India Energy Security Scenarios, 2047

User Guide:

Efficient Envelope Optimization for Residential and Commercial Buildings

Note: The results in this documentation follow the 7.4% GDP growth rate option. To understand how the results of this sector vary with the GDP, the users are encouraged to have a look at the MS Excel model.

Additionally, users are requested to look at this sector in conjunction with the Residential and Commercial Lighting and Appliances Trajectories.

Contents

I. Introduction

I.a Sector Overview

The Construction sector in India is the second largest employer and contributor to economic activity after the Agricultural sector. Construction accounts for second highest inflow of Foreign Direct Investment after the services sector and employs more than 35 Million people. The Indian construction industry is valued at over USD 126 Billion (Make in India, Government of India, 2014). The construction sector can be classified into two sub-segments:

- Real estate (Residential, Commercial/Corporate, Industrial and Special Economic Zones)
- Infrastructure (Transportation, Urban Development and Utilities)

The contribution of the real estate sector to India's gross domestic product (GDP) was estimated at 6.3% in 2013. It is also expected to generate more than 17 million employment opportunities across the country by 2025. (Confederation of Real Estate Developers' Associations of India (CREDAI) and CBRE., 2013)

According to the Twelfth Five Year Plan, this sector is one of the highest consumers of natural resources and energy. It is now being increasingly realised in the construction industry that sustainable development concepts, applied to the design, construction and operation of buildings, can enhance both the economic well-being and environmental health of communities.

In 2001, India had the second largest urban population in the world with about 286 Million were living in urban areas across India (Vaidya, 2009). As per the Indian Census, 2011, the urban population increased to 377 Million, thereby registering a growth of around 24%. As per recent estimates, nearly 590 Million people will live in Indian cities by 2030.

These statistics paint a picture of the huge opportunity of energy efficiency that exists in the construction sector, in particular, the real estate sector of India. However, although the use of energy-consuming appliances is increasing, energy consumption due to building envelope characteristics, which determine the lighting and thermal comfort level of a building, is expected to significantly influence the total energy consumption of a building. When a building does not meet the comfort criteria, occupants reply on mechanical and electrical comfort and lighting systems (Global Buildings Performance Network, 2014).

Incorporation of energy efficiency in the buildings sector would result in the development of a market for energy efficient products (Building insulation, energy efficient windows, glass and frames, high efficiency HVAC equipment), improved design practices for lighting, natural ventilation/free cooling systems, lower energy use and electricity bills, reduced connected load and an improved power factor. (Shabnam Bassi, Bureau of Energy Efficiency). However, there exist certain barriers like lack of awareness about the benefits of incorporation of energy efficiency measures, a higher initial cost of energy efficient technologies, and lack of information about the payback periods for the same and an asymmetry in the sharing of costs and benefits.

State and local governments, real estate developers, and financial institutions are critical to the successful development and implementation of energy-efficient buildings. While existing government policies, building-rating systems, and active stakeholders do provide a foundation for accelerating progress in energy efficiency, as India's real estate market continues to grow, the current policy framework needs to be further developed and implemented by coordinated stakeholder action. It is therefore critical that these three leading stakeholder groups : state and local governments, real estate developers, and financial institutions drive development and adoption of energy efficiency measures in the buildings market for new construction and major retrofits.

I.b Trends in the building sector

It has been estimated that 70% of the building stock that will be there in the year 2030 is yet to come up in the country (Kumar S. R., 2010). Residential and Commercial sectors account for 29% of the total electricity consumption (Planning Commission, 2014).These highlight the need for incorporating energy efficiency measures in the buildings sector.

The potential to reduce energy consumption through energy efficient design of new buildings and retrofits in existing buildings is high, and could reduce the need for lighting, heating, ventilation and air conditioning. Most commercial buildings in India have an Energy Performance Index of 200-400 kWh/sq/m per year as compared to similar buildings in North America and Europe which have an EPI of less than 150 kWh/ sqm/ year. Energy conscious building design has shown to reduce EPI to 100-150 kWh/sqm/year. (UNDP and GEF, 2011)

Till date, India’s policymakers have focused on reducing energy consumption in new commercial buildings, but it is notable that achieving a high target, would depend on the inclusion of the residential buildings sector in the target area. Residential buildings make up 75% of India’s construction market, and until now has not been a priority for energy efficiency policy. The potential for expanding and adapting existing energy-efficiency policies to the residential segment is tremendous (The Economist Intelligence Unit, 2013).

I.c Building Envelope Optimization

Building envelope refers to the external façade and is comprised of walls, windows, roof, skylights, doors and other openings. The design features of the envelope affect the visual and thermal comfort of the occupants as well as the energy consumption in the building (USAID ECO-III Project, 2011). An integrated building design considers the envelope, heating, ventilation and cooling (HVAC) system and the lighting system as a whole. Altering the specifications of one system can change the performance of the other two significantly.

ECBC compliant buildings have energy conservation measures like the use of flash blocks, wall and roof insulation, high performance glass, high SRI paints, vegetated roofs, LPD’s (<1 w/sq.ft), high performance chillers, economizers, viable frequency drives and cooling towers, fenestration, designs that increase daylight and reduce the need for daytime lighting, gains from better insulation, plugging of leaks and use of natural ventilation.

Some of the basic measures for energy efficient envelope design are as follows:

Measures	Wall	Roof	Window
Minimize conduction losses	Use insulation with low U-factor	Use insulation with low U-factor	Use insulation with low U-factor
Minimize conduction losses	Reduce air leakage using a continuous air barrier system	Reduce air leakage using a continuous air barrier system	Use prefabricated windows and seal the joints between windows and walls
Minimize moisture penetration	Reduce water infiltration: Use continuous drainage plane Reduce air transported moisture: Use continuous air barrier Reduce moisture diffusion into the wall: use vapour barrier/retarder	Watertight airtight: Continuous air barrier, use vapour barrier/retarder	Use prefabricated windows and seal the joints between windows and walls
Minimize radiation losses	Use light coloured coating with high reflectance	Use light coloured coating with high reflectance	Use glazing with low solar heat gain coefficient (SHGC) and use shading devices

Source: (USAID ECO-III Project, 2011)

I.d Existing Policy Framework

The National Building Code (NBC) developed by the Bureau of Indian Standards defines norms and standards for health, safety and comforts of buildings and attempts to incorporate sustainable parameters to a certain extent. The Energy Conservation Building Code (ECBC) was launched by the Bureau of Energy Efficiency, Government of India in 2007 as a step towards promoting energy efficiency in the buildings sector.

The Energy Conservation Building Code (ECBC) sets minimum energy performance standards of various components of a commercial building having a connected load of 100 kW and above, or a contract demand of 120 KVA and above, and takes into account the climatic zone where the building is located. The purpose of this Code is to provide minimum requirements for the energy efficient design and construction of the buildings.

Adoption of these norms and standards are a pre-requisite for obtaining green ratings such as the “Green Rating for Integrated Habitat Assessment (GRIHA)” rating system of ADARSH or “Leadership in Energy & Environmental Design (LEED)” of the Indian Green Building Council (IGBC). These ratings are tools that help to assess sustainable parameters in green buildings.

The ECBC provides design norms for:

- Building envelope, including thermal performance requirements for walls, roofs, and windows;
- Lighting system, including day lighting, and lamps and luminaire performance requirements;
- HVAC system, including energy performance of chillers and air distribution systems;
- Electrical system; and
- Water heating and pumping systems, including requirements for solar hot-water systems.

I.e Key Policies Considered

Since the buildings sector has interlinkages with a number of other sectors, both on the demand side as well as the supply side, this modelling exercise aims to project the energy demand in Buildings by taking into account a variety of policies, some that are already in place and some that have been recently launched in India.

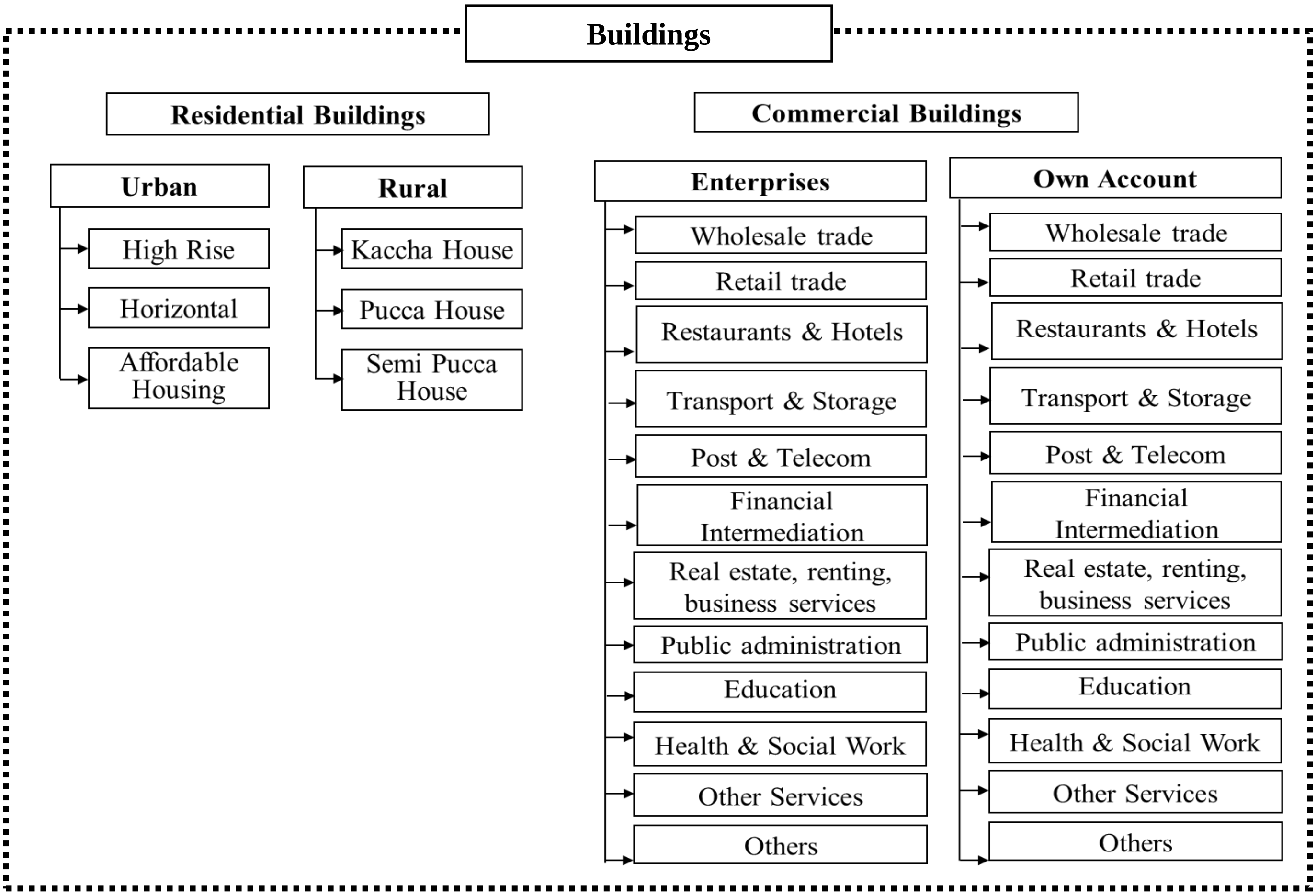
In order to make projections at different stages, some of the policies that have been considered are as follows:

1. Housing for all by 2022
2. 24x7 Power for all by 2019
3. 100 smart cities
4. Increased adoption of efficient building codes by states
5. Development of a large retrofitting programs for commercial buildings
6. Standards and Labelling Programme for Appliances
7. Increased incentive schemes by the Government to promote adoption of energy efficient buildings e.g.: Rebate in property tax etc.
8. Expansion of the scope of building codes in terms of Energy Performance Index to help cover more buildings
9. Market transformation E.g.: Demand Side Management (DSM) based Efficient Lighting Programme (DELP)

II. Categories

The exercise aims to capture the potential to reduce energy consumption in buildings through the use of energy efficient construction material. Efficiency gains due to the adoption of more efficient lighting and appliances, to meet the reduced energy demand, have been considered separately in the residential lighting and appliances section. The buildings sector has been defined to include residential and non-industrial buildings. Non industrial buildings include offices, hospitals, hotels, retail outlets, educational buildings and public services including government offices.

A snapshot of the different categories and subcategories of the components are presented as follows:


Buildings
Residential Buildings
Commercial Buildings
Urban
High Rise
Horizontal
Affordable Housing
Rural
Kaccha House
Pucca House
Semi Pucca House
Enterprises
Wholesale trade
Retail trade
Restaurants & Hotels
Transport & Storage
Post & Telecom
Financial Intermediation
Real estate, renting, business services
Public administration
Education
Health & Social Work
Other Services
Others
Own Account
Wholesale trade
Retail trade
Restaurants & Hotels
Transport & Storage
Post & Telecom
Financial Intermediation
Real estate, renting, business services
Public administration
Education
Health & Social Work
Other Services
Others

How the sector choices work:

Levers ? 1 2 3 4

External Temperature Rise
Residential Buildings
- Urban Planning
- Penetration of energy efficient buildings
- Lighting and Appliances

Commercial Buildings
- Penetration of energy efficient buildings
- Lighting and Appliances

For Estimating the Residential Sector energy demand:

1. The user can pick how he/she expects the structure of cities to pan out in the years to come. (Till 2047 – between high rise development, horizontal development and affordable housing)
2. The user can then pick how many of these structures would use energy efficient building material for construction purposes based on the different policy and behavioural drivers as detailed later in this document.
3. The user then picks the configuration of appliances (of different efficiencies) which will be utilized in these buildings to meet the demand for heating, cooling, lighting etc. Other residential appliances like televisions etc. are also included in the analysis and the choices for energy efficiency configurations for these are also available to the user.

The aggregate residential buildings demand is estimated by a combination of the above levers.

For estimating the Commercial sector Energy Demand:

1. The user can pick the penetration of energy efficient construction in the commercial building stock.
2. The user then picks the configuration of appliances (of different efficiencies) which will be utilized in these buildings to meet the demand for heating, cooling, lighting etc.

The aggregate commercial buildings demand is estimated by a combination of the above levers.

Three choices are offered to the user on how he/she expects the external temperature to rise till the year 2047. The chosen option for temperature rise impacts the heating and cooling demand for buildings.

III. The main outputs of the analysis

1. Space heating and cooling demand
2. Hot water demand
3. Electricity demand from the different categories of appliances (Category 1: Appliances that meet the heating and cooling demand, Category 2: Appliances that meet the hot water demand and Category 2: Other appliances like lights, televisions etc.)

IV. Fixed Assumptions

1. Estimation and projection of floor space per capita:

The IESS, 2047 V2 offers the user a choice between three different rates of growth of the economy. The trend of space requirement per capita for the three different growth rates of GDP has been arrived at by analysing the historic growth of residential and commercial floor space per capita viz a viz the GDP, computing the elasticity of activity demand in buildings with respect to GDP and projecting the space requirement till 2047.

For the 7.4% CAGR of GDP option, Residential floor space per capita is expected to rise from 10.8 Sqm/Capita in 2012 to 32.9 Sqm/Capita in 2047 and Commercial floor space per capita is expected to rise from 0.6 Sqm/Capita in 2012 to 5.9 Sqm/Capita in 2027

2. External Temperature

Extensive literature review was done to arrive at an average external temperature for India for the Summer, Winter and Monsoon seasons. The user is given three options on how this temperature will rise in the next 35 years to come. The temperature stress scenarios are aimed at giving a broad range of possible scenarios as to how the temperature can change in the years to come.

Season	Average Temperature (Degree Celsius)	Temperature Scenarios till 2047	
Summer	37.5	Scenario 1	No temperature rise till 2047
Winter	10	Scenario 2	A 2 degree Celsius rise in temperature till 2047
Monsoon	33	Scenario 3	A 4 degree Celsius rise in temperature till 2047 (Most pessimistic)

Source: http://www.imd.gov.in/doc/climate_profile.pdf and http://www.worldweatheronline.com/New-Delhi-weather-averages/Delhi/IN.aspx

3. Internal Thermal Comfort Temperature

In order to estimate the heating and cooling requirement for the chosen external temperature scenario, the Internal Comfort temperature depending on the different levels of appliance ownership is estimated for the three seasons, for urban and rural areas separately.

The appliance ownership patterns in urban and rural areas in turn also depend on the three levels of GDP growth of the economy and can be accessed in detail in the documentation of the 'Residential Lighting and Appliances' section of the IESS, 2047.

For the GDP Growth scenario of 7.4% (CAGR) till 2047, the appliance ownership patterns of cooling devices and the internal thermal comfort temperatures for Summer, Winter and Monsoon, have been estimated for the year 2012 as follows:

Appliance penetration	**Region**	**2012**	**2017**	**2022**	**2027**	**2032**	**2037**	**2042**	**2047**
Ceiling Fans	Urban	93%	95%	96%	98%	100%	100%	100%	100%
	Rural	64%	73%	82%	91%	100%	100%	100%	100%
Room Air Conditioners	Urban	7%	15%	24%	32%	40%	45%	50%	55%
	Rural	4%	11%	17%	24%	30%	35%	40%	45%

For details and references, please refer to the "Residential Lighting and Appliances" documentation

Internal Comfort Temperature for Summers	2012	2017	2022	2027	2032	2037	2042	2047
Urban	30.56	29.91	29.25	28.58	27.90	27.58	27.25	26.93
Rural	32.8	31.8	30.8	29.7	28.6	28.2	27.9	27.6

Author's own calculations

4. Dimensions of different categories of buildings

The Buildings sector aims to encompass different categories of buildings that have been spoken about earlier in this document. For the purpose of the same, the dimensions of the different categories of buildings along with a floor-space ratio has been estimated to arrive at the total area of building space contributing to the generation of energy demand.

Category	**Urban**	**Rural**	**Affordable Housing**
Area	108	108	55
Height	3	3	3

Source: Expert consultations and
http://www.kpmg.com/IN/en/IssuesAndInsights/ThoughtLeadership/Affordable_Housing.pdf

Floor Area Index	
High Rise Development	10
Horizontal Development	2
Affordable Housing	3
Kaccha House	1
Pucca House	1
Semi Pucca House	2

5. Rate of heat loss (U- Values) for different kinds of buildings and construction material

ECBC	**U values**		**High rise**	**Horizontal**	**Affordable**
	Wall		4.40	4.40	4.40
	Roof		2.61	2.61	2.61
	Window	U value	33.00	33.00	33.00

Source: http://www.beeindia.in/schemes/documents/ecbc/eco3/ecbc/ECBC-User-Guide(Public).pdf

Type of Structure	Material	Thickness(mm)	R value
Wall	Burnt Clay Brick	230	0.38
Wall	Plaster both side	12	0.02
Wall	Air film outside		0.04
Wall	Air Film Inside		0.13
Wall- R value			**0.59**
Wall-U value			**16.95**
Roof	rcc slab	100	
Roof	Mud Phuska	75	
Roof	Cement Mortar	20	0.03
Roof	Air film outside		0.06
Roof	Air Film Inside		
Roof R Value			**0.40**
Roof_U Value			**25.00**
Floor_ U Value			**29.40**
Window	U value		58.00
	SHGC		0.82
	CLF		0.48

Source:
http://cpwd.gov.in/Publication/IGDBooklet.PDF,http://www.sciencedirect.com/science/article/pii/S1876610214011540 ,http://164.100.47.134/intranet/RuralHousingIndiraAwasYojana.pdf

BAU			**High rise**	**Horizontal**	**Affordable**
	Wall		17.22	17.22	17.22
	Roof		29.42	29.42	29.42
	Window	U value	58.00	58.00	58.00
		SHGC	0.82	0.82	0.82
		CLF	0.48	0.48	0.48

Source: Expert consultations and http://www.gbpn.org/sites/default/files/08.%20INDIA%20Baseline_TR_low_0.pdf

6. **Percentage of household space to be cooled**

	2012	**2017**	**2022**	**2027**	**2032**	**2037**	**2042**	**2047**
Urban	21.00%	21.78%	23.85%	25.92%	27.99%	30.06%	31.34%	32.63%
Rural	21.00%	21.78%	23.85%	25.92%	27.99%	30.06%	31.34%	32.63%

Benchmarked with IEA ETP Building Document 2013

7. **Hot water demand per household:** 20 litres/ day/ capita (CPWD Manual assumes 100 litres per day of household hot water demand,. Assuming the family size of 5, the demand/capita has been arrived)
8. **Specific heat of water:** 4.3 Joules/Gram degree celcius
9. **Average temperature to which water will be heated:** 41 degree Celsius (http://www.ukhca.co.uk/pdfs/BathingShowering.pdf)
10. **Efficiency of water heater:** 54.35% (https://docs.google.com/spreadsheets/d/1hkwTseqfly_plkUoGOPcRFFBXCOA46Q8FzZVJd5gD-Q/edit#gid=0)
11. **Occupancy heat gains :** *According to ASHRAE 55, one person occupies 12 sq.m of floor area in a built up space and emits 120 W of Heat. (Expert views from BEE and ASHARE 55)*

V. Drivers and Assumptions

The main **drivers** of the buildings sector considered for this analysis are as follows:

- Increased scale and speed of urbanization and migration. (NSDC)
- An increasing share of the services sector in the Indian economy which increases the demand for office space.
- Sharp growth in organized retailing, which is expected to grow at over 25% in the next few years (NSDC)
- Increasing purchasing power of consumers.
- Wise architectural design/Innovation in architecture and use of material with low embodied energy.
- Increased awareness and regulatory instruments leading to stricter implementation of green building codes.
- Increased incentive schemes by the government for transitioning to energy efficient buildings like a reduced tax on investment for retrofitting existing building, reduction in the registration fee, rebates in electricity charges for those using solar water heaters, low interest loans for green housing etc.
- Single family and multi-family households are expected to show the highest growth rates between 2005 and 2050 (Global Buildings Performance Network, 2014)

Assumptions:

- The India Energy Security Scenarios, 2047 includes the energy consumed in using these buildings (lighting and appliances).
- Energy embodied in construction of these buildings and structures is not considered here.
- The potential to reduce energy consumption through improvement in efficiency of appliances and equipment, already accounted for in the commercial and residential lighting and appliances sectors, is not taken into account.
- Buildings can be made more efficient by designs and construction material that reduce the need for heating, lighting, ventilation and air conditioning.
- Energy intensity savings that are realized, over and above what is possible through improvements in appliances and equipment is taken into account.

VI. Methodology and interlinkages with other sectors

Residential Buildings: Space cooling and water heating demand was calculated on the basis of the temperature differential in different seasons and the thermal conduction capacity of building materials for each type of building, based on its dimensions, both in rural and urban areas.

- The estimated space cooling demand is assumed to be met different categories of cooling appliances based on a ratio which is a function of their wattage and efficiency ratios. The user in turn has a choice to pick between different configurations of appliance efficiency based on their efficiency levels, levers for which has been provided in the residential lighting and appliances section. Hence a combination of the trajectories of residential building envelope and residential lighting and appliances give the total demand for energy in the residential buildings sector in India.
- The hot water demand calculated is met by two categories of appliances, geysers and solar water heaters. The user has an option to select the different penetrations of solar water heaters, which he can do from the trajectories of solar water heaters, being offered in the supply side. The rest of

the demand is being met from various other appliances like geysers etc. The total energy demand from hot water is a combination of the two aforementioned choices.

Commercial Buildings: A similar approach is followed for estimating the energy demand from commercial buildings. Since the commercial lighting and appliances sector follows a modelling approach which uses the Energy Performance Index as the basis, the savings realized due to utilization of more energy efficient building material is built into estimating the cooling demand. For more details on the commercial lighting and appliances sector, please refer to the detailed documentation on the methodology of commercial lighting and appliances.

VII. Costing

The cost per square meter of conventional building construction material versus energy efficient building construction material was arrived at by an extensive literature review, expert consultations and the CPWD Delhi Schedule of Rates, 2014.

On the basis of the dimensions and the penetration of different kinds of buildings, the cost per unit area of conventional and energy efficient construction was arrived at. Following which, based on the energy saved (in terms of a reduced cooling load) by an energy efficient building as opposed to a conventional building, an estimate of an incremental cost per unit saved has been arrived at.

The incremental cost per unit area of conventional versus buildings that are constructed by using energy efficient building materials is presented as follows:

Wall	INR/ Sq. m	250
Roof	INR/ Sq. m	700
Window	INR/ Sq. m	1300

Source: Expert consultation and Delhi Schedule of rates, 2014

<u>How the costing works</u>

The Buildings sector analysis consists of two major components: The envelope interventions which reduce the space cooling load and increasing penetration of energy efficient appliances which meet this cooling load.

While the costing for Residential and Commercial Lighting and Appliances is detailed in the sections concerned, the basic principle for the aggregate cost to the economy of the buildings sector is presented below:

As the penetration of buildings with more efficient envelope increases, as mentioned above, the economy would incur additional costs with each unit of electricity saved. However, as the penetration of an energy efficient envelope actually reduces the space cooling load, lesser number of appliances (Energy efficient or otherwise) would be required to meet this resultant demand. Hence, the overall cost of the building sector is a combination of the additional cost of efficiency building materials and reduced cost of appliances used to meet the reduced load. Therefore, over the lifetime of a building, using more energy efficient materials to construct the building actually saves on cost to the economy.

<u>Costing sections in the IESS</u>

In the Buildings section of the IESS, 2047 Version 2.0 excel sheet, sheet X.a and X.b mention the cost ranges of a) the incremental cost of moving towards more efficient building materials and b) the cost of different categories of energy efficient appliances. A combination of the two, along with the aggregate energy demand of the sector gives the total cost of the different levels chosen for penetration of buildings with an energy efficient envelope and different levels of penetration of energy efficient appliances.

VIII. Trajectories

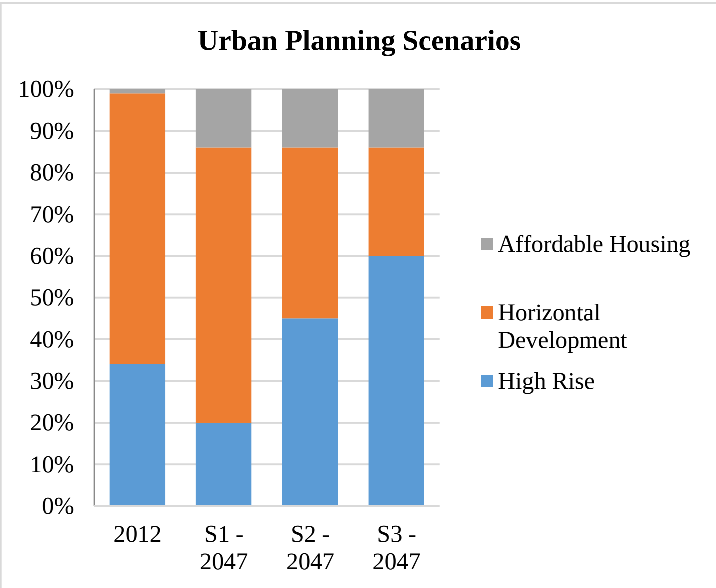
Level 1 assumes that compliance to the Energy Conservation Building Codes (ECBC) remains voluntary, as is the case since its inception at the beginning of the 11th five year plan (FYP). Institutional, technological, informational and financial barriers also exist, which hinder the applicability of the same.

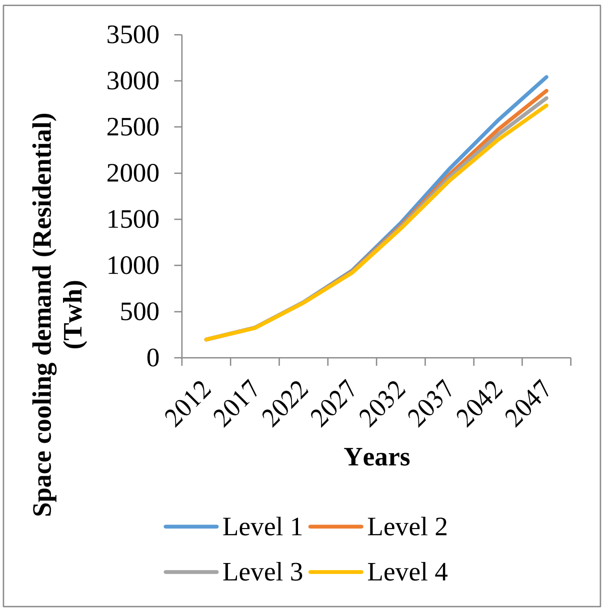
Level 2 assumes, as per the Energy Conservation Act 2001, the introduction of a bye law for ECBC compliance in new commercial buildings, and mandatory compliance in government buildings. It also assumes increasing adoption of incentive schemes, like a reduced property tax etc., for the ECBC code in new residential buildings.

Level 3 assumes that along with standard building by laws, there is development of ECBC compliance structures at state level, and the modification of the Energy Performance Index (EPI) bandwidth based scheme to multi variable EPI scheme, both in the residential as well as the commercial sectors.

Level 4 assumes a continuation of the multi variable EPI scheme and increasing mandates in states for implementation of the ECBC code. It also assumes a large scale drive towards making compliance to the ECBC code, mandatory, in new construction, till 2047.

Penetration of Efficient Envelope Interventions					
Category	**2012**	**L1-2047**	**L2-2047**	**L3-2047**	**L4-2047**
Residential					
High Rise	1%	10%	50%	75%	90%
Horizontal	0%	5%	40%	55%	80%
Affordable Housing	0%	0%	0%	0%	0%
Commercial	10%	25%	50%	75%	100%





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