

# “Energy independence in buildings”: Why and how?

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## Summary

This paper reviews the paper the energy consumption in building materials and construction practices and suggests guidelines for ‘energy independence’ in buildings. Application of low energy based building materials and construction practices; selection of lower-energy structural systems, utilizing of alternate / renewable energy resources; implementation of energy conservation and energy efficiency promoting technologies; energy audit and monitoring are some of the measures towards energy independence achievement. Mandatory regulation and credit system application in buildings will further support the task of energy saving of buildings. Studies indicate that 40-50% energy saving in buildings can be achieved, although it is reported that Zero net energy buildings are technically feasible.

## 1. Introduction

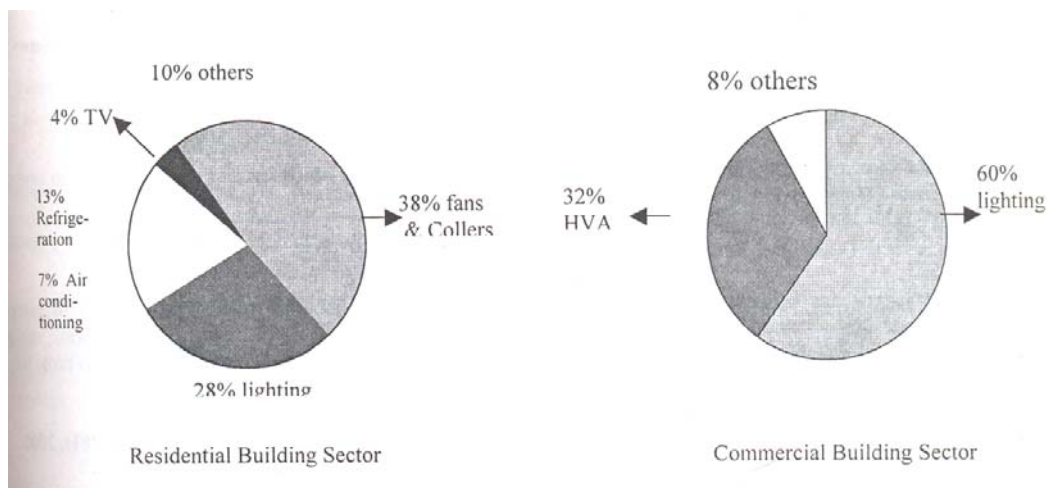
India’s commitment to Kyoto Protocol and an unprecedented growth in energy demand made to go for initiatives towards energy conservation and protect environment. The implementation of Clean Development Mechanism, Green House construction, Energy Management System and formulation of energy related codes and regulatory authorities are some of the bold steps taken in the recent past by Government of India and are applicable to all energy intensive industries.

Construction industry is not an exemption. Building construction and its facility management consumes massive energy and impacts on natural resources. While residential, commercial, and institutional buildings together consumed 31% of global energy and emitted 1900 mega tones of carbon in 1990, it is estimated that by 2050, this share would rise to 38% and 3800 mega tones, respectively. By incorporating energy efficiency measures resulting in returns in five years or less, emissions can be reduced by nearly 400% and energy saving by 40 to 50% by 2050 (1). The challenge is to conserve energy in buildings by implementation of energy management system and generation of energy on demand by alternate energy renewable resources. This leads to “Energy Independence” in a building.

This paper reviews energy consumption in a building and suggests measures towards achieving “Energy Independence” in buildings.

## 2. Energy Consumption Buildings

Building construction and its facilities maintenance services consumes a significant energy depending upon its geographic location, design, type of construction and materials used and other facilities provided. This is primarily because of energy-intensive solutions are not sought while constructing a building and meeting its demands for cooling, ventilation, and lighting and at times for heating in earlier days. Estimates suggest that about 20-25 percent of the total energy demand is due to manufacturing materials required in the building sector, while another 15 percent goes into the running needs of the building (1). The commonly used building materials like cement, manufactured sand, steel, clay bricks, tiles, glass etc are high energy embodied materials and are from non-renewable resources. This accounts for a high proportion of the total embodied energy in buildings. Besides, in major constructions like bridges, fly-overs, dams, multistoried complexes, malls etc. an additional electrical and mechanical energy costs are added and it accounts for about 15-20 percent additional energy consumption. (2). Once building is constructed, it is the operating energy that comes into play on a recurring basis. The energy operating costs increase on the various facilities provided and period of use of these facilities. They are recurring costs, which are found to increase with time. The distribution of annual electrical consumption in urban residential and commercial building sectors is presented in Fig. 1(3). The total specific consumption for conditioned residential (urban) buildings in India range from 280 kWh/m<sup>2</sup> to about 500kWh/m<sup>2</sup> (3). Energy audit studies indicate that about 20 to 25% of energy wastage is noticed in Government buildings (1) and can drastically be reduced by retrofitting of old buildings with modern less energy consuming materials / appliances.



**Fig.1 Annual Electricity consumption In Indian buildings**

In India, because of its vast differences – in residential habits of rural and urban, climatic zones, income groups requirements, construction practices, availability of variety of building materials etc. have led to different housing patterns, which influence energy consumption considerably. Particularly urban housing and commercial complexes consume very high energy due to provision of comforts such as air-conditioners, lifts / escalators, pumping etc. As several energy efficient systems like sensors, intelligent materials etc. are now available; there is a tremendous scope for energy conservation technologies to adopt. The Government of India has introduced the necessary standards, organizations to provide guidelines, technical and financial assistance for effective implementation of energy conservation in buildings.

### 3. The International Scenario

Many developed countries introduced Energy Conservation Policies more than a few decades ago and gained stringent benefits in saving energy and improvements in energy efficiency.

USA	:	Energy Policy and Conservation Law 1975
UK	:	Energy Policy Act, 1991
France	:	Clean Air & Rational use of Energy Act, 1976
Japan	:	Law concerning Rational use of Energy, 1979
South Korea	:	Rational Energy Utilization Act, 1979
Indonesia	:	Presidential Decrees, 1982

Energy conservation in building codes of the West, largely address heating and cooling loads because of their climatic conditions, though those are not key issues in most parts of India.

### 4. National Scenario

Energy Conservation Building Codes in India is of recent development. Considering the vast potential of energy improvement, the Government of India enacted the following Acts:

#### 4.1 Energy Conservation Act, 2001

The Act provides for the legal framework, constitutional arrangement and a regulatory mechanism at the Central and State level to embark upon energy efficiency drive in the country. There are short term and long term measures, which enforce implementation of energy policies in phased manner.

#### 4.2 Bureau of Energy Efficiency, 2002

Bureau of Energy Efficiency (BEE) operates complete pilot phase of programmes for energy efficiency in government buildings and prepare action plan for wider dissemination and implementation.

#### 4.3 Energy Saving Companies (ESCO)

They undertake energy efficiency projects through third party financing which enables the consumers to save on energy cost to a maximum extent.

#### **4.4 National Building Code (Revised) 2005**

Several changes are brought out in the recently revised National Building Code with respect to energy conservation. Classification of climatic zones, more details on lighting and ventilation, density norms, use of solar energy, extending energy conservation measures to commercial buildings etc are the provisions provided.

#### **4.5 Model Building Bylaws, 2002**

#### **4.6 Urban Development Plan Formulation and Implementation Guidelines (UDPFI), 2002**

These documents do not contain any specific guidelines for energy conservation. However certain basic provisions indirectly account to saving of energy by requiring some of the compliances.

### **5. Energy independence in buildings**

Efforts are being made to build houses / structures which are energy independent i.e. to generate all of the energy they require through a combination of energy efficiency and renewable energy generation technologies. Energy Independence in buildings can be achieved through a two-pronged approach.

1. By implementing energy conservation and energy management system, energy load in a building is reduced.
2. The established lower energy demand can be made available with the alternate sources of energy such as solar and other renewable technologies.

Such studies were carried out in Japan (4), Florida, USA (5) which indicated that Zero Net Energy buildings are technically feasible with no energy demand from the utility grid. An attempt is made to review the various possibilities to conserve energy (both embodied and electrical) in a building and how to achieve its 'energy independence'

### **6. Energy conservation in buildings**

For the purpose of discussion on energy conservation in building, it is considered 'Building' means any structure or erection or part of a structure or erection, which is having a connected load of 500 kW or contract demand of 600 KVA and above and is intended to be used for commercial purposes' (as per Energy Conservation Act, 2001). The E C Act does not cover thus residential buildings or any other buildings, which cannot be said to be used for 'commercial' purpose. However the author feel that EC Act should be made applicable to residential complexes also, particularly apartment complexes and housing estates in metro cities if energy consumption is 500 kW or more.

The efforts to conserve energy in buildings need a multi-disciplinary holistic approach. The available options in architectural design, building materials and construction methodologies, utilities requirements and waste management system need to be carefully evaluated to minimize energy usage, minimize the ecological degradation, and to achieve the desired comforts with the least recurring cost of conventional energy. Following "Green Building Concepts" and "Energy Management System" energy consumption in new constructions can significantly be reduced. However, the strategy is different in case of old buildings wherein "Energy Audit" to be carried out to identify areas of modification / retrofitting, replacement of high energy consuming appliances, controlling energy losses etc.

### **7. New concepts for energy conservation**

The unprecedented growth in energy consumption and wide gap between demand and supply focuses to adopt new strategies to reduce energy consumption and depend on other renewable energy sources. They are:

#### **7.1 Green Building Concept**

Green building could take care to use energy efficient materials and construction practices, eco-friendly architectural principles, natural light and ventilation and waste management system, which has direct influence on energy saving and reduction in green house impact.

## 7.2 Renewable Energy Technologies

Renewable energy systems meet partially or fully energy load of a building, thus considerably reducing the overall electrical and thermal loads. Solar energy could be utilized for a variety of purposes like generating electricity, providing hot water, heating and lighting buildings.

## 7.3 Energy Efficient Buildings

Energy efficient building design is essentially an integrated approach of using energy efficient materials and appliances, renewable energy resources, and systems approach of energy management and energy audit.

## 7.4 Zero Net Energy Buildings

These buildings are self-sufficient in their energy consumption. They are designed and constructed to generate all of the energy they require through combination of energy saving and renewable energy technologies.

## 7.5 Smart Materials and Sensors

Various facilities in buildings could be integrated through microprocessor based "Building Management System" for effective energy saving with minimum human interface. Smart materials and sensors predict and control wastage and excess usage of energy.

## 7.6 Building aesthetics

Architects and designers should have interaction with building facility consultants to design energy efficient building by considering all the aspects related to energy saving measures and standards. In many cases structures are designed with respect to functional requirements and elevation giving least importance to energy efficiency facility. This results in energy inefficient buildings and any modification / retrofitting leads to enormous expenditure.

## 7.7 Use of low energy embodied materials

Most of the old constructions involve high-energy embodied materials such as steel, glass, Ordinary Portland Cement (OPC), Clay bricks etc. **Table-1** (6,7) shows energy requirements of different building materials. Use of low energy embodied building materials such as blended cements, masonry cements, by-product based (fly-ash) bricks/blocks, light weight blocks/panels, wood substitute products etc, consume less energy **Table-2** (8). In case, high-energy materials to be used, care should be taken to use less quantities without sacrificing the quality and performance. The choice of materials for window frames and doors is now quite wide. Traditionally all windows and doors were made of timber, the only suitable eco-material available. Other alternative materials Are steel, aluminum and polyvinyl chloride (PVC).

**Table 1 Comparative Energy Requirements of Building Material**

Material	Primary energy requirement of Building Materials (MJ/kg)
<b>High energy:</b>	
Aluminium	130-270
Polystrene	100-140
Copper	100
Stainless steel	100
Galvanised steel	60
PVC	50-90
Zinc	35-70
Steel	20-60
Lead	25
Mineral wool	16-20
Glass	12-25
Plaster boards	8-10
Cement	5-10

<b>Medium energy:</b> Lime Clay bricks and tiles Concrete In Situ Blocks Precast Sand-lime brick Timber (sawn)	3-5 2-7 0.8-1.5 0.8-3.5 1.5-0.8 0.8-1.2 0.1-5
<b>Low energy:</b> Sand, aggregate Fly ash, volcanic ash Soil	<0.5 <0.5 <0.5

**Table-2 Energy Savings in the Manufacture of Building Materials through Use of Industrial Wastes**

Building Material	Composition	Material compared	Energy savings(%)
Portland Pozzolana Cement	75% Ordinary Portland Cement	100% Ordinary Portland cement	20
Portland blast furnace slag cement	60% Ordinary Portland cement 40% Blast furnace slag	100% Ordinary Portland Cement	30
Masonry Cement	50% Ordinary Portland Cement 50% Tailings / waste chalk	100% Masonry cement (50% Ordinary Portland cement+50% limestone)	20
Lime-pozzolana Mixture	25% Acetylene gas lime 75% Fly ash	25% Lime 75% Calcined brick	75
Calcium silicate brick	90% Fly ash tallings 10% lime (waste source)	Burnt clay brick	40
Burnt brick	75% clay 25% Fly ash	Brunt clay brick	15

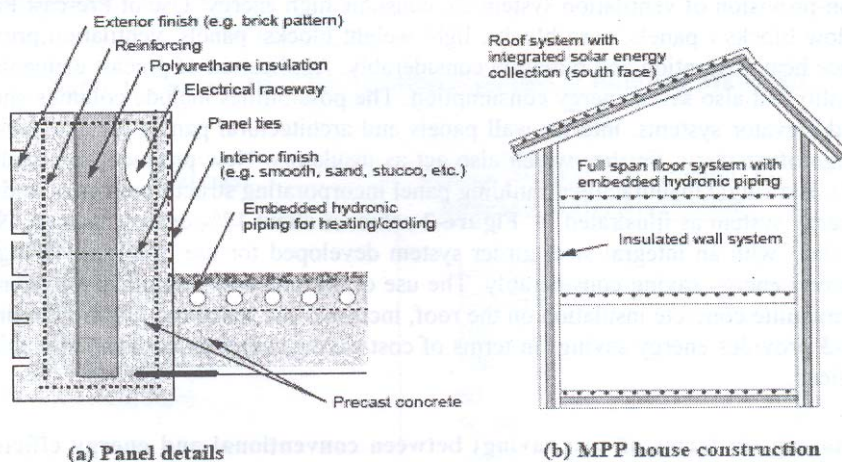
### 7.8 Construction practices

Present Constructional practices like use of solid brick walls, low concert roof, enormous quantity of reinforcement, non-provision of ventilation system etc consume high energy. Use of Pre-cast Panels, the Girder-Slab System, hollow blocks / panels, aero blocks, light weight blocks/ panels, ventilation provision, protective coatings etc. reduce heat absorption and radiation considerably. Application of precast elements in buildings not only improves quality but also saves energy consumption. The possibilities include columns and beams, balcony supports, stair and elevator systems, interior wall panels and architectural panels for exteriors. Exterior panels can provide a range of aesthetic finishes which also act as insulators. New products like Multi-functional Pre-cast Panels (MPP), is a single manufactured building panel incorporating structure, interior and exterior finishes, insulation, and energy system as illustrated in **Figure-2** achieves about 17% energy savings (9). Similarly, precast hollow-core slabs with an integral steel girder system developed for use in middle to high-rise residential construction improves energy saving considerably. The use of 40 mm thick expanded polystyrene insulation on the walls, and vermiculite concrete insulation on the roof, increases the space for air-conditioning loads by about 15 % (7). **Table-3** provides energy saving (in terms of cost saving) between conventional an energy efficient construction practices.

**Table-3 energy saving (in terms of cost saving) between conventional and energy efficient construction practices.**

SI NO	Conventional practice	EE technology	% saving
1	<b>Foundations</b> Stone/bricks Footings	Bricks arch Pile foundations	15 25
2	<b>Walling</b> 230 mm brick walls 230 mm brick walls Burnt clay walls Clay brick walls Clay brick walls Solid masonry	180 mm brick walls 115 mm brick walls Stabilized soil blocks Flyash bricks FaL-G bricks Hollow blocks Aeriated insulated panels	13 20 20 25 20 20 20
3	<b>Roofing</b> 110 mm RCC Tiles over timber rafters RCC RCC RCC RCC RCC RCC RCC RCC	85 mm thick sloping RCC Tiles over RCC rafters Brick panel with joists Ferrocement shell roofing Filler slab roofing Waffle roofing Jack arch brick roofing Brick funicular shell roofing Precast blocks over inverted T beams	30 25 20-25 40 22 15 15 30 25
4	<b>Other Items</b> Timber door frames Timber doors  Cast sunshades Timber/RCC shelves	RCC door frames Ferrocement doors PVC doors Cement particle boards Precast sunshades Precast panels	30 30 25 15 35 20-30

**Fig.2 Multi-functional pre-cast panels**



**Figure 1: Multi-functional precast panels for residential construction**

## 7.9 Design and Orientation

Building orientation plays significant role in energy saving. Sun and wind are two crucial climatic elements while deciding orientation of a building. It has to ensure minimum solar radiation in summer and maximum in winter. Similarly wind direction is also to be taken care by orienting the windows. In many cases, irrespective of functional requirement, windows of bigger size are provided for beautification, which allows unwanted heat gains or losses. However, when properly selected and installed windows can minimize cooling, lighting and heating charges. Use of energy efficient glazing system in buildings is not of practice till recently. A significant reduction in specific energy demand is possible by installing multiple glazed windows **Table-4**(3). Thus window sizes and the glazing are the very crucial elements and can be decided as functional requirement of the area under consideration and thermo-visual comfort requirements.

**Table – 4**

### Energy saving potential of multiple glazed windows over single glazing (24 hours usage)

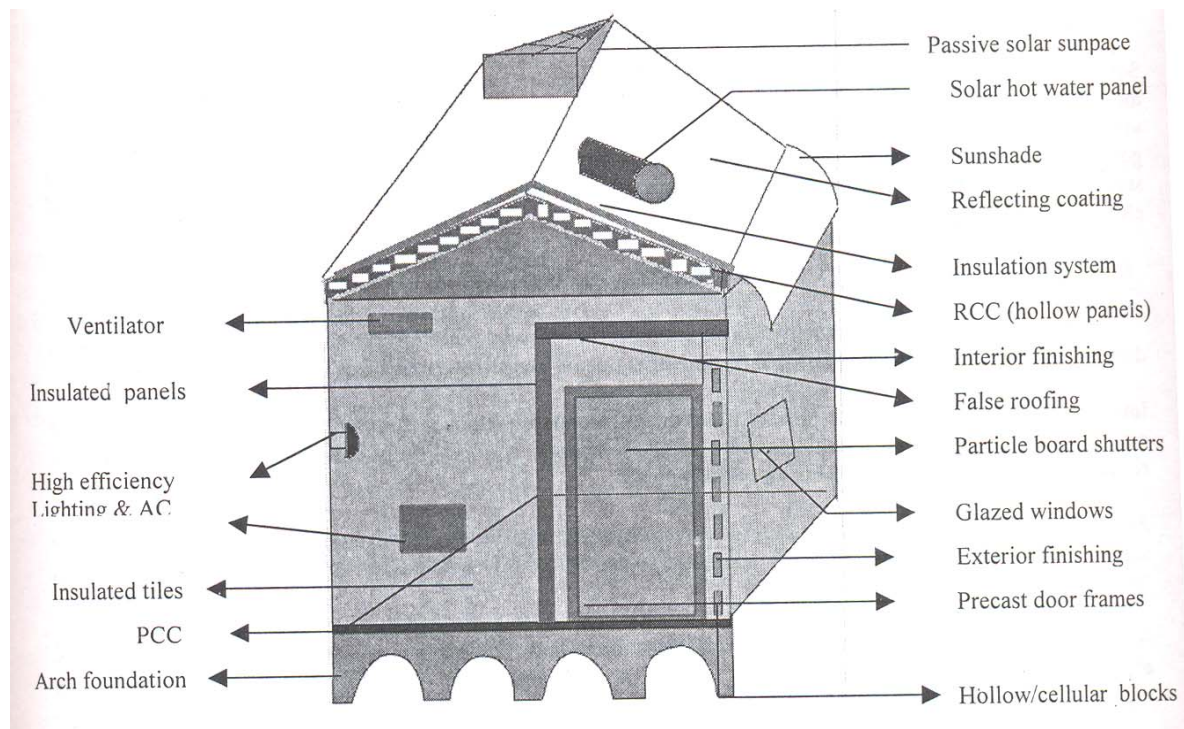
Window Type	Percentage Area +	Specific Energy Demand kWh/m <sup>2</sup> /a (includes lighting) (Percentage saving as compared to the single glazing)				
		Warm & Humid	Composite	Moderate	Cold & Cloudy	Cold & Sunny
Double Glazed	10%	350(7.8)	299(11.7)	139(6.1)	145(3.9)	472(9.6)
	20%	385(7.8)	334(11.1)	145(11)	150(4.4)	514(10.9)
Double Low-E with Argon	10%	336(11.5)	296(15.6)	134(9.4)	142(5.9)	428(19.2)
	20%	369(11.7)	323(14.1)	137(15.9)	147(6.3)	446(25.6)
Triple Glazed Energy Efficient Windows	10%	322(15.3)	268(20.9)	124(16.2)	140(7.8)	401(24.3)
	20%	354(15.3)	307(18.3)	129(20.9)	145(7.6)	431(28.1)

+The percentage area is window area (percent of floor area)

## 7.10 Building Envelope

The building envelope is a critical component of any facility since it protects the building occupants and regulates the indoor environment. It includes roof, walls, windows, and doors and controls the flow of energy between the interior and exterior of the building. An optimal design of the building envelope may provide significant reductions in heating and cooling loads-which in turn can allow downsizing of mechanical equipment. Building elements such as walls, roofs, partitions, false ceilings, open balconies, roof shadings etc and their orientation play crucial role in heat radiation. Roofs and walls receive maximum solar radiation. Insulation and other provisions reduce heat transmission. Roof may be covered with glazed / insulated tiles or apply heat reflective coatings. Shading of walls and windows, roof overhangs, protective coatings etc can be applied to reduce heat flow into the building. Use of hollow blocks in walls, hollow slab panels in buildings reduces inside temperature 3 to 5°C. A typical energy efficient building envelope is presented in **Fig. 3**.

**FIG.3 Typical energy buildings envelope**



Ventilation is necessitated for inducing air motion in the normal occupancy zones and for removal of unwanted heat from the building. Natural ventilation of buildings using ambient air movement is an economic option for enhancing room air circulation and reducing mechanical forcing costs.

### 7.11 Building Services

The major consumption of energy in buildings is from different facilities provided and their operating cost. In common, building services include heating, ventilation and air-conditioning (HV AC system), lighting system, water and gas supply, fire alarm and detection system and security system. The trend percentage of electrical loads of various utilities in multistoried buildings is HV AC (60%), lighting (23%), lifts (6%) and others (11%) (6). By following energy management system in which energy audit and energy efficient measures are a part, the energy consumption can be optimized wisely.

To minimize energy consumption in HV AC system, thermostats, load cycling controllers, higher efficiency and high power factor motors, intelligent sensors etc can be provided. Case studies indicate that opting for air-conditioning in most of the residential buildings which are not designed for consumes 15-25% extra energy(3). The type of Air Conditioner to be selected depends on space, air conditioner capacity, Energy Efficiency Ratio, design conditions etc. Room air conditioner with Energy Efficiency Ratio (EER) of at least 9.0 and more than 10 is to be selected for mild and hot climates respectively. Similarly single-package and split systems require a Seasonal Energy Efficiency Ratio (SEER) of 9.7 and 10 respectively as per National Minimum Standards (10).

Provision to make use of natural light to a maximum extent is the first step towards energy saving. Selection of more efficient lighting system and correct selection of light fixture and accessories shall save consumption in internal illumination. Compact Fluorescent Lamps (CFL) will produce a saving up to 60% (11). Selection of light fixture creates desired light effect and ensures proper light distribution. Use of high frequency ballasts can improve performance of lamps. Installation of sensors such as ambient lighting based control, Passive Infra-red factor for elevators / lifts, and water pumps with a scheduled maintenance certainly optimize energy consumption. Elevators have independent microprocessor based control for efficient operation.

### 7.12 Non-conventional source of energy for buildings

Solar energy is a most suited renewable and alternate power source for buildings to provide heat, lighting mechanical power and electricity. Solar photovoltaic power system installation although costly at present, is viable on life cycle-cost point of view. In Maharashtra, it is made mandatory that all commercial buildings must go in for solar energy for water heating. The use of solar water heater can

be preferred from the fact that a standard 100 liter capacity system as an alternative to electric geyser (for residential use) can save 1500 units of electricity annually (12).

## 8.0 Strategies for energy saving in buildings

Public awareness on energy conservation techniques in buildings, guidelines for energy efficiency, database on availability of energy efficient appliances, incentives etc. must be taken up on top priority.

Interaction between consumers, builders, designers, architects, engineers, facility manager and equipment, manufactures should be established to have effective energy conservation in buildings. Necessary mandatory regulations have to be introduced in respective states.

As the energy efficient items are generally more expensive than less efficient items, it is necessary to evolve suitable procurement methods whereby comparative cost should be worked out on 'life-cycle-cost' and not on 'initial-cost'.

An exhaustive road map has to be made with short-range and long range-plans for implementation of energy efficiency concept in new (both residential and commercial) and existing buildings with concurrent changes in regulations of Central and State Government authorities.

New concepts like – Energy Management System, Green Buildings, Energy Efficient Buildings, Solar Energy utilization etc should be made known to the building industry.

A source of funds for implementation of energy saving technologies must be identified. The non-renewable energy technologies are to be made at affordable costs.

## 9.0 Conclusions

“Energy Independence” in a building can be achieved through a two-pronged approach. First, by following energy conservation and energy management strategies, a minimum energy demand will be established. Secondly, alternate sources of energy will be identified to generate the required demand. This needs a holistic approach interlinking policies, public awareness and technologies for achieving energy independence in a building.

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