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Impact of ECBC on building energy consumption at city level, Phase 3

Case of Ahmedabad

2017-2018

August-2018

For private circulation only

Suggested citation: Rawal, R., Pandya, H., Shukla, Y., Rawal, D., Dey, S., Raza, A., Sharma, K., Sharma, M. (2018). Impact of ECBC on building energy consumption at the city level, Phase 3. Ahmedabad: Centre for Advanced Research in Building Science and Energy.

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Acknowledgement

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support renewable energy, energy efficiency and sustainable transport solutions. We sincerely thank Shakti Sustainable Energy Foundation for giving Centre for Advanced Research in Building Science and Energy, CEPT University the opportunity to explore the study with the funding support.

Contents

List of Figures

List of Tables

List of Graphs

1. Executive Summary

Growing population and rapid urbanization constantly increase the demand for energy. We can see its adverse effects on ecological and climatic conditions. Hence, it becomes very important to shift towards sustainable approaches for managing these urban energy demands. Energy Conservation Building Code (ECBC) is one such major step taken by the Ministry of Power, Government of India in 2007 towards promoting the energy efficiency at the building levels.

Energy Conservation Building Code (ECBC) sets minimum standards for the design and construction of buildings. It (ECBC) promotes the energy efficient design or retrofits of the buildings without affecting their functions, comfort, health and productivity. It also serves appropriate regards for economic considerations of the building by lowering the cost of construction and by minimizing future energy consumption charges. Furthermore, its implementation will reduce (i) future energy production cost and (ii) carbon footprints in the environment.

Implementation of the code is at a minimal scale due to the lack of acts and rules which make them mandatory at the state and ULB levels. If the code is applied on a large scale, the benefits are enormous and this makes it important to point out their benefits to the decision-makers. With the same line of thought, this study focuses on quantifying the impact of ECBC at the state/city levels.

This study attempts in evaluating the existing building stock details by considering the spatial distribution and land use data. Further, the energy performance at the building level is derived. Thus, the energy performance at the city level is projected and identified. The study majorly helps in estimating the scenarios of floor space projections while demonstrating the energy-saving impact of ECBC at the city level.

The study goes on to demonstrate the usage of the spatial distribution based on GIS applications, building energy simulations and literature-resources in determining and estimating the energy consumption of the building.

2. Introduction

In 2016, CEPT worked on Impact of Energy Conservation Building Code (ECBC) at the city level and quantified energy savings by examining available floor space within the city. Under the first phase of work, CARBSE worked in the context of Ahmedabad and under the second phase that of Jaipur, Udaipur, Kakinada, Pune and Pimpri-Chinchwad. The work was based on the inputs from the property tax data available with ULBs showing the amount of floor space information. The work was non-spatial in nature and it did not consider granularity of building types. Under phase 3, CEPT has created a prototype model for city-level energy conservation prediction by correlating existing building stock, their spatial distribution and land use with the use of GIS capabilities to find total energy consumption and savings for Ahmedabad city.

Work done under phase 3 is divided into 3 tasks:

- Existing building stock with spatial distribution and land use
- Energy performance at the building level
- Energy performance at the city level (BAU and Projection)

3. Literature Review

This study deals with a co-relation of the spatial distribution of building floor space and energy. Therefore, an estimation of total building floor space needs to be done separately for different building types. There are a number of methods to estimate the base year building floor space depending on the data availability, accuracy and ease of estimation.

A journal paper, “Modelling urban building energy use: A review of modelling approaches and Procedures” (Li et al, 2017), specifies two broad categories of energy modelling for urban building stocks. The first approach is top-down models which treat a group of buildings as a single entity, where energy consumption is estimated at building sectoral level without considering differences amongst individual buildings or end uses. The second approach is bottom-up models which focus on individual building and end-use, which can be later aggregated at the urban, state, regional or national scale. The bottom-up approach is further classified into two methods, namely, statistical-based bottom-up and physics-based bottom-up. Out of these, the physics-based method has been effective and hence popular because of its higher temporal resolution (daily, hourly and/or sub-hourly) for the simulated end-use energy. Now, the top-down approach is simple to implement but it requires long-term historical data of urban scale energy consumption and other socio-economic indicators. Even though the physics-based bottom-up method is effective, it faces challenges in terms of model preparation and calibration, but still is the most effective method available.

Another journal paper, “Big data GIS analysis for novel approaches to building stock modelling” (by Buffat et al, 2017), presents new approaches to building stock modelling. The researchers use spatial datasets such as building footprints and digital elevation models allowing the derivation of wall and roof areas individually for each building. This reduces model uncertainties. Building footprints, digital elevation models, surface areas, and building volumes are more accurately derived from the cadastral survey. By replacing synthetic climate data with spatial datasets allows simulating the heat demand with location-specific data, due to their higher daily time temporal resolution. This high temporal resolution of the data facilitates the model for complex optimization such as the sizing and operation strategies of existing and novel energy systems. Additionally, using historical data allows understanding the extreme period. It is also used as a validation platform for the simulated data. The proposed model could asses and investigate large regions by using spatial data describing natural and anthropogenic land features. The validation resulted in an average goodness of fit (R^2) of 0.6.

One more journal paper, “Using building energy simulation and geospatial modelling techniques to determine high resolution building sector energy consumption profiles” (Heiple et al, 2008), shows that the Houston case study, which used the bottom-up method, can accurately capture total building energy consumption. Key information sources (i.e. GIS and building energy surveys) were used as they are available for most of the large cities of the U.S. and therefore the method is widely applicable. The process of creating a set of prototype building simulations is time-consuming. However, once the simulation structure is created for one city, it can be used for other cities too. A significant challenge in the building simulations defines realistic average operating schedules. The most notable challenge was various binary HVAC schedules that could not be readily averaged for a single prototype building. The method combines annual building energy simulations for city-specific prototypical buildings and commonly available geospatial data in a Geographical Information System (GIS) framework. This method can be applied to virtually any large U.S. city to obtain estimates of electricity and natural gas consumption within the residential and commercial sectors. As a demonstration, this method was deployed for Houston TX, and the resulting peak energy consumption within the urban core was found to be greater than 100 W/m^2.

One more of a journal, “A GIS energy model for the building stock of Goteborg” (Tornberg & Thuvander, 2005), by Jonas Tornberg and Liane Thuvander, specifies a GIS implemented energy model for the building stock for the city of Goteborg. This model aims (i) in supporting the decision-making process by benchmarking and (ii) communication of the environmental performance of buildings between real-estate managers and municipal administrations. Various data from different sources have been compiled using ArcGIS. For this study, the data from the building register has been obtained which also comprises the data of all existing buildings in the region for a particular year. The data notifies the location within statistic area, information from building permits, building ground floor space & year of reconstruction. Every building has a geographic reference coordinate for the centroid of the building. In this study, the national coordinate system has been applied. These data form the basis for the building stock model and have been used to construct an age-use matrix with a spatial dimension integrating the energy model. All these attributes have been added to the GIS maps comprising of 2D vector shapefiles of the buildings in the region. The total floor space has been estimated based on the GIS model. The data has been collected from majorly three sources, viz. the building register, real-estate managers and energy statistics. This data has been then mapped in GIS for different years to estimate the energy use in various sub-sectors for a particular year. Also, it gives an energy model based on energy statistics for blocks of flats. This method demands a long list of building level spatial data for the city. This process is data intensive but is accurate to map the total floor space of a city.

Along with the estimation of floor area for the base year, future projections are to be made in order to understand the future energy demand. An article published by ACEEE in the year 2014 by Hong, Zhou, Fridley, Fang and Khanna called “Modelling China’s Building Floor-Area Growth and the implications for Building Materials and Energy Demand (Hong et al., 2014) specifies a methodology to predict the future growth in building floor area. According to it, the newly added building stock for a given year depends on the existing building and the demolished building stocks for different years. This method can be used to calculate building stocks for both residential as well as commercial buildings. Here, a series of formulas leads to the estimation of building floor space for any particular year in future. The major data requirements for this method of estimation are population, the percentage of the service-sector population, economically-active population, employment rate, the share of service-sector employees among total employee population, GDP per person, floor space per capita, the age of each building, and average life expectancy of buildings. The total newly built building stock is a function of expected residential and commercial building stock in a particular year and expected demolitions in that particular year. The residential building stock depends on the projected population and projected estimate of per capita floor area residential buildings for a particular year. Similarly, for commercial buildings, projected service-sector employees and floor space per employee are estimated. In this, the population in the service sector is estimated based on economically-active population, employment rate, and share of a service-sector employee among total employees for a particular region and time. It is assumed that floor space per employee is a logistic function of per capita income only. This is a very comprehensive method of projecting building floor space. The city level data availability would always be a constraint in a country like India. Major assumptions are to be made in order to estimate the building floor space. Also as a limitation, this methodology only considers the projection of residential and commercial building stock. With proper data availability at the micro level, this tool can be a very accurate and reliable way of projecting future commercial and residential building stocks.

4. Methodology

Reviewing various literature-sources as discussed in the Literature Review section, the methodology adopted to conduct this research is as follows:

- Acquired spatial data from Ahmedabad Urban Development Authority (AUDA) and CEPT University
- Verified ward boundary and 42 TP schemes of Ahmedabad based on Land Use
- Error correction (overlapping of boundaries, gaps in boundaries) in spatial data with the use of topology
- Calculated road-width based on polygons in spatial data
- Updated plot-wise land use in spatial data based on Google Imagery and secondary sources
- Assigned transit zone (BRTS, MRTS) in spatial data
- Conversion of road polygons in central lines
- Measured roadside margins based on General Development Control Regulations (GDCR)
- Deducted margins from plot boundaries as per GDCR to find the buildable area
- Assigned zone-wise maximum permissible FSI (Base + Chargeable) based on land use data and transit zone data
- Calculated height of the building based on FSI, road-width and buildable area
- Finding total floor space for each plot by multiplying plot area with FSI
- Assigned building typologies to land use type as per ECBC
- Calculated commercial floor space for building typologies listed in ECBC 2017
- Acquired description of baseline model from Partnership in Advance Clean Energy-Deployment (PACE-D project)
- Simulated baseline models to obtain Energy Performance Index (EPI)
- Validated results through end-use energy analysis
- Prepared an input sheet for Energy Conservation Measures (ECM)
- Parametric simulations run for ECBC 2007, ECBC 2017, ECBC 2017 + and ECBC 2017 Super for Envelope, Envelope + HVAC and Envelope + HVAC + Lighting scenarios
- Commercial floor space projection based on CAGR
- Calculated distribution of ECBC compliant and non-compliant stock
- Calculated city level total energy consumption for different scenarios

- Calculated energy savings at the city level

5. Existing Building Stock with Spatial Distribution and Land Use

The city of Ahmedabad was founded in 1411 AD as a walled city on the bank of the river Sabarmati. It is the largest city in the state of Gujarat. It has been one of the most important trade and commerce centres in western India and also a major industrial and financial hub. Ahmedabad, at present, is divided into 6 zones - central, east, west, north and south and new west zone. Each zone is further split into wards. There are, at present, 64 wards in all.

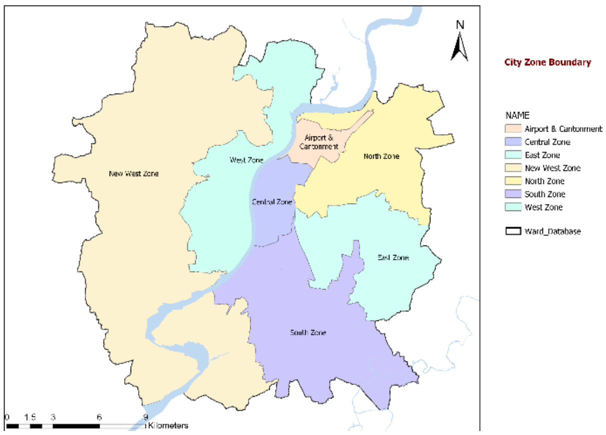


Figure 1: Zone Boundary Map

Figure 2: Ward Boundary Map

GDCR controls the development of the land use of a city. It follows the norms developed by the Urban Development and the Urban Housing Department at the state level to plan, control and regulate the land use and new development of the state. It also provides details of development regulations and controls for the land depending on its typology.

A development plan determines a zone which includes wards, development regulations and largely the FSI allotted for each zone. It also determines building height and plot margins depending on the road length and FSI.

For the study to have the total commercial floor space at the city level, the Geographical Information System (GIS) mapping approach was considered. As part of task one, spatial data was acquired from Ahmedabad Urban Development Authority (AUDA) and CEPT University. Plot-wise land use data was updated. Transit zone was assigned. Roadside margins were measured and deducted from plot boundaries based on GDCR. Maximum permissible FSI was assigned based on land use and transit data.

To find floor space for each plot, maximum permissible FSI was multiplied with the plot area. Building typologies as per ECBC were assigned to the land use types. Commercial floor space for building typologies listed in ECBC 2017 was found.

Following equations is used to calculate the floor space at the city level.

$$\text{Total commercial floor space} = \sum_{i}^{i=all\ the\ commercial\ plots} (Total\ Plot\ Area_i - Setback\ Areas_i) * Alloted\ FSI_i$$

5.1. The process of Developing GIS Database and Total Floor Space

Spatial data was developed in stages to find the total floor space of the city based on various land use types which were later assigned to building typologies as listed in ECBC.

5.1.1. Spatial Data Acquired from AUDA and CEPT Geomatics Lab

Spatial data was acquired from AUDA and CEPT Geomatics lab and mosaicked along with error rectification. This map shows the plot boundary along with the ward boundary of Ahmedabad city.

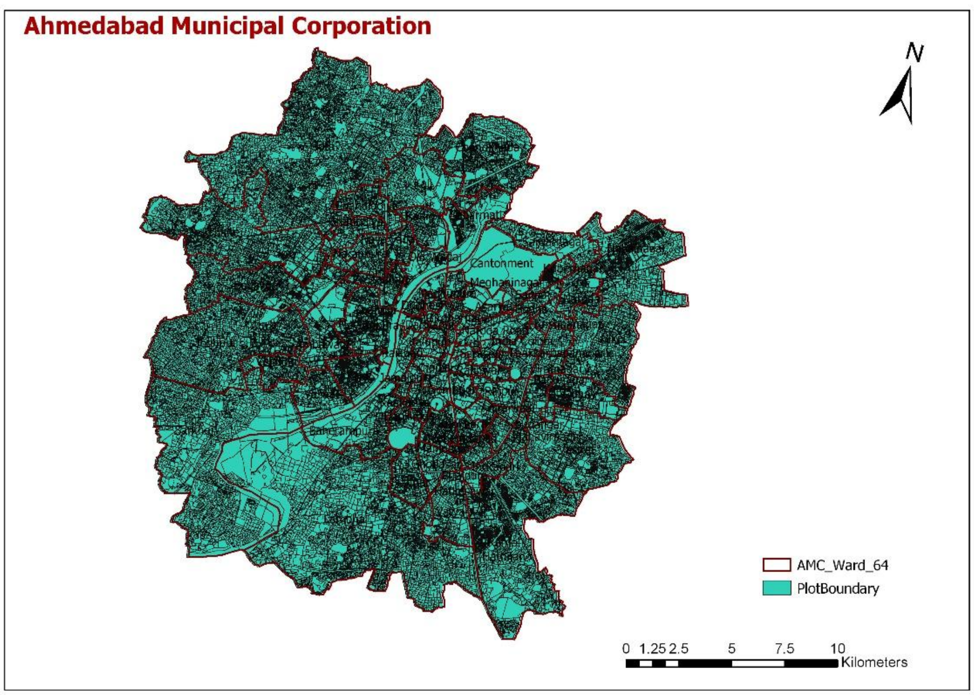


Figure 3: Plot and Ward Boundary Map

5.1.2. Rectification of Road-widths

Acquired road-width data was in feet and meter both. Hence it was converted into the meter. Missing road-widths were calculated using road polygon widths. Below mentioned maps show erroneous road-width and corrected road-width spatial data.

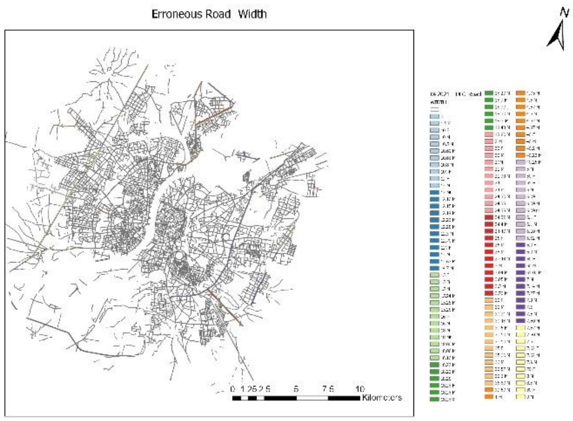


Figure 4: Erroneous Road-width Map

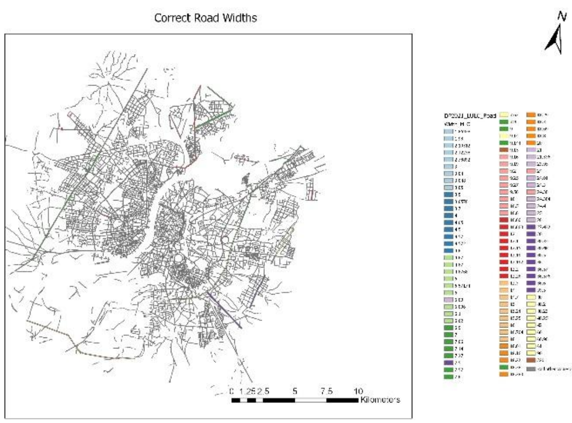


Figure 5: Corrected Road-width Map

5.1.3. Land Use Map

After assigning land use data, missing data was updated using secondary sources and Google Imagery. Based on the corrected spatial data, ward, zone and TP boundaries of land use data were identified.

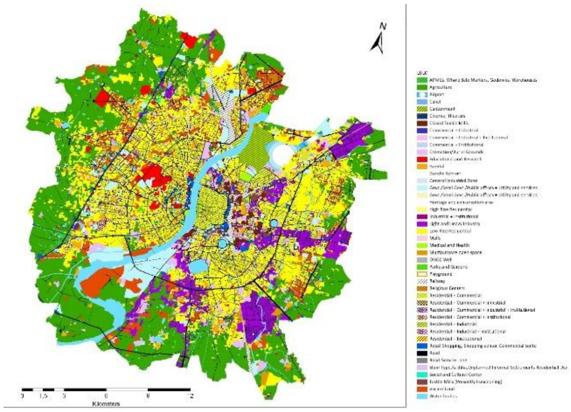


Figure 6: Plot-wise Land Use Map

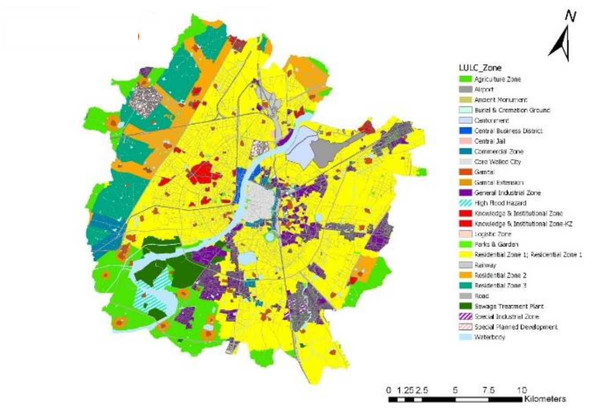


Figure 7: Zone-wise Land Use Map

5.1.4. Transit Zone Map

The transportation network in Ahmedabad includes BRTS and MRTS routes, railway tracks and roads. Based on these, a transit zone for BRTS and MRTS was determined. It was identified to find FSI and building height for the adjacent plots.

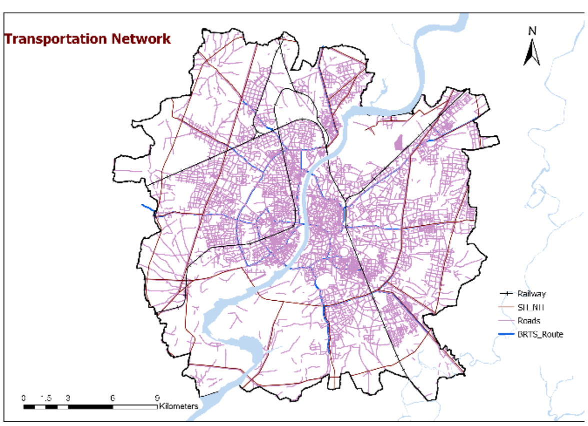


Figure 8: Transportation Network Map

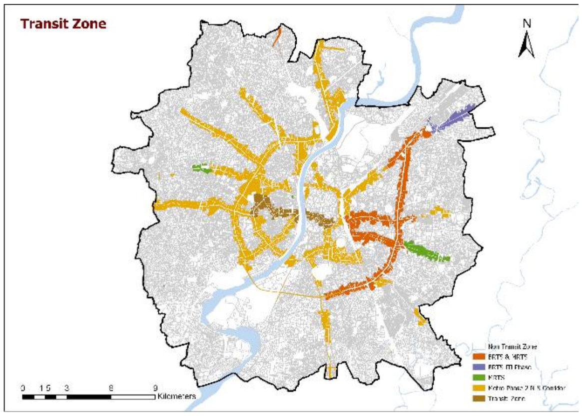


Figure 9: Transit Zone Map

5.1.5. Built-up Area Map

Margins were deducted from plot boundaries based on transit zone map, road-width, and buildable area of the plot with reference to GDCR to find the buildable area.

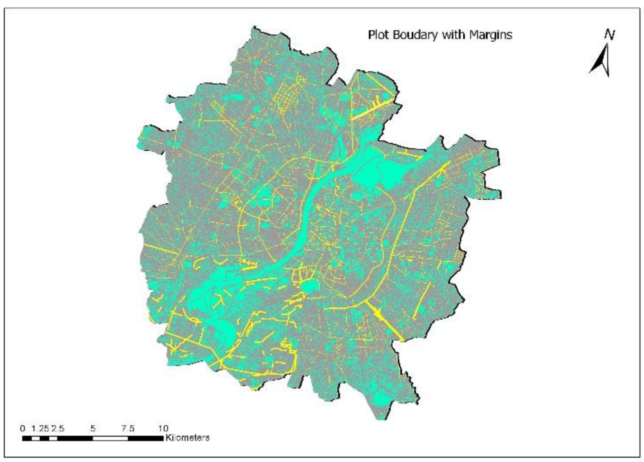


Figure 10: Plot Boundary Map with Margins

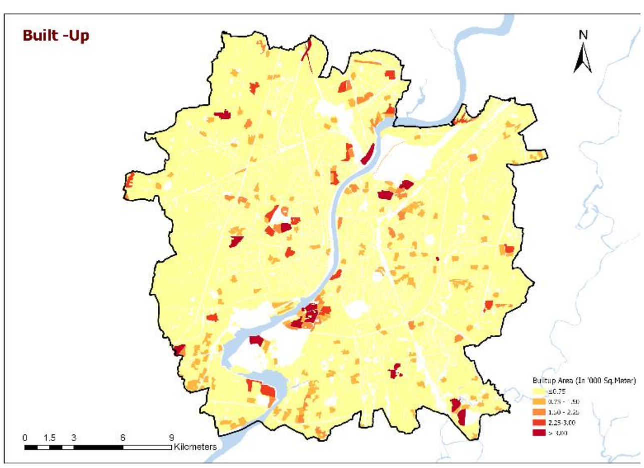


Figure 11: Built-up Area Map

Details regarding margins, which were deducted from the plot area selected based on road-width and area of the plot (GDCR), are mentioned below:

Table 1: Roadside Margin Based on Road-width

Road-width	Roadside Margin
Up to 9 m	2.5 m
9 m to 15 m	3 m
15 m to 18 m	4.5 m
18 m to 30 m	6 m
30 m to 36 m	7.5 m
36 m and above	9 m

Table 2: Rear and Side Margin Based on Plot Area

Area of Plot	Rear Margin	Side Margin
Upto 150 m^2	2.25 m	-
150 m^2 to 300 m^2	2.25 m	1.5 m
300 m^2 to 500 m^2	2.25 m	3 m
500 m^2 and above	3 m	3 m

5.1.6. Floor Space Index Map

This map shows zone-wise maximum permissible FSI (Base + Chargeable) assigned based on land use data, road-width and transit zone data.

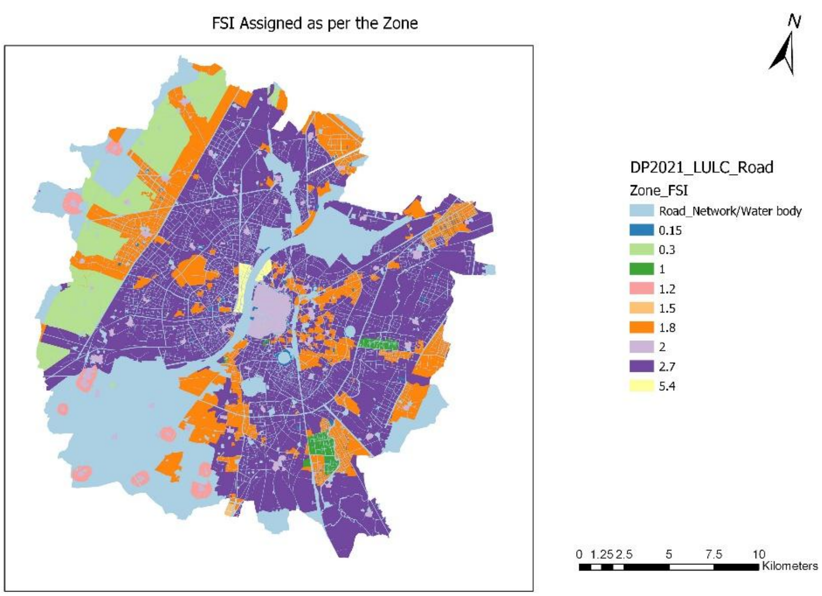


Figure 12: Zone-wise FSI Assigned Map

5.1.7. Building Height Map

This map shows the height of the building calculated based on FSI, road-width and buildable area.

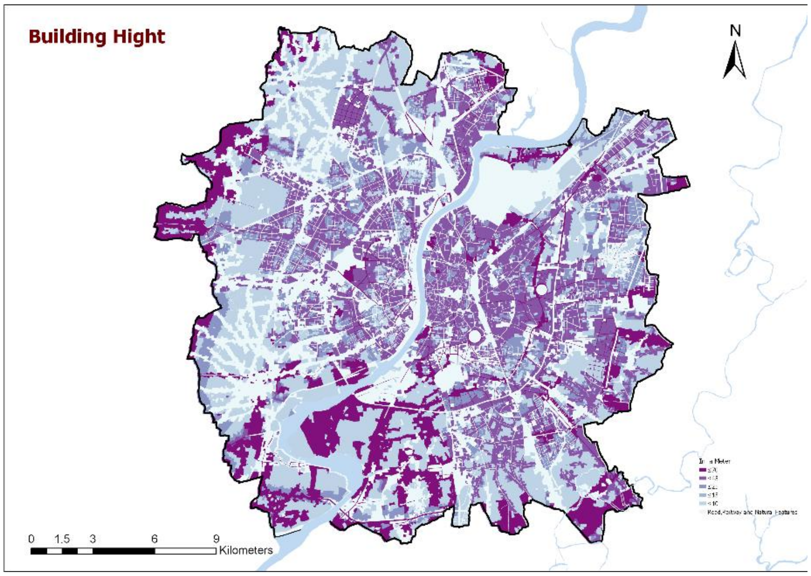


Figure 13: Building Height Map

5.1.8. Floor Space Map

This map shows floor area (Plot area * FSI). Here darker shade represents more FSI and the lighter shade the low FSI assigned to the plot.

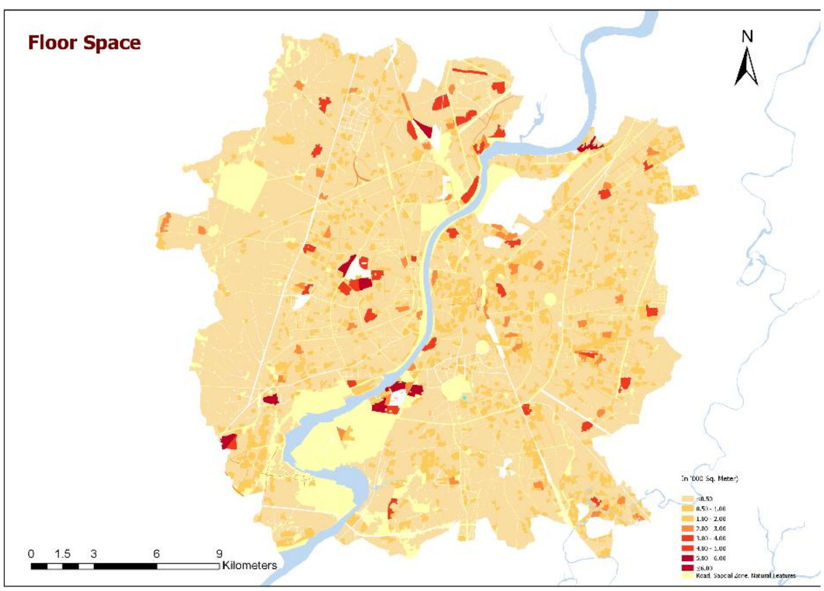


Figure 14: Floor space map

5.1.9. Key Figures on Ahmedabad Floor Space

Some of the key figures on Ahmedabad floor space in the Year 2017 as procured from the GIS database and various other sources are -

- 464.16 km^2 of land (2015)
- 131.0 km^2 Residential floor space (GIS Data 2017)
- 100.5 km^2 Commercial floor space (GIS Data 2017)

- 7584 Million kWh electricity sales (2014-15)

The Above commercial floor space numbers from the two databases suggest that the commercial spaces consume only 50% of the total consumable / allotted FSI at the city level.

6. Energy Performance at Building Level

Task two was to find energy savings through ECBC implementation. A comparison in energy savings among ECBC, ECBC+, Super ECBC and baseline model was simulated for the envelope, HVAC and lighting ECMs (12 variations).

Identification of building type and its corresponding energy saving potential were calculated using current ECBC V2 practices. A lead was taken from building typologies for commercial building, identified in national building code by creating an energy model for each typology (16 typologies) based on ECBC V2.

Energy models were prepared as per the description provided for the baseline models (for ECBC 2017) to obtain the EPI of the buildings considered in the study. The simulations for all the models were run in DesignBuilder v5.2 and Energy Plus v8.6. Once the baseline models were simulated, the parametric simulations for ECBC 2007 and ECBC 2017 were run.

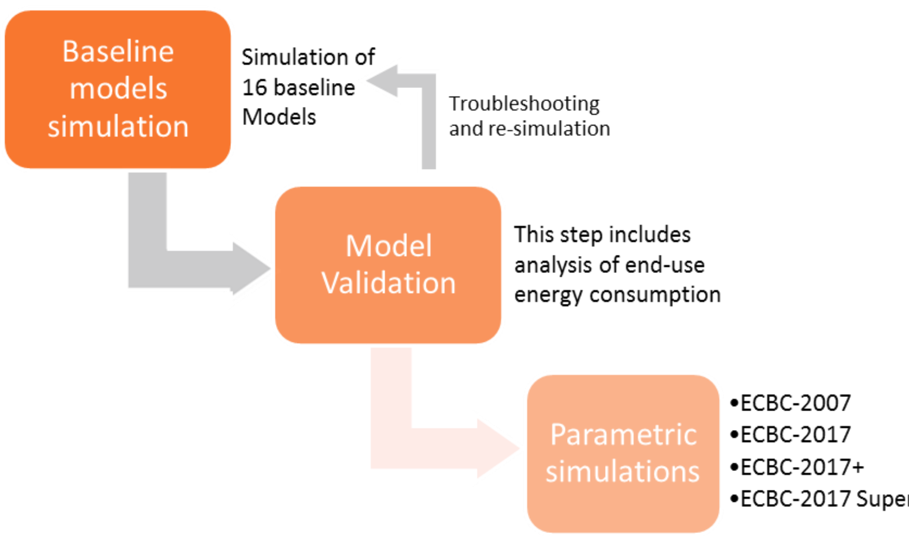


Figure 15: Steps to Find EPI at Building Level

To understand the deeper impact of ECM type on the energy performance of the building, ECMs were applied in three steps while running parametric simulations.

- Step 1 focused on envelope ECMs which includes changing properties wall, roof and window (U-value, SHGC, and VLT) as per code.
- Step 2 focused on envelope and HVAC both which include changing the HVAC system as per the code.
- Step 3 focused on envelope, HVAC and lighting which include changing LPD values and assigning lighting control as per the code.
- These steps help in understanding how each building component ECM helps in reduction of energy use at the building level.

Thus, in the last step, fully ECBC compliant models were obtained for both 2007 and 2017 version of ECBC Code.

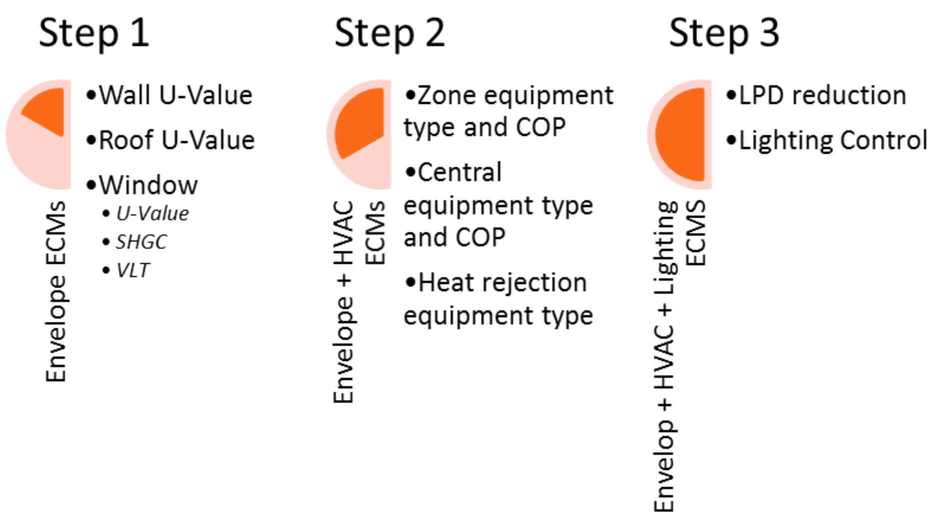


Figure 16: Impact of ECM on EPI at Building Level

6.1.1. Energy Performance of Baseline Models

Energy projections for the study are based on Energy Performance Index (EPI) which is energy consumption per unit area per year. The considered standard unit of area for all calculations is a square meter, based on which, EPI considered is in the unit of KWh/m2/yr.

After simulating all 16 baseline models, their EPI was obtained. The table below has EPI for all 16 types along with their total building area.

Table 3: EPI for Building Typology with Area

Building Typology		Area (m^2)	EPI (kWh/m^2)
Business	Small Office	10,000	76
	Medium Office	29,000	172
	Large Office	58,200	138
Educational	University, Academia	30,000	149
	Primary School	1,000	66
	Secondary School	24,000	56
Hospitality	Star Hotel	45,000	199
	Resort	10,000	197
	No-star hotel	15,000	92
Shopping Complex	Super Market	10,500	143
	Shopping Mall	37,500	198
	Open Gallery Mall	32,500	124
	Strip Retail Mall	4,000	197
Health Care	Hospital (150 + bed)	45,000	223
	Healthcare - Outpatient	10,000	111
Assembly	Assembly	6,000	202

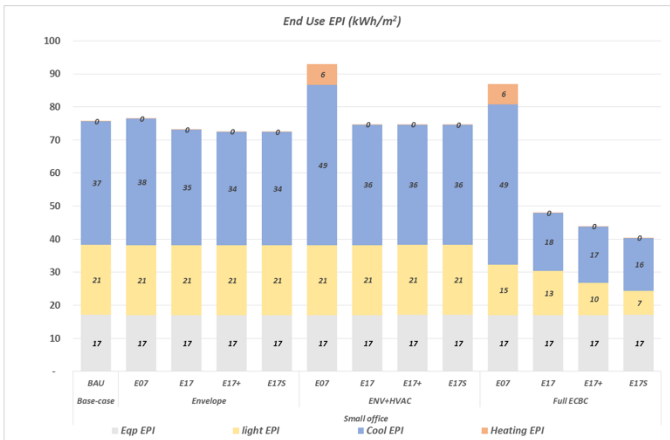
Note – The categories under building typologies shown in the table are as listed in ECBC 2017.

6.1.2. Energy Performance of 16 Building Typologies after Applying Energy Conservation Measures

Energy performance after applying ECMs to all 16 building typologies separately is shown below. The following graphs show savings in kWh/m^2 for ECM category - Envelope, HVAC and Lighting for ECBC 2007, ECBC 2017, ECBC 2017+ and ECBC 2017 Super.

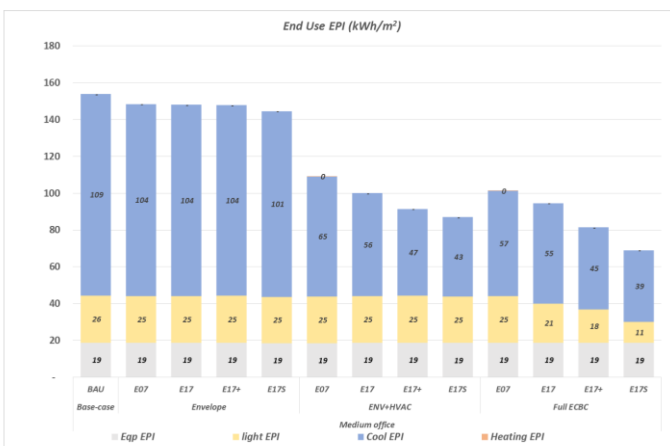
The simulation for all 12 variations was done in DesignBuilder. Gradual decrement was reported in each end use including cooling EPI, heating EPI and lighting EPI. The cooling EPI includes all the end uses related energy consumption i.e. heat rejection, pump, fans etc. No decrement was observed in equipment energy consumption as no measure related to equipment is included in ECBC.

6.1.2.1. Small Office



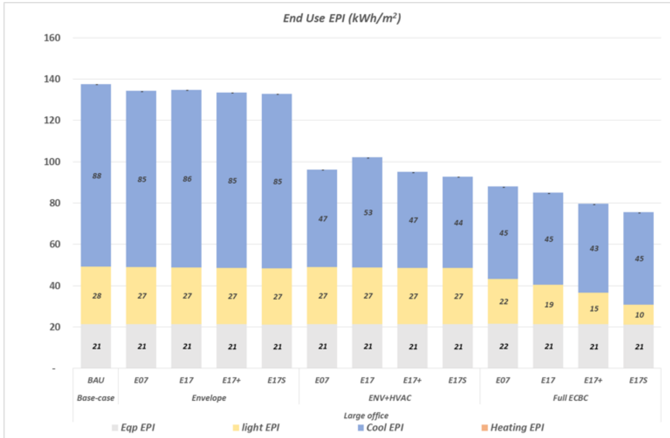
Graph 1: Small Office - EPI after ECMs

6.1.2.2. Medium Office



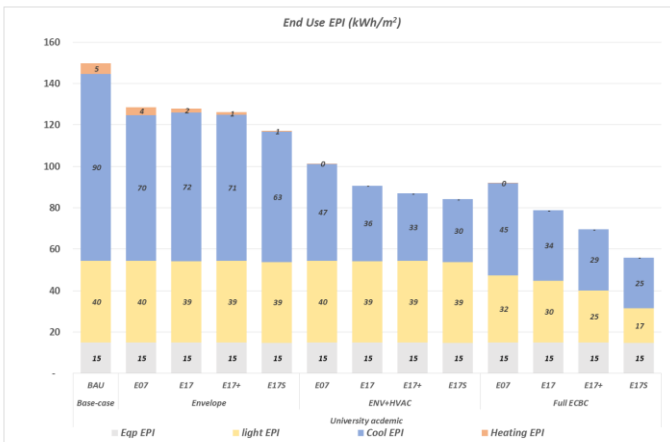
Graph 2: Medium Office - EPI after ECMs

6.1.2.3. Large Office



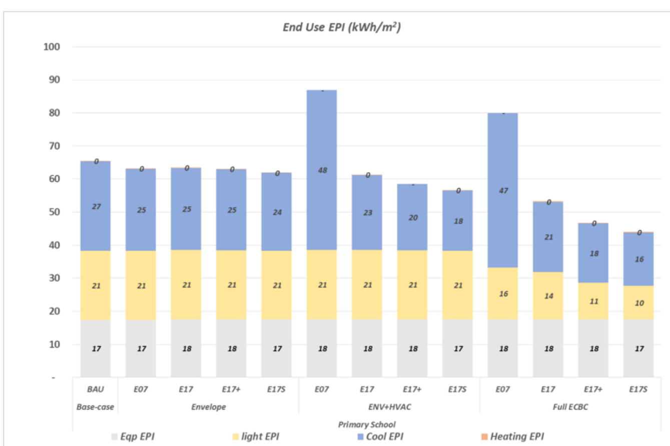
Graph 3: Large Office - EPI after ECMs

6.1.2.4. University, Academia



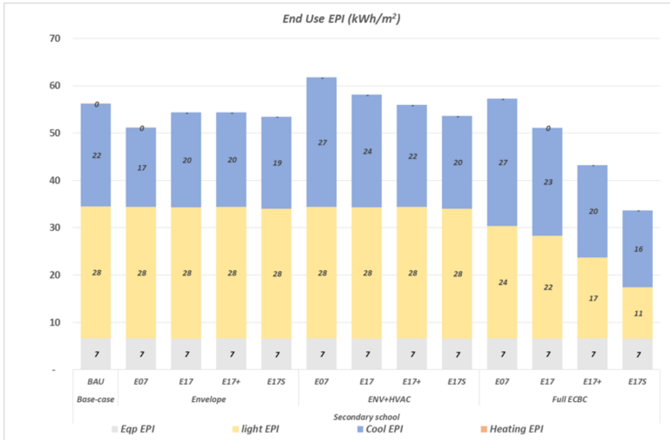
Graph 4: University, Academia - EPI after ECMs

6.1.2.5. Primary School



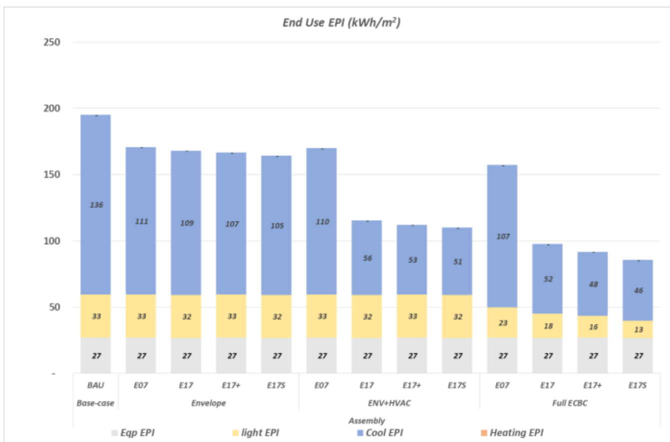
Graph 5: Primary School - EPI after ECMs

6.1.2.6. Secondary School



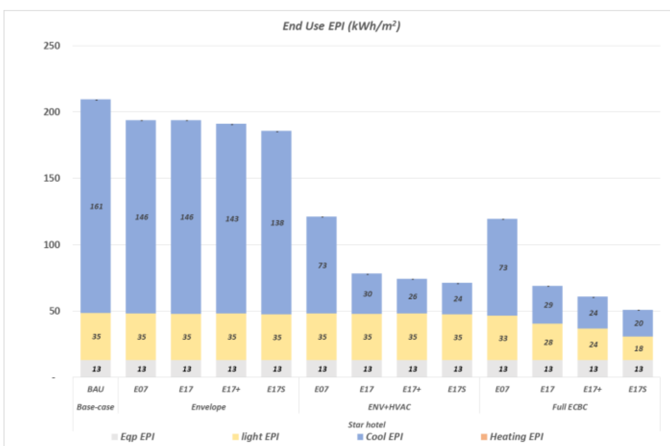
Graph 6: Secondary School - EPI after ECMs

6.1.2.7. Assembly



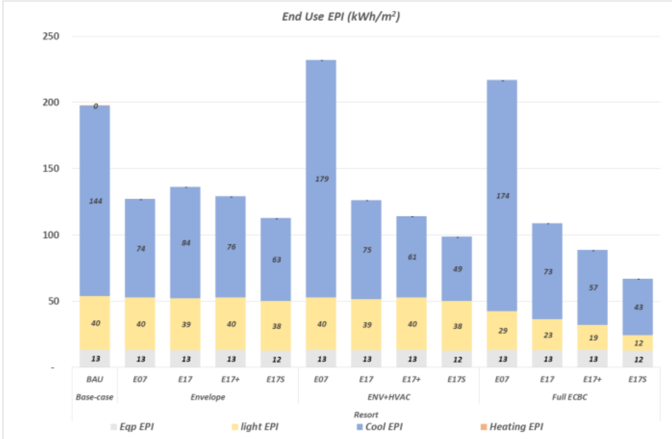
Graph 7: Assembly - EPI after ECMs

6.1.2.8. Star Hotel



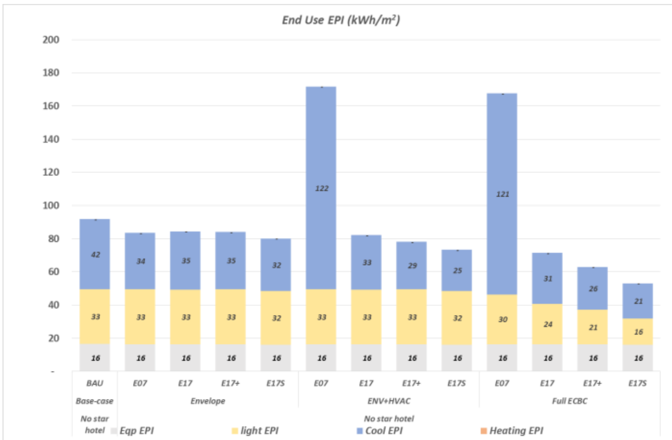
Graph 8: Star Hotel - EPI after ECMs

6.1.2.9. Resort



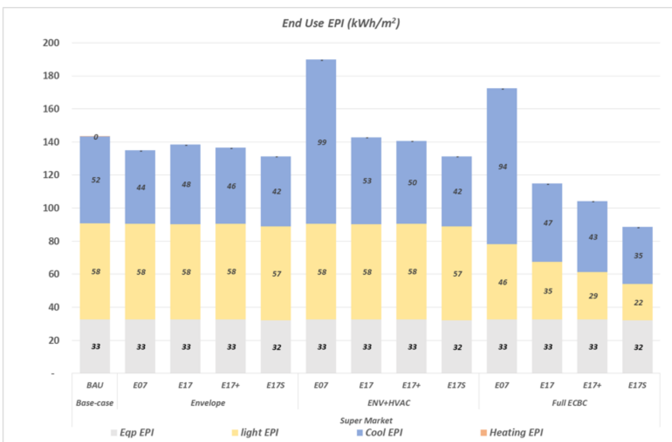
Graph 9: Resort - EPI after ECMs

6.1.2.10. No-star Hotel



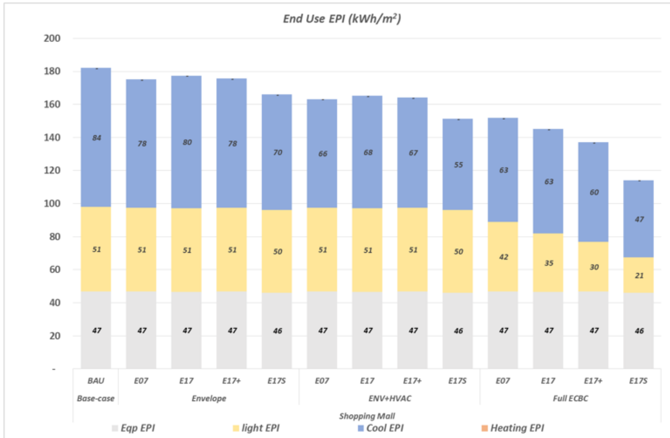
Graph 10: No-star Hotel - EPI after ECMs

6.1.2.11. Super Market



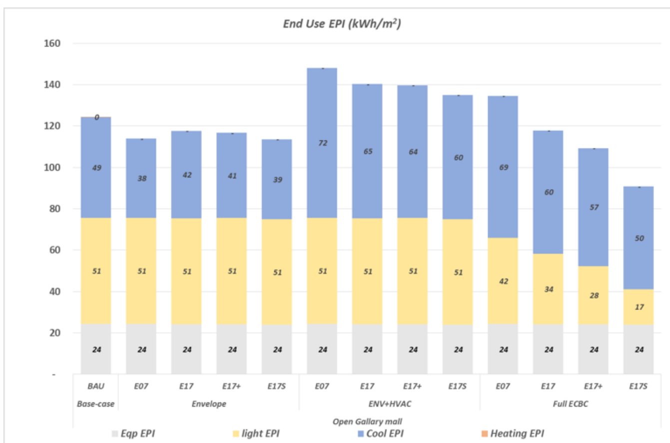
Graph 11: Super Market - EPI after ECMs

6.1.2.12. Shopping Mall



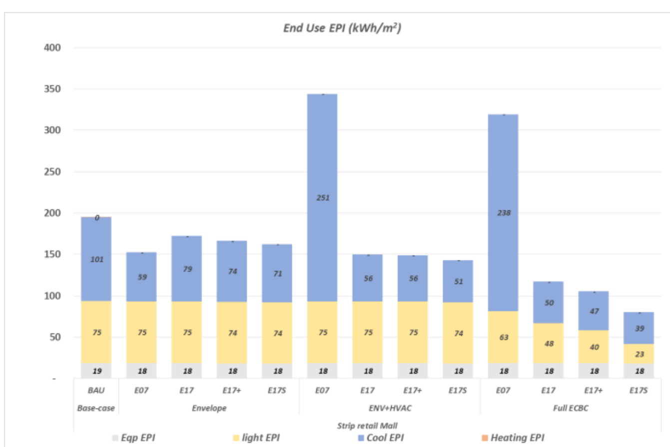
Graph 12: Shopping Mall - EPI after ECMs

6.1.2.13. Open Gallery Mall



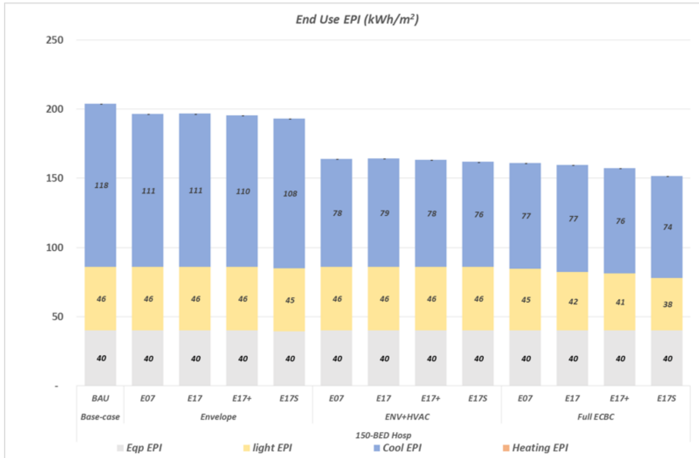
Graph 13: Open Gallery Mall - EPI after ECMs

6.1.2.14. Strip Retail Mall



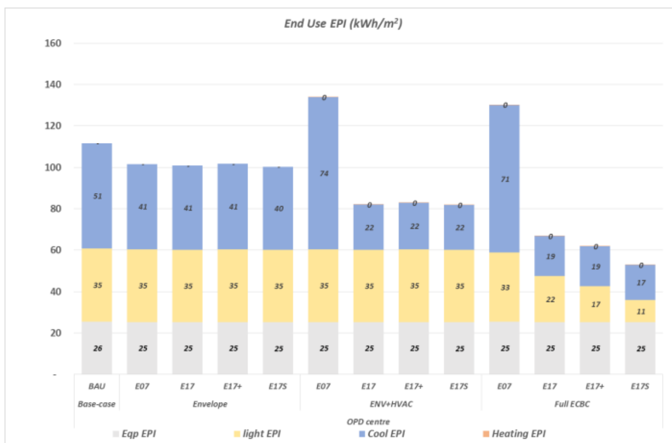
Graph 14: Strip Retail Mall - EPI after ECMs

6.1.2.15. Hospital (150 + bed)



Graph 15: Hospital (150+ bed) - EPI after ECMs

6.1.2.16. Healthcare - Outpatient



Graph 16: Healthcare - Outpatient - EPI after ECMs

6.1.2.17. EPI Comparisons

From 16 building typologies, as per ECBC, 9 building typologies were considered for the study. Energy Performance Indices of these building typologies after applying Energy Conservation Measures are as follows:

Table 4: EPI Comparisons

Energy Performance Index (EPI) Unit- KWh/m²/year		Assembly	Shopping Mall	Strip Retail Mall	Medium Office	University	Super Market	Large Office	Healthcare - OPDOPD Centre	Small Office
BAU	BAU	202.3	198.0	197.2	172.2	149.0	143.3	138.0	111.2	75.5
	ECBC 2007	177.7	176.0	153.3	149.0	128.1	135.6	134.8	102.1	71.3

Envelope measures from ECBC	ECBC 2017	175.7	178.9	173.0	148.6	128.0	139.2	135.4	101.7	72.2
	ECBC 2017+	173.4	176.4	168.0	148.4	126.0	136.8	135.1	102.2	72.1
	ECBC 2017 S	171.9	169.2	165.4	146.9	118.0	134.0	133.0	101.4	72.0
Envelope + HVAC measures from ECBC	ECBC 2007	176.9	163.1	345.0	128.0	100.8	190.7	96.6	134.7	92.7
	ECBC 2017	120.5	166.6	150.4	100.6	90.7	143.6	102.6	82.7	74.4
	ECBC 2017+	116.8	164.8	149.6	91.8	86.7	141.0	96.2	83.3	74.6
	ECBC 2017 S	115.3	154.1	145.8	88.4	83.4	134.0	93.0	82.7	74.7
Full ECBC measures from ECBC	ECBC 2007	163.6	152.5	320.0	101.9	91.6	173.3	88.3	131.0	84.2
	ECBC 2017	102.0	146.3	117.0	95.2	78.9	115.4	85.4	67.4	47.8
	ECBC 2017+	95.5	137.7	105.0	81.7	69.4	104.5	80.5	62.1	43.7
	ECBC 2017 S	89.6	116.3	81.6	70.2	56.3	90.4	76.0	53.4	40.2

7. Energy Performance at City Level (BAU and Projection)

Task three, Energy performance at the city level, was dependent on (i) the existing building stock data retrieved through the GIS approach and (ii) energy performance index of building typologies along with ECM measures. Under this task, commercial floor space projection was carried out for the year 2017-2047 based on CAGR. Distribution of ECBC compliant and non-compliant stock was projected for future years. City level total energy consumption for different scenarios was calculated and projected for building typologies, based on which, energy demand and savings potential were analyzed along with the share of savings as per building typologies. Also, Carbon dioxide not produced and cost savings (Million INR) due to electricity not produced was calculated.

Since this study relied more on spatial configurations, it will help identify opportunities to reduce peak energy demand and also help evaluate the potential of rooftop SPV integration potential. The study will be a precursor to city level stock modelling which can be replicated in other parts of the country.

7.1. MS Excel-based Projection Model

MS Excel-based Model has been prepared to calculate the projection. The model is divided into different sheets for ease of data input and data manipulation required for different scenario developments. This gives the flexibility to change assumption in accordance with the required scenario.

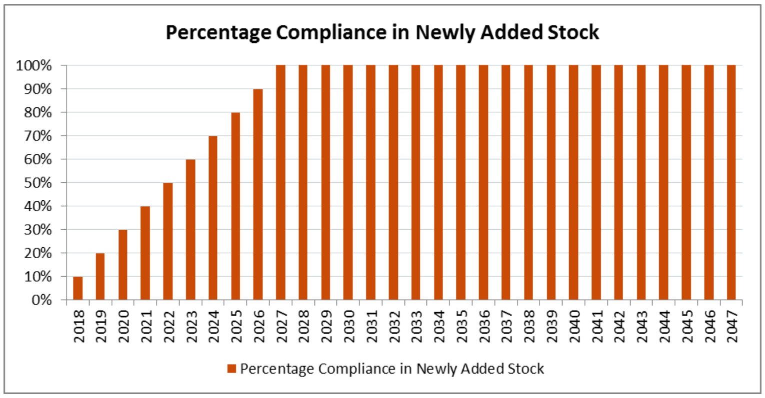
- The Index sheet contains details regarding all the sheets in the MS Excel-based model. This is also helpful to navigate across various sheets in the model.
- The Data Input Sheet requires basic information of related parameters. All the assumptions and values can be changed in this sheet according to the scenario narrative.
- Floor space calculation sheet calculates the projected floor space across different categories of buildings under consideration.
- ECBC Complaint and Non-Complaint Sheet calculates the amount of ECBC Compliant and Non-Compliant stock. Replacement of the present stock is considered in the equation. These outputs provide required details for further analysis of energy savings potential at the city level.

- Energy Savings Calculation Sheet sources data from all previous sheets and calculates the energy savings potential at the city level due to the implementation of ECBC.
- Results, Summary & Graphs Sheet reflects results from other sheets.

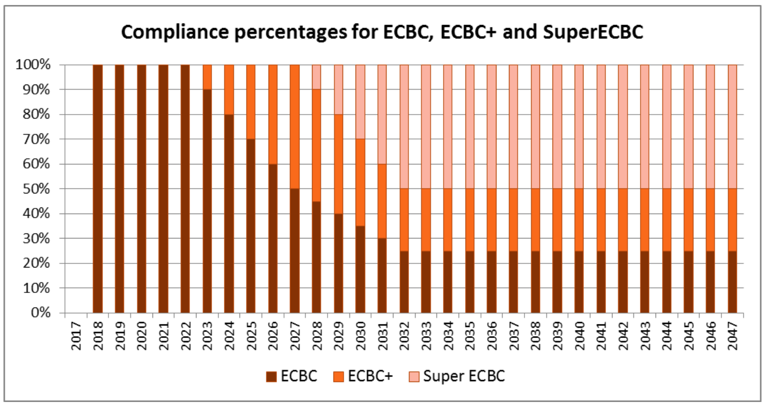
8. Key Assumptions and Limitations

Assumptions

- Floor Space Calculation -
  - Total plot sizes are as per the TP Scheme.
  - Maximum permissible Floor Space Index (FSI) allotted to the plot is consumed in total
  - The building footprint is calculated by subtracting the setback distance as per Ahmedabad Urban Development Authority (AUDA) guidelines
  - Roadside and rear side margins are calculated as mentioned in GDCR, but rear side margins are kept same as side margins. The difference between the actual and assumed margins per plot is 0.5 m from the roadside of the plot.
- Floor Space Projection –
  - Compounded Annual Growth Rate (CAGR) based - Various studies have estimated Compounded Annual Growth Rate (CAGR) for commercial floor space in India under different scenarios. LBNL-India Energy Outlook has estimated 3.0% CAGR, whereas ECO-III project estimate is 5.0% CAGR. A study under CEPT-SSEF 2015 has observed 3.18 CAGR for commercial floor space in Ahmedabad based on property tax database of the city. For the purpose of this study, we have considered LBNL estimate of 3% CAGR.
  - ECBC Compliance of the newly added stock
  - Starting from 2018, 10% of the total newly added stock will be compliant and will increase at the rate of 10% every year. By the year 2027, all the newly added stock will be ECBC compliant as shown in Graph 17.
  - Compliance percentages for ECBC, ECBC+ and SuperECBC in the total newly added compliant stock is shown in Graph 18.
  - Till 2021, all compliant stock will be following only ECBC. From 2022, 90% will be ECBC and remaining 10% will be ECBC+. ECBC+ compliance will increase by 10% every year till 2027. Post 2027, SuperECBC will get included by 10%. A detailed distribution is in Figure 2.
  - Replaced floor space - We assume that present commercial floor stock will be replaced by 1.5% every year. Thus, by the year 2047, 45% of the present stock will be replaced.



Graph 17: Percentage Compliance in Newly Added Stock



Graph 18: Compliance Percentages for ECBC, ECBC+ and Super ECBC

Limitations

- Unavailability of GIS data for 7 building typologies
  There are total 16 building typologies as per ECBC but due to unavailability of land use types, only 9 building typologies were considered for the study.

9. Calculations and Analysis

The calculations and analysis of this study are primarily divided into four major steps as follows:

- Data cleansing and categorization
- Current status – floor space, energy use and EPI
- Growth projections
- Energy projections and savings

9.1. Data Cleansing and Categorization

From the GIS database, 43 land use types were identified. 16 land use types were discarded as they were not a part of floor space considered for the study. 7 land use types were industrial and hence not considered. 10 land use types were pure and mixed residential. Rest 10 commercial land use types were assigned to 9 relevant building typologies listed in ECBC (Appendix A).

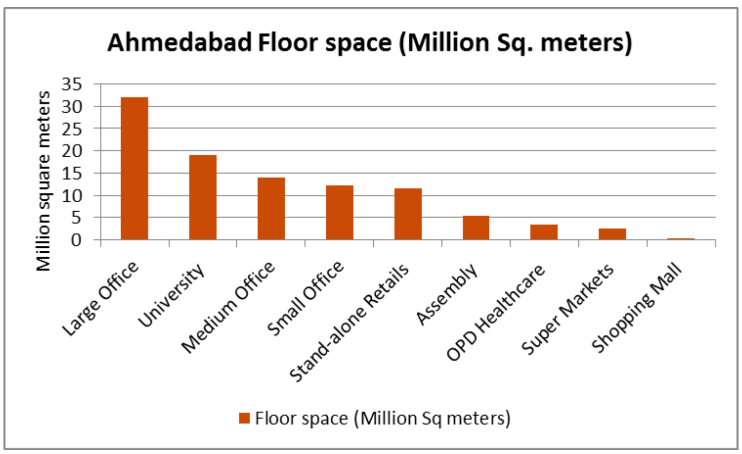
Table 5: Land Use Assigned to Building Typologies as per ECBC Details

Details	#No.
Land use categories	43
Land use categories not considered in the study	16
Land use categories (Industrial)	7
Land use categories (Residential)	10
Total building typologies (as per ECBC)	16
Building typologies (as per ECBC) considered for the study	9
Commercial land use categories assigned to 9 building typologies (as per ECBC)	10

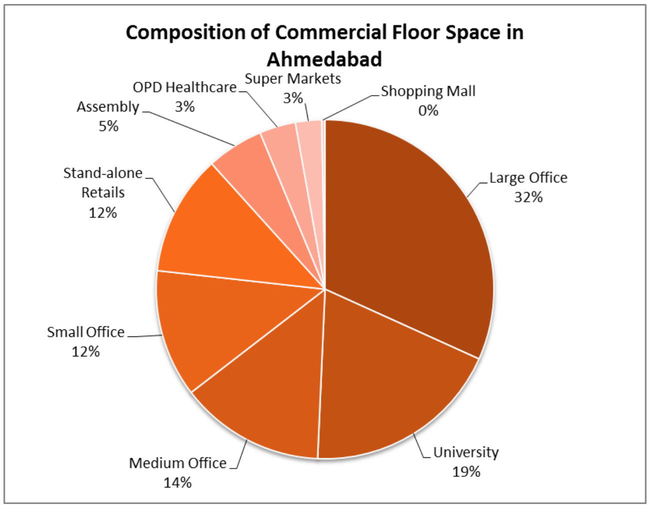
9.2. Current Status – Floor Space

9.2.1. Floor Space

Ahmedabad has a total of 101 million square meters of commercial floor space. Large offices contribute to the maximum of 32 million square meters which is 32% of the total commercial floor space. Being an education hub, the University floor space contributes to 19%, which is followed by Medium Offices (14%) and Small Offices (12%) and Stand-alone Retails (12%).



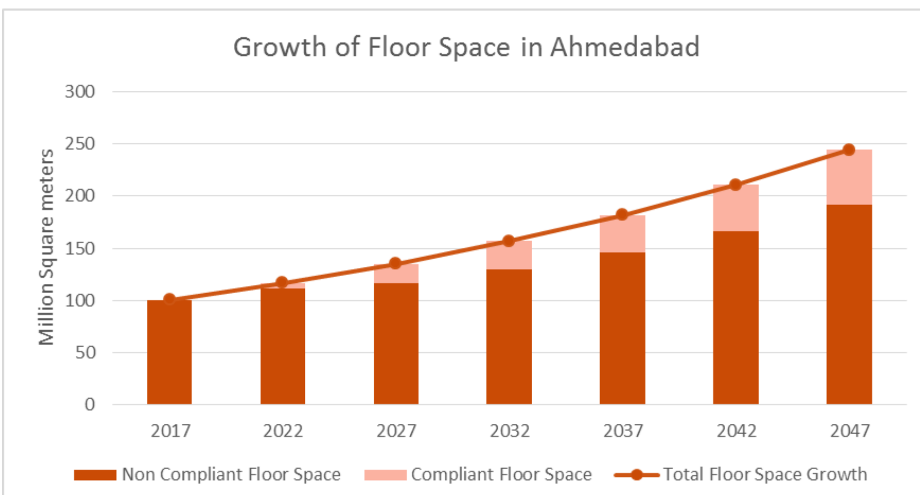
Graph 19: Commercial Floor Space as per Building Typologies in Ahmedabad



Graph 20: Composition of Commercial Floor Space in Ahmedabad

9.3. Growth Projections

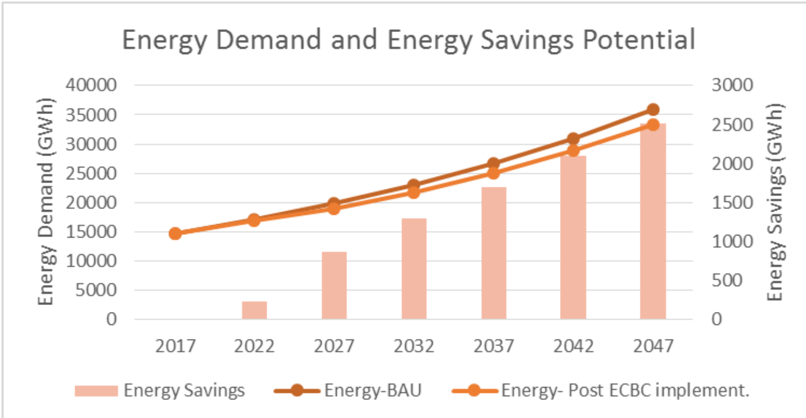
Various Compounded Annual Growth Rate (CAGR) Estimates for Commercial Floor Space were studied. This study has considered LBNL estimate of 3% CAGR. The graph shows floor space projections for Compliant and Non-compliant floor space along with total floor space from the year 2017 to 2047 at a 5-year interval.



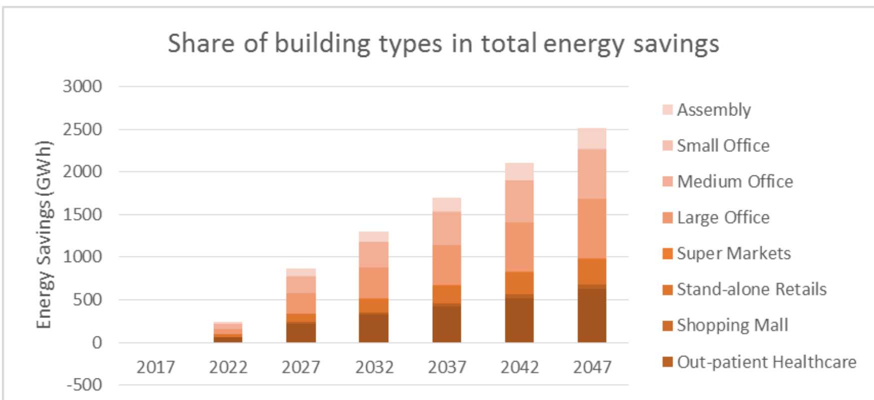
Graph 21: Floor Space Projection

9.4. Energy Projections and Savings

This section analyses energy savings potential under various scenarios of ECBC implementation.



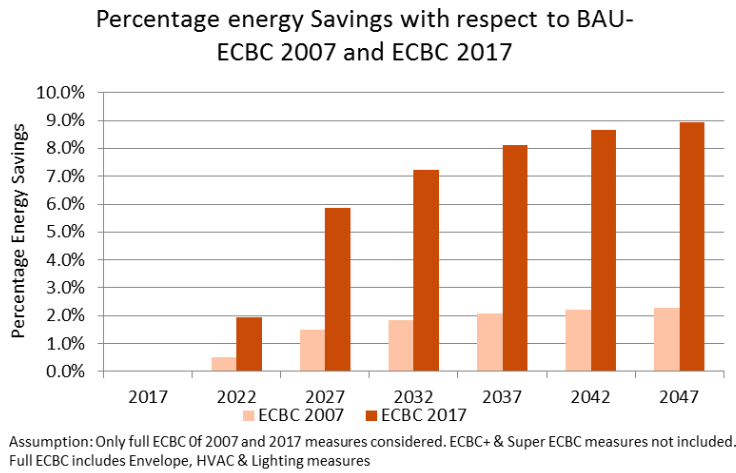
Graph 22: Energy Demand and Savings Potential



Graph 23: Share of Building Types in Total Energy Savings

9.4.1. Percentage Energy Savings with respect to BAU- ECBC 2007 and ECBC 2017

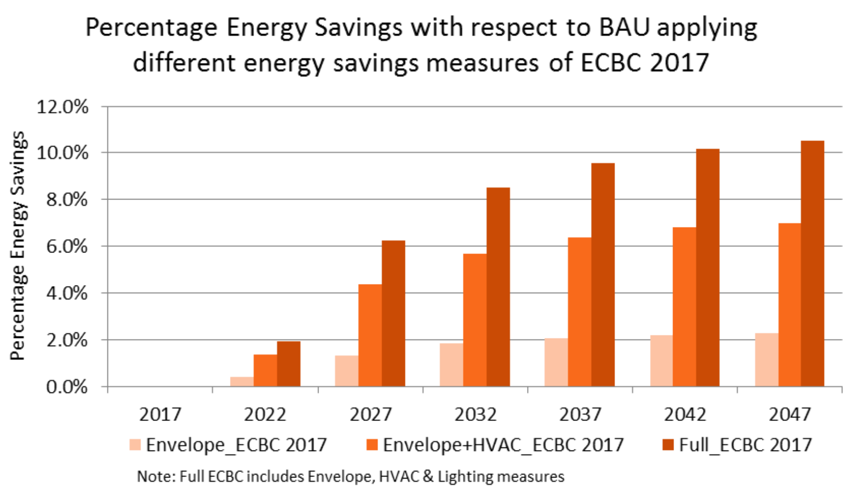
Energy Savings potential is significantly high when compared between ECBC 2007 and ECBC 2017. The study assumed that the compliant stock will be ECBC 2017 compliant. ECBC+ and Super ECBC have not been considered. Thus, EPI of ECBC 2017 is used across the total complaint stock. With the application of ECBC 2017, the study can expect savings of more than 8% with respect to the base case in the year 2047. The savings range from 2 % to 9%.



Graph 24: Percentage Energy Savings with respect to BAU - ECBC 2007 and ECBC 2017

9.4.2. Percentage Energy Savings with respect to BAU Applying Different Energy Savings Measures of ECBC 2017

Energy Savings potential at city level with respect to BAU by application of ECBC 2017 ranges from 0.5% to 10.5% depending on the energy savings measures taken. In Graph 25, we can observe the highest percentage savings for full ECBC implementation across all the years. It is also important to note that ECBC compliance of the HVAC systems contributes to the largest share in energy savings at the city level, while the Envelope measures play a significant role in the overall energy savings through the life cycle of the building. Envelope measures also prevent the energy lock-in factor of the building and also contribute to better thermal comfort and lesser HVAC demand over time.



Graph 25: Percentage Energy Savings with respect to BAU Applying Different Energy Savings Measures of ECBC 2017

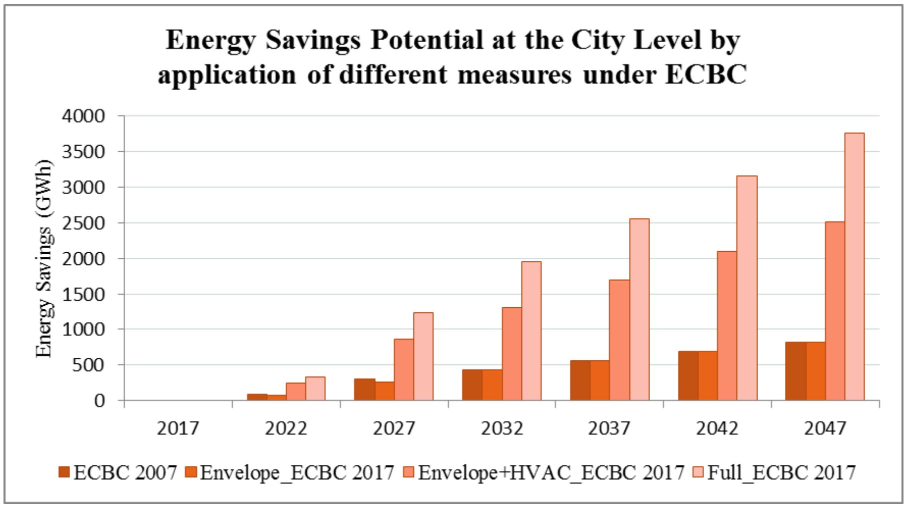
9.4.3. Energy Savings Potential under Various Scenarios of ECBC Implementation

We explored various scenarios to understand and analyze the ECBC impacts under the following scenarios:

(1) ECBC 2007: Applying all ECBC 2007 measures.

(2) ECBC 2017- Envelope measures: Applying only envelope measure from ECBC 2017.
(3) ECBC 2017- Envelope and HVAC measures: Applying envelope & HVAC measures of ECBC 2017.
(4) Full ECBC 2017: Applying envelope, HVAC and lighting measure as detailed out in ECBC 2017.

All other assumptions remain constant as detailed out in previous sections.

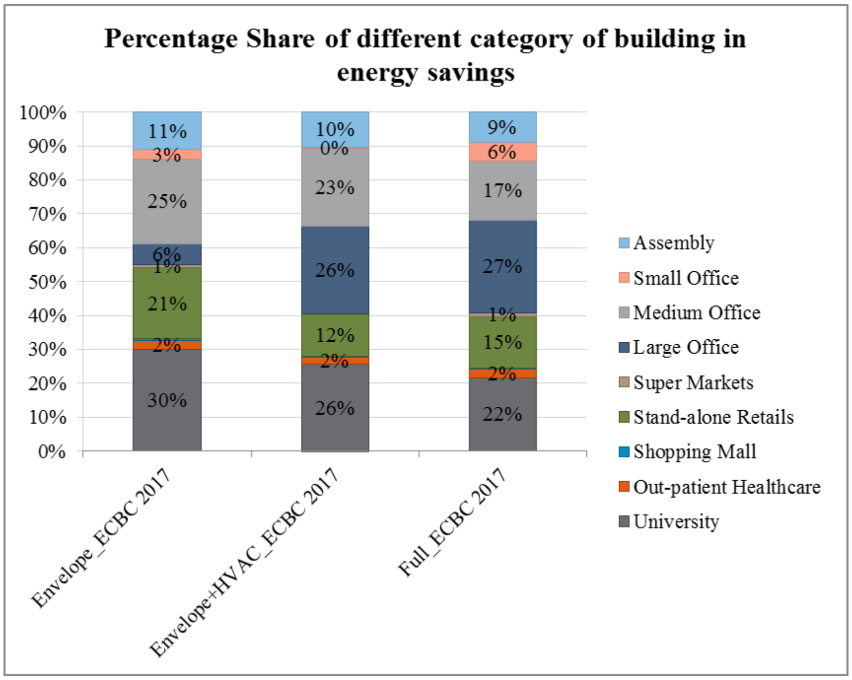


Graph 26: Energy Savings Potential at the City Level by Application of Different Measures under ECBC

Implementation of Full ECBC 2017 has an energy savings potential of 334 GWh in 2017 which will increase to 3765 GWh by the year 2047. Since stringency of ECBC 2017 is higher than ECBC 2007, we can observe that the envelope measure of ECBC 2017 can achieve savings potential level, which ECBC 2007 would have achieved, when all measures from ECBC 2007 are included. ECBC 2017 measures for HVAC can contribute to the largest share in the savings potential.

9.4.4. Percentage Share of Different Categories of Buildings in Energy Savings

The graph below throws more light in the overall percentage share in energy savings which contributes to the savings potential at the city level. The case here is, large offices followed by University, Medium offices and Stand-alone Retails when ECBC 2017 will be fully applied. It is important to observe that a Large office can save only 6% energy at city level from envelope measures, but it increases to 26% when HVAC measure is included followed by 27% when ECBC 2017 are applied in full. This is because of the fact that for a large office, total floor space is the highest in the city (32% of total commercial floor space) and the EPI of the large building has the range of 134.8 kWh/m2/yr (BAU, ECBC 2017) to 76 kWh/m2/yr (SuperECBC 2017). Both of the above factors jointly result in higher savings potential from a large office. A Medium sized office can contribute the best with the help of Envelope measures. This may be because usually there are smaller areas under HVAC. Universities have a high potential for energy savings provided they grow in accordance with the assumptions made in the study.



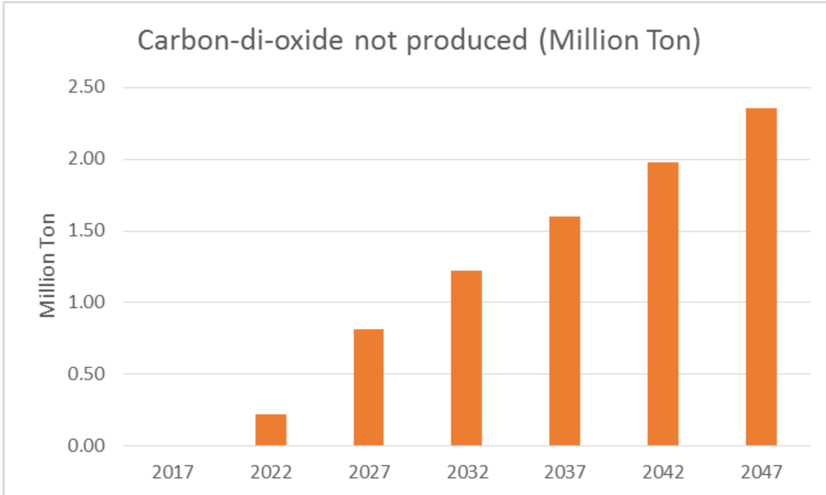
Graph 27: Percentage Share of Different Categories of Buildings in Energy Savings

9.4.5. Carbon dioxide Not Produced (Million-Ton)

Scope 2 emissions[1] were calculated CO_2 emissions were calculated based on the amount of energy savings. We considered Western grid emission factor as provided by Central Electricity Authority of India for the emission calculations. Energy savings not only save energy or cost of production but they also help reduce the amount of greenhouse gas production, of which carbon dioxide is a major component.

There can be 0.3 million tons of CO_2 savings in the year 2022, which can significantly increase to 3.5 million tons by the year 2047.

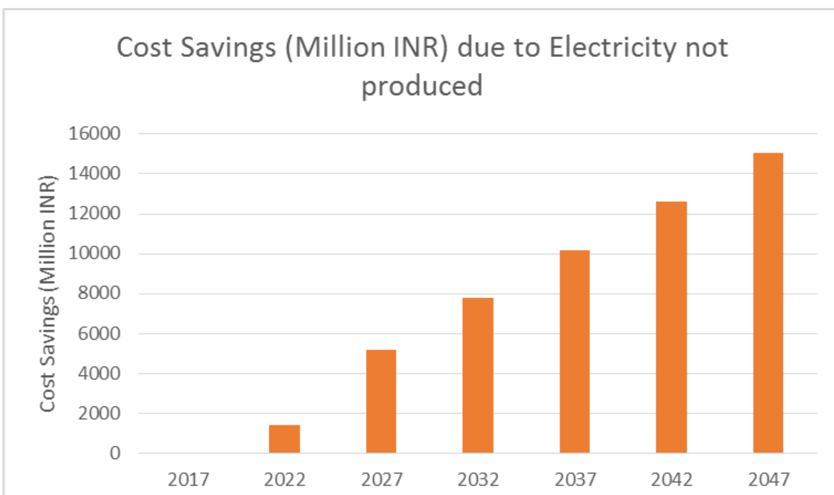
[1] **Scope 2** GHG **emissions** are indirect **emissions** from sources that are owned or controlled by the Agency. **Scope 2** includes **emissions** that result from the generation of electricity, heat or steam purchased by the Agency from a utility provider.



Graph 28: Carbon dioxide Not Produced

9.4.6. Cost Savings (Million INR) due to Electricity Not Produced

Implementation of ECBC 2017 code can save a huge cost by not producing electricity due to a reduction in energy demand at the city level. Ahmedabad alone can save 2005 million INR to 0.86 billion INR by the year 2022, assuming energy cost at a constant price of INR 6 per KWh. These savings are expected to grow at the approximate rate of 10% annually.



Graph 29: Cost Savings due to Electricity Not Produced

10. Results

The study concluded that 1 KWh/m2/year efficiency at the city level in the total existing floor space (2017 stock) at Ahmedabad can result in -

- Commercial energy saving: 0.5x GTWH/ year
- City level cost savings: 3 million INR/year
- Carbon dioxide not emitted due to building energy efficiency: 0.47 Kilo Million tons of CO2

- Avoided MWH capacity: x0.5 G MWH

11. Conclusion

The study explored the geographical mapping approach using Geographical Information System (GIS) to map the plots according to the town planning schemes and other details from Ahmedabad Development Plan. EPI was extracted using the energy simulation method using a standard model approach. These details from the mapping give us the value of floor space at the city level. EPI from the energy simulations is subsequently used in an MS Excel-based model to project energy savings at the city level. This distinct approach was adopted to develop a better and detailed understanding of floor space and energy savings at the city level.

12. Appendix

Appendix A – Land use Categories and Considered Building Typologies Assigned

	Land Use Categories	Considered Building Typologies
1	Agriculture	
2	Airport	Assembly
3	APMCs, Whole Sale Markets, Godowns, Warehouses	Super market
4	Canal	
5	Cantonment	
6	Cinema, Theaters	Assembly
7	Closed Textile Mills	
8	Commercial + Industrial	Small/Medium/Large Office – 30%
9	Commercial + Industrial + Institutional	Small/Medium/Large Office – 25% University, Academia – 25%
10	Commercial + Institutional	Small/Medium/Large Office – 30% University, Academia – 70%
11	Cremation/Burial Grounds	
12	Educational and Research	University, Academia
13	Gamtal	Small/Medium/Large Office
14	Gandhi Ashram	
15	General Industrial Zone	Small/Medium/Large Office
16	Govt./Semi Govt./Public Offices + Utility and Services	Small/Medium/Large Office
17	Heritage and Conservation Area	Small/Medium/Large Office
18	High Rise Residential	Pure Residential
19	Industrial + Institutional	University, Academia – 50%
20	Light and Heavy Industry	
21	Low Rise Residential	Pure Residential
22	Malls	Shopping Mall
23	Medical and Health	Healthcare Building- Outpatient
24	Multipurpose Open Space	
25	ONGC Well	
26	Parks and Gardens	

27	Playground	
28	Railway	
29	Religious Centers	Assembly
30	Residential + Commercial	Mixed Residential – 70% Small/Medium/Large Office – 30%
31	Residential + Commercial + Industrial	Mixed Residential – 50% Small/Medium/Large Office – 30%
32	Residential + Commercial + Industrial + Institutional	Mixed Residential – 25% Small/Medium/Large Office – 25% University, Academia – 25%
33	Residential + Commercial + Institutional	Mixed Residential – 30% Small/Medium/Large Office – 30% University, Academia – 30%
34	Residential + Industrial	Mixed Residential – 50%
35	Residential + Industrial + Institutional	Mixed Residential – 30% University, Academia – 40%
36	Residential + Institutional	Mixed Residential – 30% University, Academia – 70%
37	Retail Shopping, Shopping Center, Commercial Center	Strip Retail Mall
38	Road	
39	Slum Type, Kachcha, Unplanned, Informal Settlements Residential Use	Mixed Residential
40	Social and Cultural Center	Assembly
41	Textile Mills (Presently Functioning)	
42	Vacant Land	
43	Water Bodies	

Appendix B – Process of Assigning Land Use Type (GIS database) to Building Typologies (ECBC)

#	Particulars	Floor Space (in m²)	Land use categories #No.	Details/Comments
A	Total Floor Space	621453998.20	43	All types of land use
B	Floor Space (Land use is NA and hence Building typology is not assigned)	118964.38	NA	Land use - NA
C	Floor Space (Not included in building typology)	253513085.15	16	(1. Agriculture 4. Canal 5. Cantonment 7. Closed Textile Mills 11. Cremation/Burial Grounds 14. Gandhi Ashram 20. Light and Heavy Industry 24. Multipurpose open space 25. ONGC Well 26. Parks and Gardens 27.

				Playground 28. Railway 38. Road 41. Textile Mills (Presently Functioning) 42. Vacant Land 43. Water bodies)
D	Floor Space (Included in building typology)	367821948.68	27	(2. Airport 3. APMCs, Whole Sale Markers, Godowns, Warehouses 6. Cinema, Theaters 8. Commercial + Industrial 9. Commercial + Industrial + Institutional 10. Commercial + Institutional 12. Educational and Research 13. Gametal 15. General Industrial Zone 16. Govt. /Semi Govt. /Public offices + Utility and services 17. Heritage and Conservation Area 18. High Rise Residential, 19. Industrial + Institutional, 21. Low Rise Residential 22. Malls 23. Medical and Health 29. Religious Centers 30. Residential + Commercial 31. Residential + Commercial + Industrial 32. Residential + Commercial + Industrial + Institutional 33. Residential + Commercial + Institutional 34. Residential + Industrial 35. Residential + Industrial + Institutional 36. Residential + Institutional 37. Retail Shopping, Shopping center, Commercial center 39. Slum Type, Kachcha, Unplanned, Informal Settlements Residential Use 40. Social and Cultural Center)
E	Floor Space (Industrial)	5200455.72	27 --> 7	(8. Commercial + Industrial 9. Commercial + Industrial + Institutional 19. Industrial + Institutional 31. Residential + Commercial + Industrial 32. Residential + Commercial + Industrial + Institutional 34. Residential + Industrial 35. Residential + Industrial + Institutional)
F	Floor Space (Pure Residential)	180055414.33	27 --> 2	(18. High Rise Residential 21. Low Rise Residential)
G	Floor Space (Mixed Residential)	82026633.17	27 --> 8	(30. Residential + Commercial 31. Residential + Commercial + Industrial 32. Residential + Commercial + Industrial + Institutional 33. Residential + Commercial + Institutional 34. Residential + Industrial 35. Residential + Industrial + Institutional 36. Residential + Institutional 39. Slum Type, Kachcha, Unplanned, Informal Settlements Residential Use)
H	Floor Space (9 typologies as per ECBC)	100539445.46	27 --> 10	(Commercial excluding Industrial and Residential)

Appendix C - Floor Space as per ECBC Building Typologies

#	Particulars	Floor Space (in m^2)
1	Small Office	12254128.38
2	Medium Office	13938490.59
3	Large Office	31926060.81
4	University, Academia	19050768.10
5	Secondary School	NA
6	Primary School	NA
7	Hospital (150 + beds)	NA
8	Healthcare Building - Outpatient	3478838.06
9	Shopping Mall	319805.89
10	Open Gallery Mall	NA
11	Strip Retail Mall	11602802.61
12	Super Market	2512574.94
13	Hotel 4/5 star	NA
14	Resort	NA
15	Hotel (no-star)	NA
16	Assembly	5455976.08

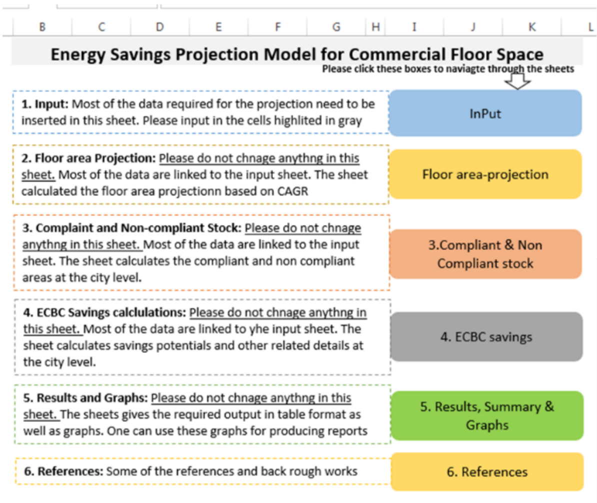
Appendix D - EPI of all 16 building typologies after applying Energy Conservation Measures

		BAU	ECBC 2007	ECBC 2017	ECBC 2017+	ECBC 2017 Super
Building Typology	**ECM Category**	**EPI**	**EPI**	**EPI**	**EPI**	**EPI**
Small Office	Envelope	76	71	72	72	72
Small Office	Envelope +HVAC		93	74	75	75
Small Office	Full ECBC		84	48	44	40
Medium Office	Envelope	172	149	149	148	147
Medium Office	Envelope + HVAC		128	101	92	88
Medium Office	Full ECBC		102	95	82	70
Large Office	Envelope	138	135	135	135	133
Large Office	Envelope + HVAC		97	103	96	93
Large Office	Full ECBC		88	85	81	76
University	Envelope	149	128	128	126	118
University	Envelope + HVAC		101	91	87	83
University	Full ECBC		92	79	69	56
Primary School	Envelope	66	64	63	63	63
Primary School	Envelope + HVAC		87	62	59	57
Primary School	Full ECBC		80	53	47	44
Secondary School	Envelope	56	51	55	55	54

Secondary School	Envelope + HVAC		62	58	56	54
Secondary School	Full ECBC		57	51	43	34
Assembly	Envelope	202	178	176	173	172
Assembly	Envelope + HVAC		177	120	117	115
Assembly	Full ECBC		164	102	95	90
Star Hotel	Envelope	199	186	187	184	181
Star Hotel	Envelope + HVAC		116	76	72	69
Star Hotel	Full ECBC		113	67	58	50
Resort	Envelope	197	129	141	132	121
Resort	Envelope + HVAC		236	130	116	106
Resort	Full ECBC		221	112	90	72
No-star Hotel	Envelope	92	84	85	84	82
No-star Hotel	Envelope + HVAC		172	83	78	75
No-star Hotel	Full ECBC		168	72	63	54
Super Market	Envelope	143	136	139	137	134
Super Market	Envelope + HVAC		191	144	141	134
Super Market	Full ECBC		173	115	104	90
Shopping Mall	Envelope	198	176	179	176	169
Shopping Mall	Envelope + HVAC		163	167	165	154
Shopping Mall	Full ECBC		152	146	138	116
Open Gallery Mall	Envelope	124	114	118	117	115
Open Gallery Mall	Envelope + HVAC		148	141	140	136
Open Gallery Mall	Full ECBC		135	118	109	92
Strip Retail Mall	Envelope	197	153	173	168	165
Strip Retail Mall	Envelope + HVAC		345	150	150	146
Strip Retail Mall	Full ECBC		320	117	105	82
150 + BED Hospital	Envelope	223	212	213	211	211
150 + BED Hospital	Envelope + HVAC		165	165	164	162
150 + BED Hospital	Full ECBC		162	160	158	152
OPD Centre	Envelope	111	102	102	102	101
OPD Centre	Envelope + HVAC		135	83	83	83
OPD Centre	Full ECBC		131	67	62	53

Appendix E – MS Excel-based Projection Model

Index Sheet



Please use this sheet to navigate across the various sheets in this excel file.

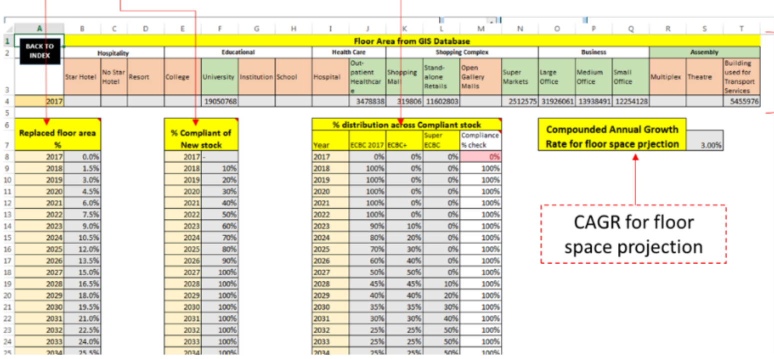
Click on the colored boxes with details to navigate between sheets

Data Input Sheet

Assumption for Replaced floor area (% at city level)

Assumption for Percentage compliance from the total stock

Assumption for Percentage compliance distribution of ECBC, ECBC+ & SuperECBC in the compliant stock



Floor area under various building categories

CAGR for floor space projection

Insert EPI for
(1) Base Case
(2) ECBC
(3) ECBC+
(4) SuperECBC

Floor Space Projection Sheet

Floor Area Projection	Hospitality			Educational				Health Care		Shopping Complex				Business			Assembly		
CAGR 3%	Star Hotel	No Star Hotel	Resort	College	University	Institution	School	Hospital	Out-patient Healthcare	Shopping Mall	Stand-alone Retails	Open Gallery Malls	Super Markets	Large Office	Medium Office	Small Office	Multiplex	Theatre	Building used for Transport Services
2017	0	0	0	0	19050768	0	0	0	3478838	319806	11602803	0	2512575	31926061	13938491	12254128	0	0	5455976
2018	0	0	0	0	19622291	0	0	0	3583203	329400	11950887	0	2587952	32883843	14356645	12621752	0	0	5619655
2019	0	0	0	0	20210960	0	0	0	3690699	339282	12309413	0	2665591	33870358	14787345	13000405	0	0	5788245
2020	0	0	0	0	20817289	0	0	0	3801420	349461	12678696	0	2745558	34886469	15230965	13390417	0	0	5961892
2021	0	0	0	0	21441807	0	0	0	3915463	359944	13059057	0	2827925	35933063	15687894	13792129	0	0	6140749
2022	0	0	0	0	22085062	0	0	0	4032927	370743	13450828	0	2912763	37011055	16158531	14205893	0	0	6324972
2023	0	0	0	0	22747613	0	0	0	4153915	381865	13854353	0	3000146	38121386	16643287	14632070	0	0	6514721
2024	0	0	0	0	23430042	0	0	0	4278532	393321	14269984	0	3090150	39265028	17142585	15071032	0	0	6710162
2025	0	0	0	0	24132943	0	0	0	4406888	405121	14698083	0	3182855	40442979	17656863	15523163	0	0	6911467
2026	0	0	0	0	24856931	0	0	0	4539095	417274	15139026	0	3278340	41656268	18186569	15988858	0	0	7118811
2027	0	0	0	0	25602639	0	0	0	4675267	429792	15593196	0	3376691	42905956	18732166	16468524	0	0	7332376
2028	0	0	0	0	26370718	0	0	0	4815525	442686	16060992	0	3477991	44193135	19294131	16962580	0	0	7552347
2029	0	0	0	0	27161840	0	0	0	4959991	455967	16542822	0	3582331	45518929	19872955	17471457	0	0	7778917
2030	0	0	0	0	27976695	0	0	0	5108791	469646	17039107	0	3689801	46884497	20469143	17995601	0	0	8012285
2031	0	0	0	0	28815996	0	0	0	5262055	483735	17550280	0	3800495	48291032	21083218	18535469	0	0	8252653

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This sheets calculates the projected floor space across different category of buildings under consideration.

ECBC Complaint and Non-Compliant Stock Sheet

Commercial Compliant and Non Compliant stockstock

	Total stock		% floor area calculations		Replaced floor area		Added floor area		for commliance/ non compliance		FOR MODEL		FOR MODEL	
	University	sl no			Replaced floor area %	Replaced floor area	Commercial floor area ADDED %	Floor added	Total area added	% Compliant of New stock(replaced+ added)	COMPLIANT new added stock	ECBC Compliant Floor area % (of total floor stock present that year)	Non-compliant stock (Sq.m)	Total stock
2017	19050768.1	1	Present stock	2017	0.0%	-	0%	-	-	-	-	-	19,050,768	19,050,768
2018	19622291.15	2	Projected	2018	1.5%	285,762	3.0%	571,523	857,285	10%	85,728	0.44%	19,536,563	19,622,291
2019	20210959.88	3	Projected	2019	3.0%	571,523	3.0%	588,669	1,160,192	20%	232,038	1.15%	19,978,922	20,210,960
2020	20817288.68	4	Projected	2020	4.5%	857,285	3.0%	606,329	1,463,613	30%	439,084	2.11%	20,378,205	20,817,289
2021	21441807.34	5	Projected	2021	6.0%	1,143,046	3.0%	624,519	1,767,565	40%	707,026	3.30%	20,734,781	21,441,807
2022	22085061.56	6	Projected	2022	7.5%	1,428,808	3.0%	643,254	2,072,062	50%	1,036,031	4.69%	21,049,031	22,085,062
2023	22747613.4	7	Projected	2023	9.0%	1,714,569	3.0%	662,552	2,377,121	60%	1,426,273	6.27%	21,321,341	22,747,613
2024	23430041.81	8	Projected	2024	10.5%	2,000,331	3.0%	682,428	2,682,759	70%	1,877,931	8.02%	21,552,110	23,430,042
2025	24132943.06	9	Projected	2025	12.0%	2,286,092	3.0%	702,901	2,988,993	80%	2,391,195	9.91%	21,741,748	24,132,943
2026	24856931.35	10	Projected	2026	13.5%	2,571,854	3.0%	723,988	3,295,842	90%	2,966,258	11.93%	21,890,674	24,856,931
2027	25602639.29	11	Projected	2027	15.0%	2,857,615	3.0%	745,708	3,603,323	100%	3,603,323	14.07%	21,999,316	25,602,639
2028	26370718.47	12	Projected	2028	16.5%	3,143,377	3.0%	768,079	3,911,456	100%	3,911,456	14.83%	22,459,263	26,370,718
2029	27161840.02	13	Projected	2029	18.0%	3,429,138	3.0%	791,122	4,220,260	100%	4,220,260	15.54%	22,941,580	27,161,840
2030	27976695.23	14	Projected	2030	19.5%	3,714,900	3.0%	814,855	4,529,755	100%	4,529,755	16.19%	23,446,940	27,976,695
2031	28815996.08	15	Projected	2031	21.0%	4,000,661	3.0%	839,301	4,839,962	100%	4,839,962	16.80%	23,976,034	28,815,996
2032	29680475.96	16	Projected	2032	22.5%	4,286,423	3.0%	864,480	5,150,903	100%	5,150,903	17.35%	24,529,573	29,680,476
2033	30570890.24	17	Projected	2033	24.0%	4,572,184	3.0%	890,414	5,462,599	100%	5,462,599	17.87%	25,108,292	30,570,890
2034	31488016.95	18	Projected	2034	25.5%	4,857,946	3.0%	917,127	5,775,073	100%	5,775,073	18.34%	25,712,944	31,488,017
2035	32432657.46	19	Projected	2035	27.0%	5,143,707	3.0%	944,641	6,088,348	100%	6,088,348	18.77%	26,344,310	32,432,657
2036	33405637.18	20	Projected	2036	28.5%	5,429,469	3.0%	972,980	6,402,449	100%	6,402,449	19.17%	27,003,189	33,405,637
2037	34407806.3	21	Projected	2037	30.0%	5,715,230	3.0%	1,002,169	6,717,400	100%	6,717,400	19.52%	27,690,407	34,407,806
2038	35440040.49	22	Projected	2038	31.5%	6,000,992	3.0%	1,032,234	7,033,226	100%	7,033,226	19.85%	28,406,814	35,440,040
2039	36503241.7	23	Projected	2039	33.0%	6,286,753	3.0%	1,063,201	7,349,955	100%	7,349,955	20.14%	29,153,287	36,503,242
2040	37598338.95	24	Projected	2040	34.5%	6,572,515	3.0%	1,095,097	7,667,612	100%	7,667,612	20.39%	29,930,727	37,598,339
2041	38726289.12	25	Projected	2041	36.0%	6,858,277	3.0%	1,127,950	7,986,227	100%	7,986,227	20.62%	30,740,062	38,726,289
2042	39888077.8	26	Projected	2042	37.5%	7,144,038	3.0%	1,161,789	8,305,827	100%	8,305,827	20.82%	31,582,251	39,888,078

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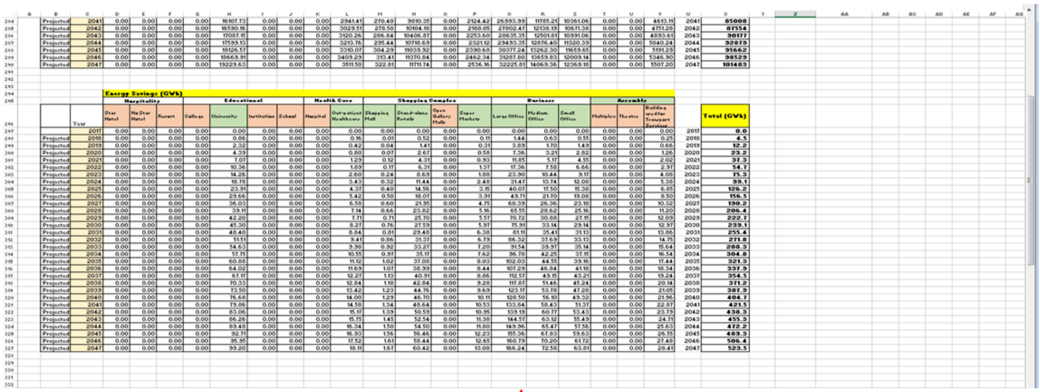
This sheets calculates the amount of ECBC Complaint and Non-Complaint stock. Replacement of the present stock has been considered in the equation. These output provide the required details for further analysis of energy savings potential at the city level.

Energy Savings Calculations Sheet



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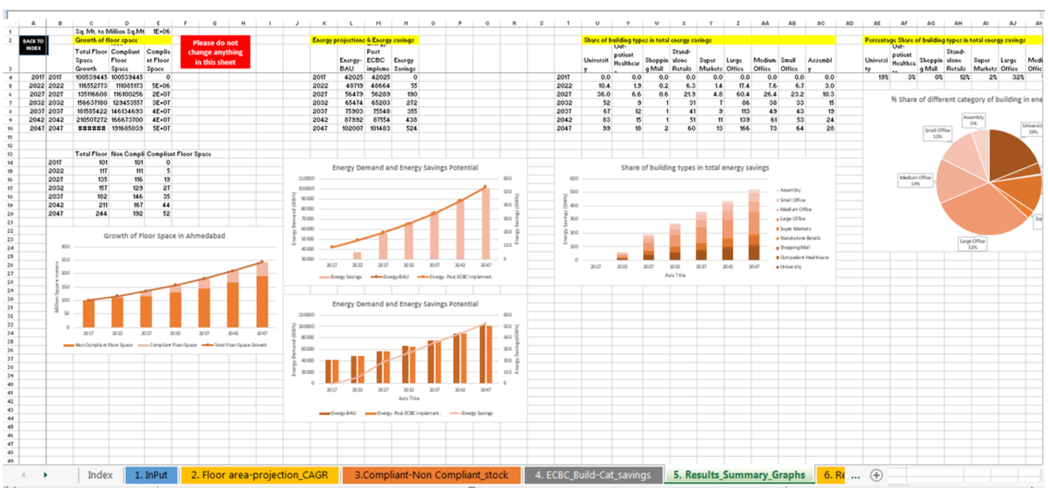
This sheets source data from all previous sheets and calculates the energy savings potential at the city level due to implementation of ECBC.

Results, Summary & Graphs Sheet



Please do not change anything here.
Results from other sheets are reflected on this sheet. The graphs and results tables can be used in the reports.