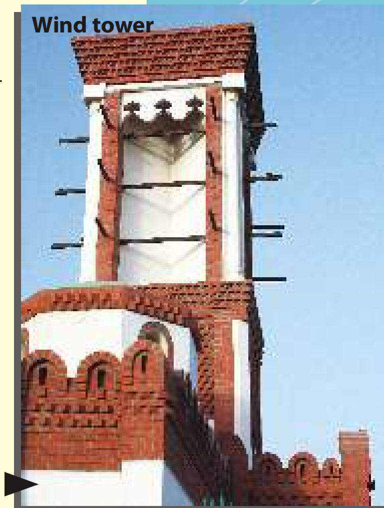
Earth air tunnel systems can be used for passive space conditioning

Earth air tunnel

At a depth of 4 m below ground, the earth's temperature remains more or less constant throughout the year. This temperature is nearly equal to average temperature of the place. For example in Delhi, the temperature in summer may go up to 45 °C during summer and fall to 4 °C during winter, but at a depth of 4 m below ground the temperature remains nearly 26 °C round the year, which is average temperature of Delhi. The earth air tunnel takes advantage of this phenomenon. Concrete hume pipes are laid at a depth of 4 m below ground and are surrounded by earth. The earth acts as a heat exchanger for air that is passed through this tunnel. Hot summer air is passed through this buried pipe, and as it

Solar chimney

For effective ventilation, specially during humid weather



Wind tower

To catch favourable cool wind from the south-west for passive cooling

passes through, there is an exchange of heat between the air and the surrounding earth. Hence, during the summer, the air gets cooled and during winter it gets heated. It works in a similar manner during the winter, absorbing earth's heat and releasing it into the structure. Tunnel air can be supplied to a house for cooling during summers and heating during winters.

Solar chimney

Solar chimneys are tall, hollow structures that are preferably located on the south/south-west portion of a building. These chimneys can help ventilate rooms and are ideal for hot climatic zones. They should, preferably, be dark in colour with lightweight construction (for instance, ferrocement). Spaces within a building have vents opening into this chimney. The chimney heats up during summer days and the air inside the chimney rises creating a low-pressure zone. The air from the rooms of the house then replaces the escaping chimney air creating a low-pressure zone inside your home. This makes way for outside air to enter the home naturally and cool it.

Wind tower

Wind towers are specifically designed to use prevailing wind to draw air out of a space and, sometimes, to push air into the space. This helps circulate cool air in the building. When hot ambient air enters the tower through openings in it, it cools, becomes heavier and sinks. Inlets and outlets in rooms induce cool air movement. In the presence of wind, air is cooled more effectively and flows faster down the tower and into the living area. After a whole day of air exchanges, the tower becomes warm in the evening. During the night, cooler ambient air comes in contact with the bottom of the tower through the rooms. The tower walls absorb heat during the daytime and release it at night, warming the cool night air in the tower. Warm air moves up creating an upward draft and draws cool night air through the doors and windows into the building. The system works effectively in hot and dry types of climate where diurnal variations are high.

APPLICABLE PASSIVE FEATURES FOR VARIOUS CLIMATIC ZONES

As mentioned earlier, buildings in different climatic zones require different passive features to make structures energy-efficient. Some features that can be adopted in particular zones are listed below.

Hot and dry

- Appropriate orientation and shape of building
- Insulation of building envelope
- Massive structure
- Air locks, lobbies, balconies, and verandahs
- Weather stripping and scheduling air changes
- External surfaces protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Courtyards, wind towers, and arrangement of openings
- Trees, ponds, and evaporative cooling

Warm and humid

- Appropriate orientation and shape of building
- Roof insulation and wall insulation
- Reflective surface of roof
- Balconies and verandahs
- Walls glass surface protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Ventilated roof construction, courtyards, wind towers, and arrangement of openings
- Dehumidifiers and desiccant cooling

Moderate

- Appropriate orientation and shape of building
- Roof insulation and east and west wall insulation
- Walls facing east and west, glass surface protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Courtyards and arrangement of openings

Cold

- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation, wall insulation, and double glazing
- Thicker walls
- Air locks and lobbies
- Weather stripping
- Darker colours
- Sun spaces, greenhouses and trombe walls

Composite

- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation and wall insulation
- Thicker walls
- Air locks and balconies
- Weather stripping
- Walls, glass surfaces protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Exhausts
- Courtyards, wind towers, and arrangement of openings
- Trees and ponds for evaporative cooling
- Dehumidifiers and desiccant cooling

ENERGY-EFFICIENT LIGHTING

Lighting in a home is generally responsible for 20% of the electricity bill.

Efficient lighting reduces energy consumption, thereby, saving energy and money, without compromising on the quality of light. Lighting improvements are the surest way of cutting energy bills. Using new lighting technologies can reduce energy use in the house by 50% to 75%. Lighting controls offer further energy savings by reducing the amount of time that lights are on without being used.

Indoor lighting

Use fluorescent tubelights and energy-efficient CFLs (compact fluorescent lights) in fixtures at home for high-quality and high-efficiency lighting. Fluorescent lamps are much more efficient than incandescent (standard) bulbs and last up to six times longer. Although fluorescent and compact fluorescent lamps cost a bit more than incandescent bulbs, they pay for themselves by saving energy over their lifetime.

A 15 W CFL can replace a 60 W incandescent bulb and a 20 W CFL can replace 100 W bulb. The average cost of a CFL is Rs 100, and the excess investment is easily paid back in a year's time. A 36 W triphosphor tubelight, provides 32% more light than an ordinary tubelight and can be used in larger spaces. T5 tubelights are good replacements for ordinary tubelights. They save about 40% energy and last twice as long as ordinary tubelights. The cost of a T5 tubelight varies between Rs 450 and Rs 500.

Outdoor lighting

Many homeowners use outdoor lighting for decoration or security. Consider PV-powered lights for areas that are not close to an existing power supply line. Solar outdoor lights also come as stand-alone fixtures. An 11 W CFL, with a 74 W photovoltaic module and a 12 V/75 AH battery, costs Rs 22 000–24 000. When fully charged, the battery can power a light from dusk to dawn.

Outdoor lights can be powered by small PV (photovoltaic) modules that convert sunlight directly into electricity.

ENERGY-EFFICIENT AIR CONDITIONERS

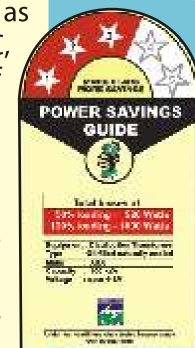
ACs (air conditioners) are used to cool or heat a room and usually consume the highest energy among all home appliances. Window ACs and split ACs are most commonly used. These are available in different sizes—0.75 tonne, 1 tonne, 1.5 tonne, and 2 tonne. Insulation of the walls, roof, and efficient windows in the room would allow you to pick an AC with lesser tonnage.

Selecting the right size

The energy consumption of an AC depends on the size of the AC. Therefore, select an AC that suits your requirements. A 1-tonne AC is appropriate for a 150 sq ft room, while 2-tonne AC is sufficient for a room, which is 300 sq ft in area.

Selecting an efficient AC

The efficiency of an AC affects energy consumption as much as the size of the AC does. Select an efficient AC, preferably one that has a BEE Star label. The number of stars on the BEE label indicates the efficiency of an AC; the higher the number of stars the more efficient the appliance. For instance, a BEE 4-star rated 1.5-tonne AC would consume 194 units of electricity in a month compared to an inefficient AC of the same size that would consume 278 units during the same period. An efficient 1.5-tonne AC would cost about Rs 16 500, whereas an ordinary AC would cost about Rs 15 000. The additional Rs 1500 invested on the efficient AC will be recovered in less than six months due to savings in the electricity bill. In case of the non-availability of the BEE star label, check the EER (energy efficiency ratio) mentioned on the AC. An EER of 8 is equivalent to a 1-star BEE label and an EER of 10.6 and above is equivalent to 5-star BEE label.



Installing an AC

While installing an AC, ensure that the exterior (or back) of the AC is not exposed to direct sunlight and is away from heat sources such as chimneys. Efficient airflow across the exterior would ensure efficient operation of the AC. Seal doors and windows properly to make sure that air does not escape through them. This would help in reducing energy consumption.

RENEWABLE ENERGY DEVICES/SYSTEMS

Solar water heating system

A solar water heater is a device that uses heat energy of the sun to provide hot water for various applications. In homes, it is useful for bathing, washing, cleaning, and

Flat plate collectors-based solar water heater

other chores. A domestic solar water heater, with a capacity of 100 lpd (litres per day), is sufficient for a family of four or five members. It can easily replace a 2-kW electric geyser and can save up to 1500 units of electricity a year. It pays back the cost in three to five years depending on the electricity tariff and hot water use in a year. After this, hot water is available almost free of cost during remaining lifespan of the system, which is about 15-20 years.

The system is generally installed on the terrace and requires minimum maintenance. It works automatically and one does not have to operate any part of the system. Typically, a surface area of 3 sq m is required to install it. The system can also be installed on a south-facing windowsill if space is not available on the terrace.

Two types of systems are being promoted—one based on FPC (flat plat collectors) and the other on ETC (evacuated tube collectors). The life of FPC-based systems is generally 15–20 years, and they are costlier than ETC-based systems. There are 57 BIS (Bureau of Indian Standards)-approved manufacturers of these systems, and they have had a stable market in the country for the last many years.

Evacuated tube collectors-based solar water heater

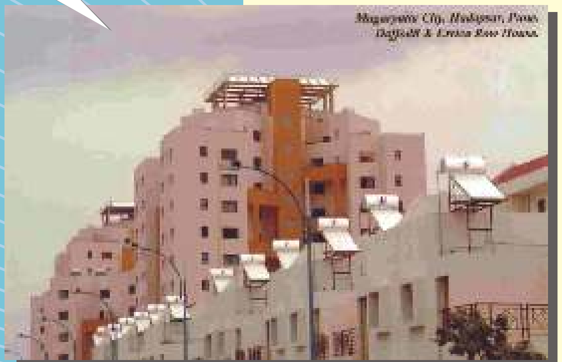
ETC-based systems are relatively new and could be more reliable for colder regions and regions that have hard water. The life of these systems is, however, less since their collectors comprise glass tubes, which are fragile. There are 29 suppliers of these systems approved by the MNRE. The list of manufacturers and suppliers is available at the Ministry's website (www.mnre.gov.in).

The cost of solar water heaters, with a capacity of 100 lpd varies between Rs 18 000 and Rs 25 000. To offset the initial high price, loans at 2% are offered to users through banks/financial institutions. The list of such banks/ financial institutions is available on the Ministry's website. In addition, some state governments also provide state subsidy. For example, Delhi Transco Ltd offers Rs 6000 as rebate on installation of the system. A few governments also provide rebate in property tax and in electricity tariff if a solar water heater has been installed at home. Details are available on the Ministry's website.

The installation of a solar water heating system in a home/building needs to be planned at the time of its construction. The following points may be kept in mind while planning for the same.

i) A 3-4 sq m (per 100 lpd system) shadow-free area should be available on the terrace for installation.

Systems integrated with buildings in Magarpatta City



ii) Provision for concealed PER pipes, with required insulation for installation of the system, should be made at the design and construction stage of homes/ buildings.

A number of builders and developers have already started constructing houses and apartment blocks, which are fitted with solar water heating systems. An example is Magarpatta City, where a large number of such housing and office complexes have come up on the outskirts of Pune.

Building integrated PV system

A PV system can be incorporated in a building as part of the building's structure. In new buildings, PV systems can be built-in at the design and construction stage. They can be retrofitted on existing buildings as well. Photovoltaics can be integrated in every possible structure—from bus shelters to high-rise buildings. They can also be used as landscaping elements.

A BiPV system

Incorporating PV in a building results in the following value additions.

- Generating electricity at the point of demand without any extra use of land area
- Reducing the cooling load of the building, as it also acts like a shading element
- Replacing building construction material, such as glazing elements, depending on the building design

In building integrated PV systems, PV modules are used as part of the building envelope. PV systems can be incorporated in a building in three basic ways.

- *Façade-integrated photovoltaic systems* Curtain walls, semitransparent PV windows, PV awnings, and so on
- *Roof-integrated photovoltaic systems* Atrium roofs, flat and tilted roofs, skylights, tiles, and slates among other materials
- *Shadow-Voltaic* PV systems that can be used as shadowing systems

Other renewable energy devices/systems

There are various other renewable energy devices/ systems, such as solar cookers, solar lanterns, solar home systems, and solar inverters, which can be used for saving conventional energy *after* the home/building is constructed. Details of these devices are available on MNRE website (www.mnre.gov.in).

ANNEXURE

List of architects/experts/institutes/organizations with experience in designing energy-efficient homes/buildings

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Auroshilpam, Auroville – 605 101

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K-38, Jungpura Extension, New Delhi – 110 014

Vidur Bhardwaj, Consultant Architect, Design & Development Architects, Engineers & Interior Designers
C 58 Defence Colony, New Delhi – 110 024
E-mail: vidurb@vsnl.com / rakheja@hotmail.com

Vineeta Badawe, Director, V V Architects Pvt. Ltd
6 Kilpauk Garden Road, 1st Street , Kilpauk
Chennai – 600 010
E-mail: vva@badawegroup.com

Institutes/Organizations

Gherzi Eastern Ltd
16, Mahanirban Road, Kolkata – 700 029

Ghosh Bose and Associates Pvt. Ltd
8, Harrington Mansion, 8, Ho Chi Minh Sarani
Kolkata – 700 071

HUDCO
India Habitat Centre, Lodhi Road
New Delhi – 110 003

Himachal Pradesh State Council for Science Technology and Environment,
B-34, SDA Complex, Kasumpti
Shimla – 171 009

Solar Energy Centre
Ministry of New and Renewable Energy, Gual Pahari
Gurgaon District, Haryana

TERI
Darbari Seth Block, IHC Complex, Lodhi Road
New Delhi – 110 003

List of State Nodal Agencies for new and renewable energy

Available on the MNRE website: www.mnre.gov.in

List of manufacturers of solar energy systems

Available on the MNRE website: www.mnre.gov.in