A

THESIS REPORT

ON

INVESTIGATION OF ENERGY CONSUMPTION PATTERN IN RESIDENTIAL NEIGHBOURHOOD: CASE STUDY, CHITRAKOOT, JAIPUR

IS SUBMITTED AS A PARTIAL FULFILLMENT OF THE

MASTER OF PLANNING

BY

ABHIMANYU CHAUDHARY

(2017PAR5417)

UNDER THE GUIDANCE OF

Dr. NAND KUMAR

Department of Architecture & Planning

DEPARTMENT OF ARCHITECTURE & PLANNING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF ARCHITECTURE & PLANNING
MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY
JAIPUR (RAJASTHAN) 302017

CERTIFICATE

This is certified that the thesis report entitled **"INVESTIGATION OF ENERGY CONSUMPTION PATTERN IN RESIDENTIAL NEIGHBOURHOOD: CASE STUDY, CHITRAKOOT, JAIPUR"** prepared by Abhimanyu Chaudhary (ID-20177PAR5417), in the partial fulfilment of the award of the degree Masters of Planning of Malaviya National Institute of Technology Jaipur is a record of bonafied research word carried out by him under my supervision and is hereby approved for submission. The contents of this thesis work, in full or in parts, have not been submitted to any other institute or university for the award of any degree or diploma.

Date: **Dr. Nand Kumar**

Place: Department of Architecture & Planning MNIT Jaipur

DEPARTMENT OF ARCHITECTURE & PLANNING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY

JAIPUR (RAJASTHAN) 302017

CANDIDATE'S DECLARATION

I hereby certify that the following work presented in the dissertation report titled "**INVESTIGATION OF ENERGY CONSUMPTION PATTERN IN RESIDENTIAL NEIGHBOURHOOD: CASE STUDY, CHITRAKOOT, JAIPUR**" submitted in partial fulfillment of the requirements for the award of degree of M.Plan (Urban Planning) is an authentic record of my own work carried out during the period of July 2018 to June 2019 under the supervision of Dr. Nand Kumar, Department of Architecture and Planning, Malaviya National Institute of Technology, Jaipur, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree of this or any other institute.

Abhimanyu Chaudhary

This is to certify that the above statement made by the candidate is true to the best of my knowledge.

Dr. Nand Kumar

Dissertation Supervisor

The M. Plan viva-voce examination of Mr. Yogesh Sharma (M.Plan Student), held on ____________________

External Examiner External Examiner

Dr. Pooja Nigam	**Dr. Satish Pipralia**	**Ar. Meenu Varshney**
Coordinator	DPGC Convener	Head of Department

ACKNOWLEDGEMENT

I want to express the most profound appreciation to my dissertation guide Dr. Nand Kumar, who has the attitude and the substance of a genius: he continually and convincingly conveyed a spirit of adventure in regard to research, and an excitement in regard to teaching. Without his guidance and persistent help, this dissertation would not have been possible.

I would like to thank all my panel members, Ar. Ram Niwas, Dr. Nand Kumar, for their constant guidance and review of my work at every stage throughout the year. I want to thank Dr. Satish for sharing his experiences regarding Energy Components in Housing. I want to thank Dr. Jerome Kaempf and his team for in support in software for analysis. In addition, a thank you to Ms Shikha, who demonstrated to me concern of the topic. A big thanks to Mrs. Rachna from Samadhan, Mr. Rakesh and Mr. Chandresh From Samadhan for helping me sort my case studies and providing the required data needed in this research. It was a pleasure to learn from their experiences in the field of energy.

I would like to thank Himanshu for his help in conducting surveys in different parts of Jaipur City and for many memorable evenings out and in. Above all, I am grateful to my Parents for trusting in me and for their financial support. They have always let me fly to pursue my dreams and good-naturedly put-up with my emotional and physical distance during long stretches.

ABSTRACT

The energy demands of the building are getting changed with the urban forms. There are different software available for the computing the energy demand of the locality and buildings. The climatic conditions for the specific urban area are combines and these softwares facilitate in computing the demand of energy for heating and cooling that area. The energy demand of the Chitrakoot locality is calculated in this study. The CitySim simulation learning software is employed in order to estimate the demand of energy. The detailed energy simulation of the entire zone is calculated for determining the minimum requirement of the electricity for the purpose of cooling and lighting. In this thesis, different case studies and literatures are studied, survey are taken for collecting the sufficient information required for estimating the energy performance of that particular zone. The software tool is employed for energy simulation that involves the creation of 3-D model of the associated location. The created model is imported in the CitySim. There are several parts in the software, the canvas, district properties and other. The selection of annual information related to weather situation, building properties, components of the wall, roof, floor and the thickness facilitates in managing the energy consumption. Through changing materials, insulation thickness, solar panels, the energy consumption will be managed. It facilitated in increasing the understanding related to the different factors that impacts the consumption of energy. With the inclusion of suggestions and recommendations, there would be great chances of reducing the energy demand at some extent.

Contents

List of Figures

List of Tables

1. Introduction

1.1 Brief Idea

The process of planning and modelling are the two basic levels involved for planning the design pattern of the buildings. This can be classified on the basis of the neighbourhood scale. Neighbourhood scale model is designed by the urban planners and developers help in developing business-scale models. The objective of this study is to use the simulation CitySim software for estimating the energy demands (Abdullahi, et al., 2015). The energy demands of the buildings and the specification of the properties of building is understood using the analytical tools and software. The requirement is the comprehensive knowledge for implementing effective plans for designing the buildings and more accurate knowledge related to building characteristics as well as emission factors with an intention to reduce the demand of energy in the residential sector. CitySim is the software incorporated for determining the energy demand required for the purpose of cooling and lighting. It study several cases and conduct surveys for gathering information and discuss the results in order to determine the factors that influence the energy demands of the buildings (Ascione, et al., 2014).

1.2 World Energy Consumption

The energy demand is increasing with the increase in population. The total world population in the year 2005 is 6.45 billion, out of which 3.17 billion populations is urban population. The study depicts that around 60% of the population will reside in the cities by the year 2030. Nowadays, there is the great availability of the resources that are renewable like bio-mass, solar energy, hydro-power, wind energy and many more and non-renewable those are obtained by processing the fossil-fuels and therefore these resources help in fulfilling the energy requirements. But it has been found that the rate of consumption of fossil fuels is higher that its rate of generation that degrades the surrounding and increases the problem related to resource scarcity (Abdullahi, et al., 2015).

Table 1.1 Energy Sources

Energy Sources	
Renewable	**Non-Renewable**
Energy generated from Sun Solar Biomass Bio-fuels Wind	**Energy generated from fossil-fuels** Coal Tar sands Oil Natural Gas
Energy generated from Gravity Hydropower Tidal	**Energy generated from atoms** Nuclear
Energy generated from the interior of the Earth Geo-thermal	

(Source: Abdullahi, et al., 2015)

Global energy consumption is the energy consumed all across the world by different individuals or organizations. The climatic conditions and income level are the factors influencing the consumption of energy. However the major differences in the energy demand can be seen in the developed and developing nations. United States consumes far greater energy than the Germany. The largest consumer of the energy is China, the 40% of the world's energy consumption is consumed by the US and China together (Ascione, et al., 2013).

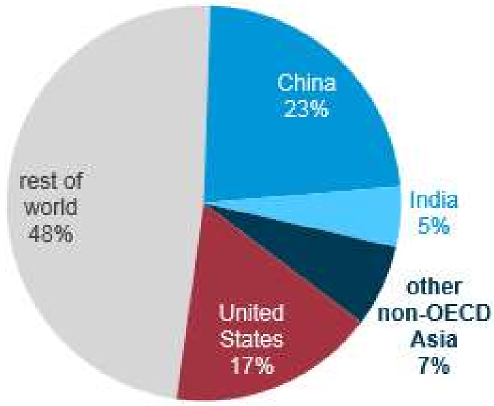


Figure 1.1: World's primary energy consumption 2015 ***(Source: Urban Science, 2017)***

The energy consumption is doubled over 35 years from 1971 to 2005. In 2017, China consumes around 23.2% of energy consumption, US consumes 16.5% and India consumes 5.6% of the total world's population (Donkers, 2013).

Traditional Precedents

The inclination of winter heat gain and declination of summer heat gain to buildings is attained through stretching the courtyard farm compounds from east to west in a village named as Czech village (Hachem, et al., 2012).

Figure 1.2: Locenice, Czech Republic

(Source: International PUARL Conference, 2012)

In a diurnal and dry climate as that of Afghanistan or New Mexico, there are individuals who work outdoors while the duration of winters (Travel, 2012). At night, in order to sleep, they retreat inside. While during summer, the reverse pattern is that they work inside the doors during the day in order to prevent heat and sleep on the roof during the cooler nights (Hachem, et al., 2012).

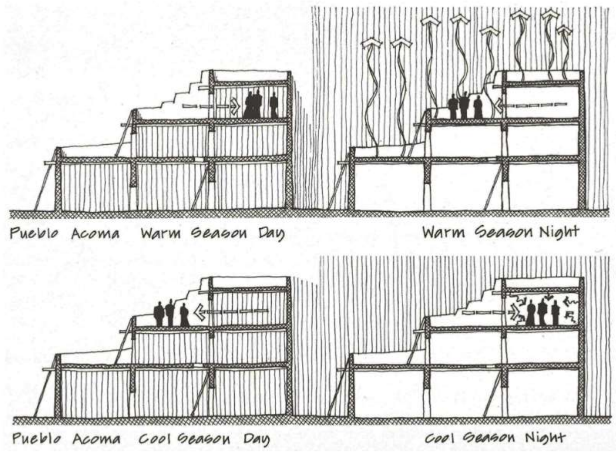


Figure 3: Acoma Pueblo; From G.Z. Brown, Sun, Wind, and Light, (John Wiley & Sons, Inc. 1985) Used by permission

Figure 1.3: Acoma Pueblo

(Source: International PUARL Conference, 2012)

1.3 Energy Consumption in Developed Countries

An industrialized country with a great economy is the one that is considered as the developed country. For an instance, United States of America, Australia, Canada, France, Italy, United Kingdom and many more. The consumption of energy is greater in the developed countries like the energy consumption in the America is 25% that have only the 5% of the world's population. This extensive consumption of energy results in this statement that the country is required to go on energy-diet for balancing the energy requirements. The focus of this report is on the effective consumption of energy, the efficient usage of those sources of energy that can generate less power. Using the renewable energy, fossil fuels and reusable materials would support in reducing the consumption of energy. The essential fossil fuels include the oil, natural gas and coal (Jusuf, et al., 2017).

1.3.1 Energy Consumption in Germany

It has been found out that from the energy consumption pattern of Germany that around 85% of the energy that USA is using is generated from fossil fuels and only the 15% is generated from the renewable sources (Keirstead, et al., 2012).
This can be observed with the pie-chart represented in the figure. Further, the 18% of the coal and 13% gas are the fossil fuels and 23% nuclear energy is accounted of the total energy (Mauree, et al., 2017).

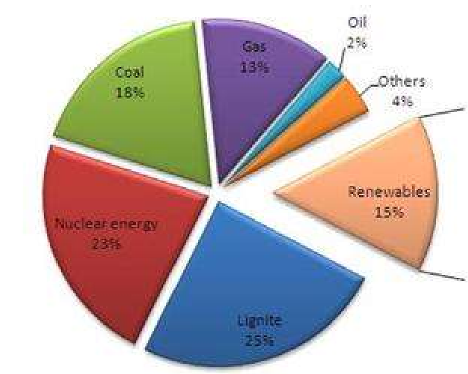


Figure 1.4: Germany Energy Consumption

(Source:* Sustainability, *2018)

This subsequent energy flow diagram provides an idea related to the sharing of energy among different sectors in the year 2009. Clearly, it depicts the high degree of reliance on the import of energy that is around 70%. In process of conversion, 25% of the total energy is lost, therefore the availability of energy for final utilisation is 8714 PJ out of the 13398 PJ. This final utilisation of energy is evenly distributed in the given three sectors that are households, industry and transport. The minor share is only represented by the services and trade.

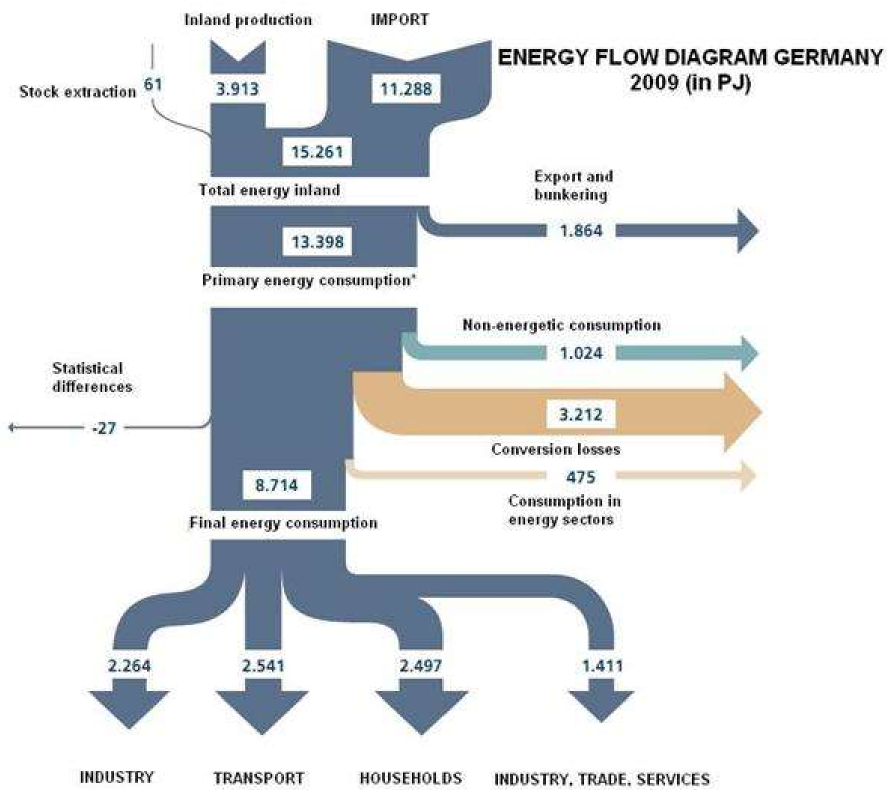


Figure 1.5: Energy Flow Diagram

(Source: Renewable and sustainable energy reviews, 2009)

1.3.2 Energy Consumption in UK

In 2017, the largest share in the final consumption of energy is 40% that is accounted by the transport sector. The 28% of the energy is accounted by the domestic sector, 17% by the industry and the rest 15% is accounted by the service sector. Here, the total energy consumption is 141,175 ktoe. The consumption has uplifted with the coming years, in field of transportation, the 43% of the increase is accounted by the petroleum and 24% with the gas. The utilisation of gas in field of domestic sector is 58% of those fuels and sectors which see a declination (Mauree, et al., 2018).

The maximum of the additional consumption is found to be in field of domestic and service sectors. It had been observed that these are the sectors that utilise more proportion of energy for the purpose of water heating and space especially the domestic sector. On the basis of fuel, the largest proportion of difference is represented by the gas. The residential customers are most commonly using the gas for the purpose of space and water heating (Moghadam, et al., 2016).

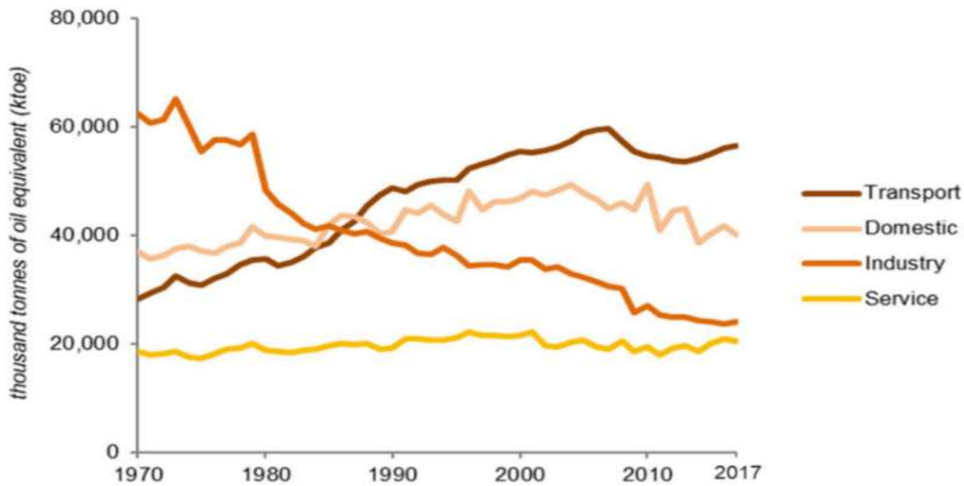


Figure 1.6: Energy Consumption in different sectors

(Source: Sustainability, 2018)

1.4 Energy Consumption in Developing Country

1.4.1 Energy Consumption in India

The consumption of energy grows the fastest in developing countries like India and it will rise more by 2040. Annually, it is found to be uplifted by 4.2% which is very faster as compared to any other economies globally. The chance of overtaking China that has the largest energy growth market has been increased and it can be happened by the late 2020s. The second largest sources for the production of domestic energy will overtake gas as well as soil by 2020 (Moghadam, et al., 2016).

The demand growth of 165% by India is around thrice of the entire non-OECD growth of 61%. This pace of growth is even greater than the BRIC countries: Brazil (+60%), Russia (+6%) and China (+41%). The share of India in rise of global demand will be 5% by 2016 to 11% in 2040. The biggest growth can be seen with the increase in demand of coal which is amplifying by 132%. The renewables (+1409%), nuclear (+412%), hydro (+80%), gas (+185%) and oil (+129%) are following it. The evolution of energy mix is at slow pace in India. By 2040, the fossil fuels will meet 82% of the requirements down from 93% in the past year 2016. The falling from 57% in 2016 to 50% by 2040 can be realized in meeting the demands of coal. The rise can be seen in the use of renewable which is from 2% in 2016 to 13% by 2040 (Mutani, et al., 2016).

The consumption of power more than trebles (+241%) and the dominant fuel source is found to be coal that share of generation falls from 77% to 64% from the year 2016 by 2040 as renewables uplifts from 5% to 23%. The energy utilisation in field of transport is 4.4% annually and the dominant fuel source is considered to be oil that would have a share of 96% in the market by the year 2040. The combusted and non-combusted industries would have a share of 60% in the market by the year 2040. The production of energy as consumption share is amplified from 56% to 60% in the year 2016 by 2040 and the increase in import by 141%.

A decrease in oil production (-24%) is equalize by raise in coal (+154%), gas (+99%), and non-fossil fuels by 544%. The coal will remain the dominant fuel, import of oil (+175%) will increase and results in amplifying the import of energy (65%) followed by gas (+291%) and coal (+79%). By 2040, India's energy intensity of GDP will be 37% lower than in 2016 while the usage of carbon intensity will decrease by 13% (Perez, et al., 2011).

Table 1.2: Primary energy consumption (units in Mtoe unless otherwise noted)

	Level (annual)		Shares		Change (abs.)		Change (%)		Change	
	2016	**2040**	**2016**	**2040**	**1990-2016**	**2016-2040**	**1990-2016**	**2016-2040**	**1990-2016**	**2016-2040**
Primary energy consumption (units in Mtoe unless otherwise noted)										
Total	724	1921			529	1197	271%	165%	5.2%	4.2%
Oil (Mb/d)	4	10	29%	25%	3	6	269%	129%	5.2%	3.5%
Gas (Bcf/d)	5	14	6%	7%	4	9	315%	185%	5.6%	4.5%
Coal	412	955	57%	50%	302	543	275%	132%	5.2%	3.6%
Nuclear	9	44	1%	2%	7	35	493%	412%	7.1%	7.0%
Hydro	29	52	4%	3%	14	23	94%	80%	2.6%	2.5%
Renewables (including biofuels)	17	256	2%	13%	17	239	>1000%	>1000%	>10%	>10%
Transport	94	265	13%	14%	71	172	307%	183%	5.5%	4.4%
Industry	385	1018	53%	53%	282	633	275%	165%	5.2%	4.1%
Non-combusted	47	122	7%	6%	34	74	258%	156%	5.0%	4.0%
Buildings	198	517	27%	27%	142	319	253%	161%	5.0%	4.1%
Power	353	1045	49%	54%	271	692	329%	196%	5.8%	4.6%
Production										
Oil (Mb/d)	1	1			0	0	41%	-24%	1.3%	-1.1%
Gas (Bcf/d)	3	5			2	3	129%	99%	3.2%	2.9%
Coal	289	734			182	445	171%	154%	3.9%	4.0%

Source: Moghadam, et al., 2016

1.4.2 Residential Electricity Consumption in India

Residential electricity consumption (REC) is the whole amount of electricity consumed by households in order to meet several purposes like cooking, cooling rooms and many more. There are times when the individuals start using group of different sources of energy for meeting their end-requirements. For an example, people might utilise both the inductive stove with the use of electricity and cook-stove with the use of biomass in order to cook food relying on source availability. Solar and electric water heater are utilised by the people for heating the water that includes only the electricity components of the final-used in the REC (Perez, et al.,2011). REC formulates a quarter of the total consumption of electricity and probably gets increased with the passing time because of electrification, raised in incomes, growth in technologies that enable more equipment at affordable rates. A great perceptive of the consumption patterns of the household and knowledge of the factors that influence them can give brief idea for policy designing and providing technological responses in order to effective fulfil the raised demands (Robinson, et al., 2009).

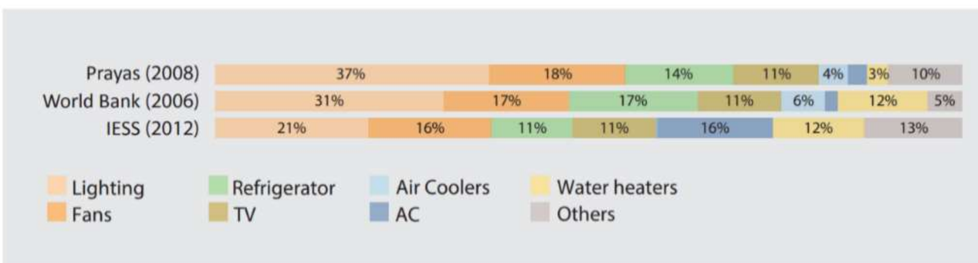


Figure 1.7: End-use contribution to total consumption of electricity in India

(Source: Sustainability, 2018)

The households are still utilising electricity for the purpose of lighting and the declination in sharing the light energy is due to amplified ownership of electricity concentrated equipments and appliances like air-conditioners (ACs), refrigerators and many more.

It is represented that in 2012, there is increase in sharing of tubelights as well as Compact Fluorescent Lights (CFLs) which is more than the shared incandescent bulbs. It might have happened because of Bachat Lamp Yojana which was launched in 2009 by the BEE. The purpose of this Yojna is to promote CFLs. There are some assumptions based on which some findings are expected that will be discussed in subsequent sections. A better analysis will be enabled with the survey related to energy consumption and REC distribution per end-use will also be estimated (Ali, et al., 2018).

1.5 Problem Identification

Household disposable income is expected to amplify by an average of 4.2% per year that is next to highest among IEO2017 of India while China has the highest. By the year 2023, India will surpass China and account for nearly 19% of the raise in population globally over the projection period. It is realized that around 45% of the population of India will reside in urban places by the year 2040 and raise of approximately 12% points from 2015.

In 2015, there is about 14% of the total delivered use of energy in India and it has been found that the growth of commercial energy is higher than the residential energy in India. The building energy is greatly consumed by the residential sector which represents more than 70% of the total buildings over the complete projection period.

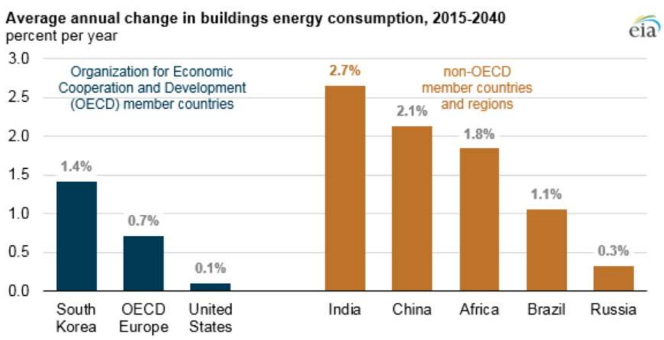


Figure 1.8: Average annual change in buildings energy consumption 2015-2040

(Source: PloS one, 2017)

1.6 Need of the Study

There is raise of delivered energy consumption by an average of 2.7% per year between the year 2015 and 2040 in India. This will be twice of the average increase all across the world. The requirement of this study is to reduce the consumption of energy through estimating the energy demands of the buildings with the help of CitySim software. This study is conducted for delivering the solutions that facilitate in achieving the sustainability in effective utilisation of resources. In this thesis, the discussion is related to the energy consumption. The energy performance of the locality comprised of several buildings is computed using the energy simulated software that estimate the usage of energy for cooling and lighting. The objective is to highlight the factors influencing the energy demand of buildings and the results produced is the quantification of detailed energy demand required for managing the housing arrangement of the buildings (Sossan and Paolone, 2016).

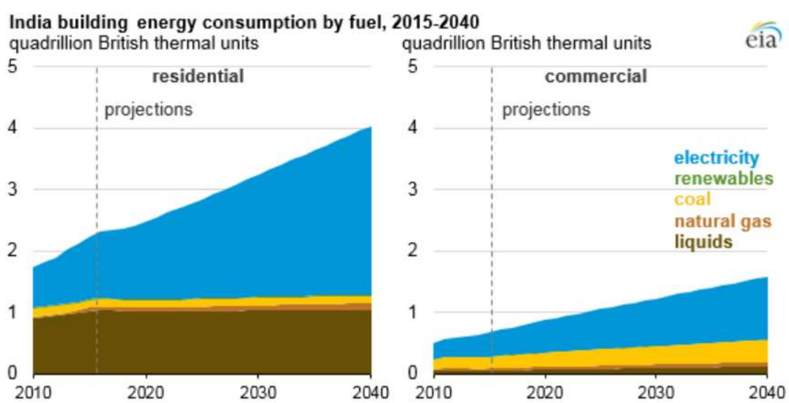


Figure 1.9: India building energy consumption by fuel, 2015-2040

(Source: PloS one, 2017)

1.7 Objectives

The objectives framed for this thesis are presented below:

1. To study and identify the control parameters of energy consumption
2. To study current cooling consumption of study area (Primary Source)
3. To model selected location for the purpose of simulation
4. To suggest energy saving measures in the study area

1.8 Detailed Methodology

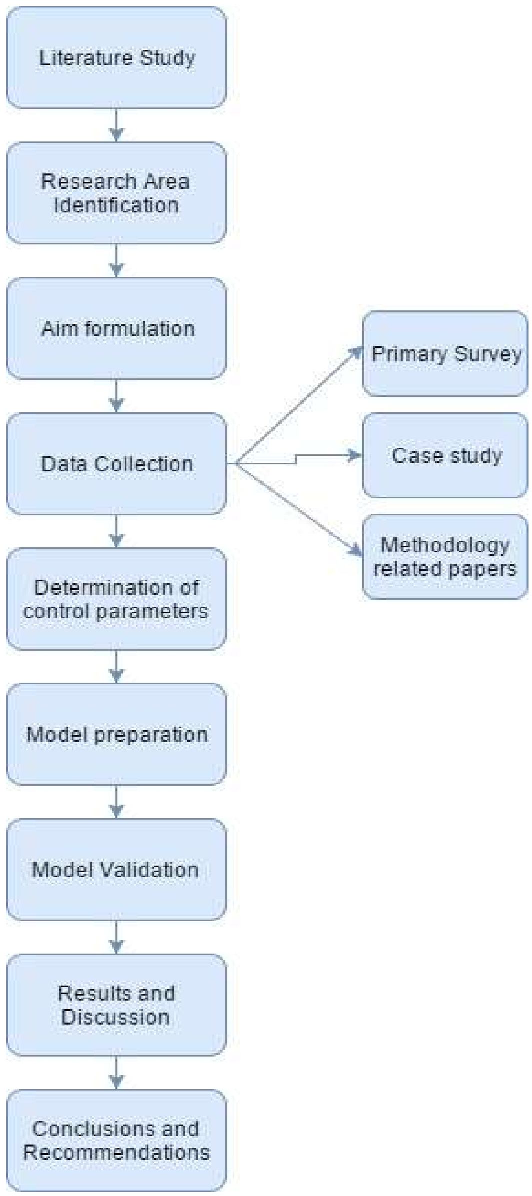


Figure 1.10: Detailed Research Methodology

(Source: Author, 2019)

Table 1.3 Objectives

Objectives	Task to be performed	Information needed	Information sources	Possible outcomes
To study and identify the control parameters of energy consumption	Primary Survey, Gathering significant information from Rajasthan Housing Board	Assumptions are needed	Survey analysis, Rajasthan housing board office	Energy demand analysis
To study current cooling consumption of study area (Primary Source)	Reviewing literatures, articles and journals related to CitySim implementation and using 3-D creation models like Sketch-up, Autocad	Assumptions are needed, Understanding of software tools	Secondary sources, CitySim software, 3-D model tools	Simulation results for energy consumption
To model selected location for the purpose of simulation	Energy management, sustainable utilisation and effective use of materials	Information related to the Green materials, knowledge related to green appliances as well as equipments.	Secondary sources, Solar sources	Sustainability in consumption of energy
To suggest energy saving measures in the study area	Prepare strategies for evaluating solar potential and execute it.	Consolidate the outcomes Solar sources	Previous study outcomes, simulation software	Estimating the generation of energy Assessment results

(Source: Author, 2019)

1.9 Limitations

- Level of detail 2 (LOD 2) model of the site is utilised for performing simulation.
- Software citysim has limited data inputs to perform analysis on neighbourhood scale
- Only cooling load is analysed for the purpose of study

1.10 Research Method

This research includes the secondary sources and primary surveys for the collection of data. The software tool is used for the energy simulation of the particular zone.

1.10.1 Data Gathering

The significant information related to the residential sector and simulation software has been gathered using the secondary and primary sources of data collection.

1.10.2 Modelling methods

The tool used for the energy simulation is CitySim learning which is incorporated with an intention to realize the energy demand of the buildings. This thesis includes the suitable survey and different analytical approaches for the accuracy as well as relevancy of this study.

1.10.3 Analysis

Several tools and techniques are employed for performing the detailed analysis that facilitates in identifying the existing scenarios, suitable topologies, etc.

1.10.4 Recommendation

The suggestion is to plan intervention while designing the building in order to reduce the energy demand for the locality selected in this study.

1.10.5 Conclusion

This would be dependent on the statistical information and analytics performed in this thesis that facilitate in reducing the consumption of energy for attaining the sustaining in consumption of energy.

1.11 Thesis organization

Chapter 1 depicts the need of the study and provide the purpose of this thesis with understanding the extent of energy consumption all across the world. It highlights the energy demands in developed and developing nations. The residential electricity consumption of the developing country, India is also presented in this chapter.

Chapter 2 facilitate in collecting information and learn about the different energy simulation software used for the purpose of reducing the electricity consumption in the residential areas. It involves the critical review of the different literature that provides significant information required for conducting this study. It concentrates on the consumption of electricity rather than the entire energy consumption in the particular area. It is based on estimating the energy requirements and the different factors affecting the energy needs at the household level. This information helps in formulation of a foundation for the future developments performed in this thesis.

Chapter 3 provides the brief idea of the primary survey and study area that help in determining the control parameters in residential sector that has nearly the same characteristics.

Chapter 4 presents the methodology that is followed in this thesis. It will explain the modelling performed by the CitySim software and provide the detailed information related to procedure used for estimating the consumption of electricity by the buildings present in the particular locality.

Chapter 5 will include the result section for providing the energy demand from the month of January to May. It suggests the preferred orientation in order to reduce the electrical energy consumption.

Chapter 6 concludes this thesis project and facilitate in computing the electricity demand depending on the usage of cooling and lighting appliances. Depending on the energy demand, the recommendations will be provided for design patterns of the building in order to reduce the extensive consumption of electricity.

2. Literature Review and Case Studies

2.1 Field of Research and its organisation

For organising the research, it is classified into two segments, the first part focus on the methodologies used for energy simulation of the buildings and locality. The simulation methods are demonstrated in this section that depicts the significance of CitySim software for estimating the electrical energy consumption of the locality. It identifies the factors like the design pattern of the buildings, its characteristics played a significant role on the energy demand of the buildings. There is need to gather the data for energy simulation and methods are provided for the simulation of the usage of energy by the buildings. Overall, the process of this research or study is depicted in this chapter (Thomas, et al., 2014)

The part second of this chapter provides the different case studies based on the estimation of energy used by the buildings. The consumption of domestic energy and several factors influencing the demand of that energy is presented in the second part of this chapter. It amplifies knowledge related to the usage of energy at household level and focus on reducing the usage of electrical energy demand in the residential sector. Overall, both the parts focus on presenting the computation of energy demand of the buildings in residential sector and the factors influencing this electrical energy demand are also considered (Swan and Ugursal, 2009).

2.2 PART 1: Studies on energy modelling methods

The sustainability of the surrounding and energy-efficiency is the subject of this study. It analyses the energy demand of the buildings in residential sector. For assessing the effects on energy performance and energy demand, it is required to study the factors and understand the relationships between several factors influencing it. The structure of the buildings, variation of climate, characteristics of the surface of the buildings, etc are the aspects that has both the affirmative and negative influence on the cooling and lighting demand of the buildings (Strzalka, et al., 2011).

2.2.1 Framework to Evaluate Urban Design Using Urban Microclimatic Modelling in a) Future Climatic Conditions

This paper is related to the assessment of urban design with the help of Microclimatic Modelling. The workflow is designed that connects several methodologies which are invented separately. This is performed with an intention to derive the consumption of energy of university school campus in future climatic conditions. The three different scenarios of the years 2039, 2069, 2099 and renovation scenario (Minergie-P) were run. The influence of the change in climate results in varying the demand of heating as well as cooling of building which is effectively analysed in this paper. It depicts the impact with the changing climate in the specific context. The simulation results ensure that in the coming years, there are the chances of declination of the heating requirements and inclination of the cooling demands. It represents that while considering the local urban climate, there would be the high probability of raise in the demand of cooling.

b) Simulation Software

CitySim or Envi-Met are the Micro-Scale models that have quite brief computations related to radiative transfer. The benefit of employing these models is to give an improved introduction of the surface. As Envi-Met facilitates in performing studies related to micromatic flows nearest to buildings. However, periodic boundary situations wouldn't be considered and this can be deviated from the actual outcome after a day or two. CitySim is another model which could be executed for 8760 hourly time-steps. However, local airflows wouldn't be considered and that results in declining the effectiveness regarding the appropriateness of the description related to micro-climate particularly in context to urban areas (Mauree, et al., 2018).

c) Materials and Methods

There are two main kinds of weather datasets for the future that could be used in order to analyse the impact of climate change. The statistical or dynamical downscaling of global climate models (GCMs) is utilised for this purpose.

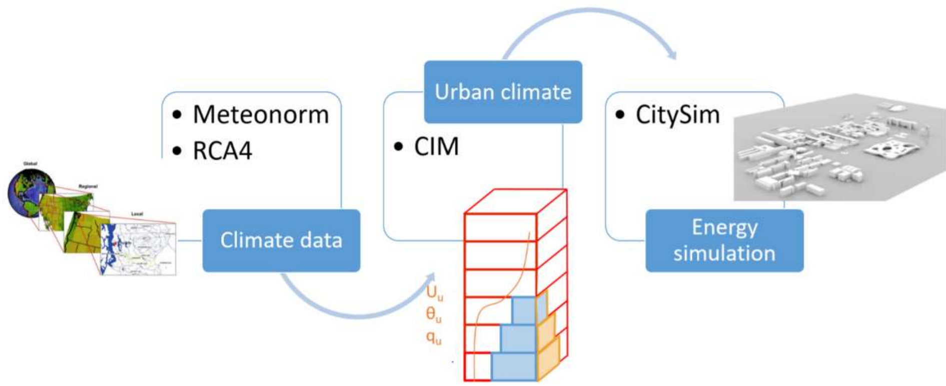


Figure 2.1: Illustration of simulations flow (CIM – Canopy Interface Model)

(Source: Sustainability, 2018)

d) Results

The results of RCA4 which is the fourth generation RCM (Rossby Centre regional climate model) model is utilised in it. While employing the future climate information, the limitation faced is related to the uncertainties which are due to the use of several climate models, scenerios related to emissions, initial conditions and many more.

e) Conclusion

The use of CitySim and urban energy modelling tool is to compute the demand of energy at the scale of locality. As an analogy, it provides an east resistor-capacitor network in order to represent the behaviour of buildings thermally. The use of radiation model depends upon the simplified radiosity algorithm (SRA) that is integrated in CitySim. Robinson and Stone proposed a model that uses two hemispheres for demonstrating the radiant external surrounding.

2.2.2 CitySim: Comprehensive micro-simulation of resource flows for sustainable urban planning

CitySim is the software utilised for proper housing arrangement and building appropriate structure of the buildings in order to reduce the energy demands for the purpose of lighting and cooling in the residential sector. The building related resources would be stimulated and optimized with the following ways:

→ Related Climatic conditions and site location
→ Default datasets adjustment for the varied building types and age
→ Definition of 3D structure of the building, modelling energy demand and storage systems, enhancement of aspects of system and building
→ Data parsing in XML form and result analysis

CitySim is efficiently used for the urban scale energy simulation. There are chance of attaining the accuracy in modelling, problem due to computational overheads and proper availability of information for computation of energy demand (Robinson, et al., 2009).

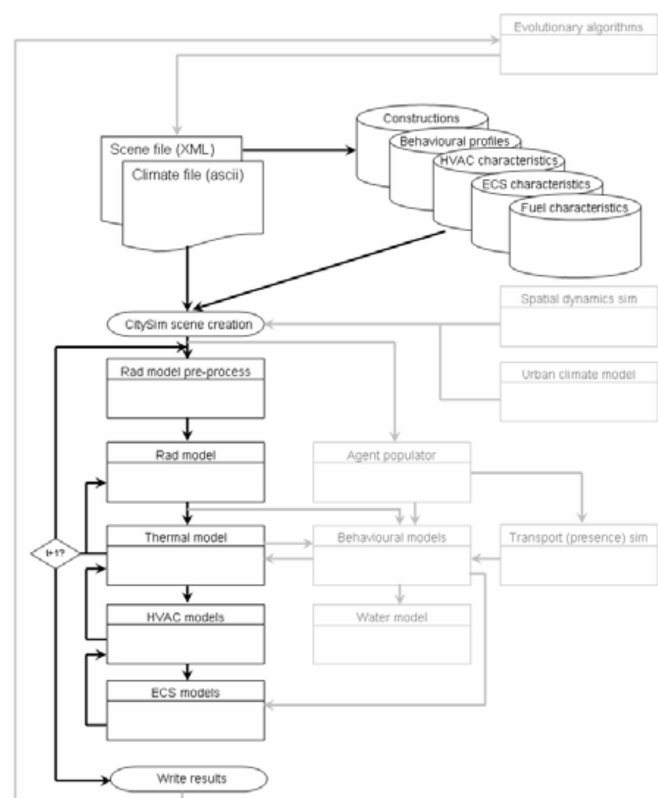


Figure 2.2: Conceptual structure of CitySim

(Source: Eleventh International IBPSA Conference, 2009)

The different core models of this software are Thermal model, Radiation model, Behavioural mode, Plant and equipment model.

The figure presenting the conceptual structure of the CitySim software, the file of the XML format produced by the Graphical user interface (GUI) comprised of the geometrical information of the buildings of residential sector and several aspects affects its energy demand. In the CitySim solver, the data is parsed for the creation of object instance based on the building patterns (Robinson, et al., 2009).

Conclusion

The development in the recent years facilitates in simulation of the renewable energy, therefore the model like CitySim help in optimising and stimulating the energy demand of the buildings.

2.2.3 GIS-Based Residential Building Energy Modeling at District Scale

The strategic planning process is needed for reducing the CO2 emissions and overall consumption of energy of buildings. The insufficient scalable data modeling methods and the gap between the building energy modeling approaches and planning implementation introduces the consumption of great extent of electrical energy that is required to be controlled. In districts of **Dublin**, the selection of methodology depicts that what kind of buildings and their location plays an essential role in reducing the consumption of energy. The objective is to invent an energy model for the local authorities in order to estimate the total consumption of energy and CO2 emissions at district-level (Ali, et al., 2018).

Methodology

1. GIS-based residential building energy modeling is the methodology selected in this paper. It is the bottom-up approach used at the district level. It involves the classification of the whole district into small areas for including more description.
2. It involves the collection of data that includes weather, geometric non-geometric related information.
3. The archetypes are invented at district level and energy demand is evaluated.
4. Several geographical scales are employed.

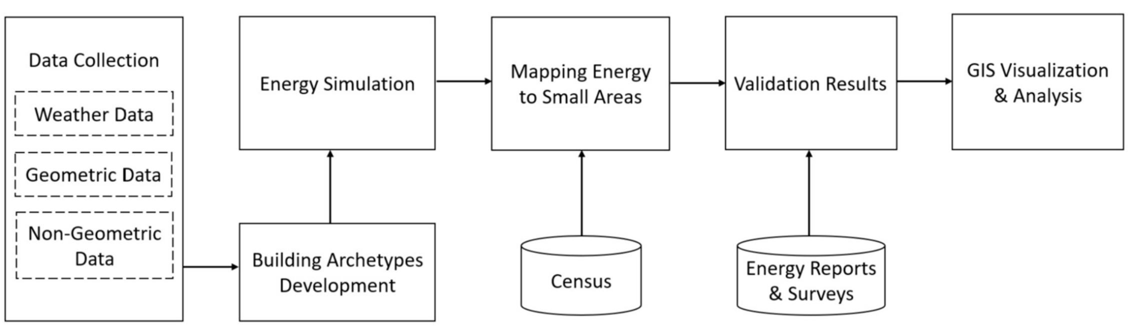


Figure 2.3: Methodology for GIS-based residential building energy modelling

(Source: 4th Building Simulation and Optimization Conference*, 2018*)

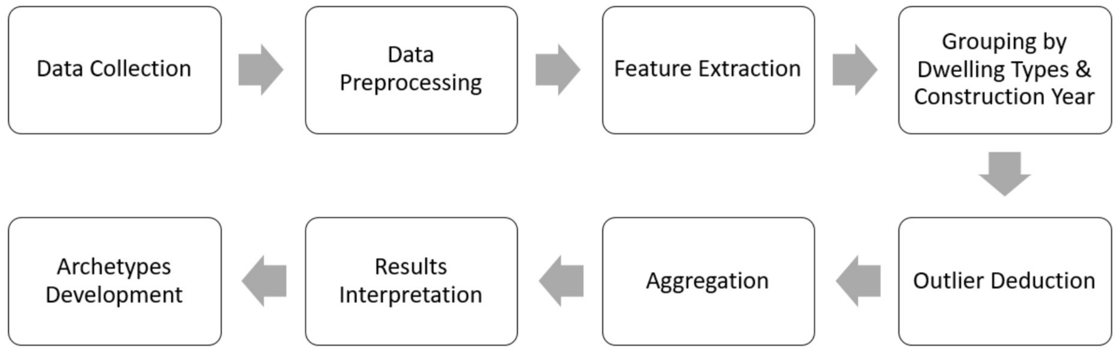


Figure 2.4: Methodology for inventing new building archetypes

(Source: 4th Building Simulation and Optimization Conference*, 2018*)

Energy Simulation

The software used for simulation is EnergyPlus, it is software used for stimulating the environmental performance and modeling energy demands of the buildings. The result is further stored in order to utilize it for the purpose of GIS mapping.

Results

The results are validated by computing the energy demand of each archetype which are further compared with the national and international statistics that gives the energy usage values for that particular year. The difference is found from -6% to +2% as per the nation and error acceptance is 5%-20% (Ali, et al., 2018).

2.2.4 Clustering and visualization method to evaluate urban heat energy planning scenarios

According to Moghadam, et al. (2019), a methodology is proposed that uses cite archetypes for simulating the energy utilisation of urban locations. The assessment of the planning scenarios of the urban areas is also performed in the publication. The aim is to present an innovative framework in order to compute the effective utilisation of energy at city scale. The 3D model is designed for computing the energy requirements of micro-climatic situations and cities.

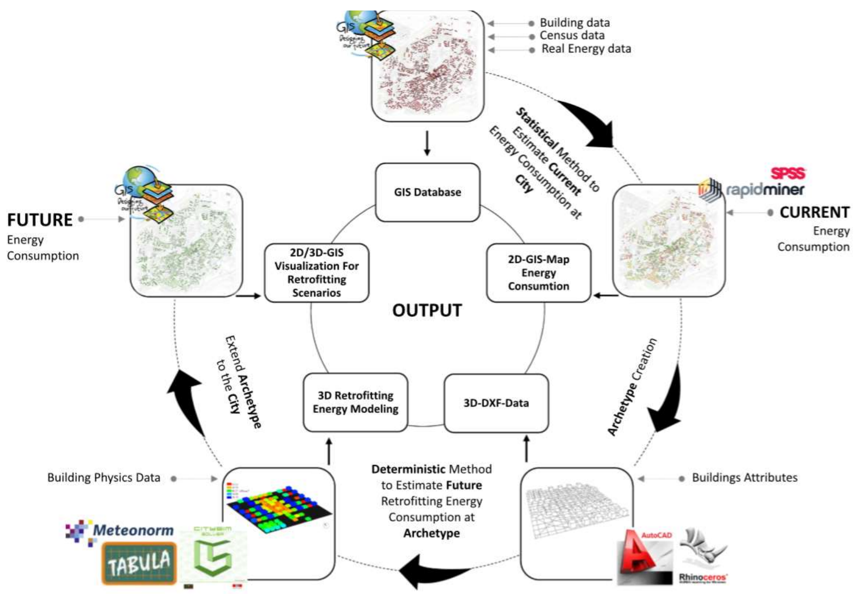


Figure 2.5: Flowchart explaining the methodology for creating and using the archetype

(Source: Cities, 2019)

Table 2.1: Physical Characteristics of buildings

Physical characteristics (U-value) of buildings for each period of construction.

Period of construction from TABULA	Type	Wall ($W m^{-2} K^{-1}$)	Roof ($W m^{-2} K^{-1}$)	Floor ($W m^{-2} K^{-1}$)	Windows ($W m^{-2} K^{-1}$)
Before 1919	Terraced House (TH)	1.61	1.80	2.00	4.90
1919 –1945	Single Family House (SF)	1.48	1.80	2.00	4.90
1946–1960	Single Family House (SF)	1.48	2.20	2.00	4.90
1961–1970	Multi Family House (MF)	1.15	1.10	0.94	4.90
1971–1990	Multi Family House (MF)	0.8	0.75	0.98	3.70
1991–2005	Multi Family House (MF)	0.59	0.57	0.77	2.20
Since 2006	Terraced House (TH)	0.34	0.28	0.33	2.20

2.2.5 Solar-based sustainable urban design: The effects of city-scale street canyon geometry on solar access in Geneva, Switzerland

According to Mohajeri, et al. (2019), the highest radiation for surfaces is (100kWhm-2) for streets oriented WNE-ESE and for facades, it is (1400 kWhm-2) for facing SSW. Street surfaces gains the maximum monthly radiation is 80 kWhm-2. The moderate correlations are only presented by the solar radiation received for the street surfaces and facades with the different measured geometric parameters. These parameters are street width, street length, SVF, asymmetric aspect ratio and many more. The highest radiation is received by the street surfaces in case the aspect ratio is low or the value of SVF is high. For receiving the high radiation for a street surface, the months are May to August, length of street is 15m wide, aspect ratio less than 2.0, SVF value above 0.1 is considered. The Facades outcomes for the same months are quite similar, however that radiation received by the facades are much greater than the street surfaces. The solar access of street surfaces is reduced for the summers and the solar access of building facades is maximised during winders for the effectiveness of the city-scale design. It facilitates in amplifying the thermal comfort.

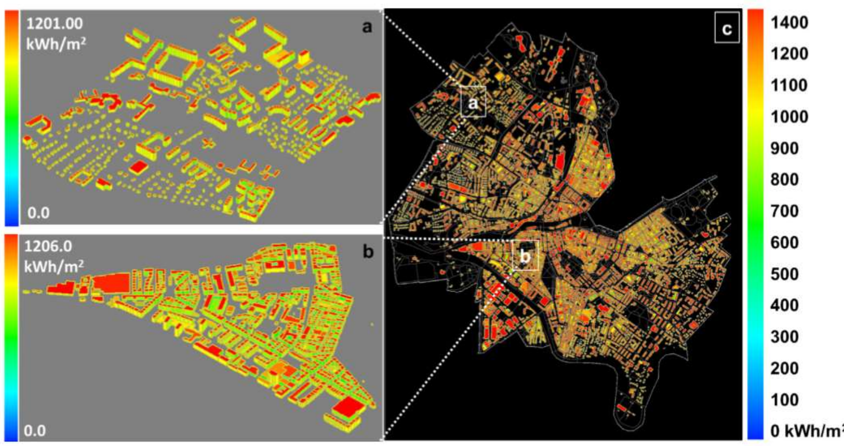


Figure 2.6: Annual mean solar radiation in KWHm-2 of building roofs and facades in Geneva using CitySim

(Source: Applied Energy, 2019)

2.2.6 Influence of Buildings Configuration on the Energy Demand and Sizing of Energy Systems in an Urban Context

According to Mauree, et al. (2017), this study is regarding the development of a co-simulation platform that combines the Canopy Interface Model (CIM), CitySim, a meteorological model, building simulation model and energy system design model. The simple urban configurations are chosen in the study for analysing the different processes that impacts the energy system design and energy consumption of the buildings. This study derives two scenarios for CIM-CitySim coupling, these are aligned and staggered buildings. This publication helps in identifying the significant scenarios of the urban planning that effectively utilises the energy. These simulations are executed for one particular year with the use of climatic information from the Ecublens district in Switzerland, Meteonorm. Meteonorm data is used for the first simulation and modified Meteonorm dataset for the other simulation. It involves the use of CIM-CitySim framework for inclusion of the local modification of the urban setup.

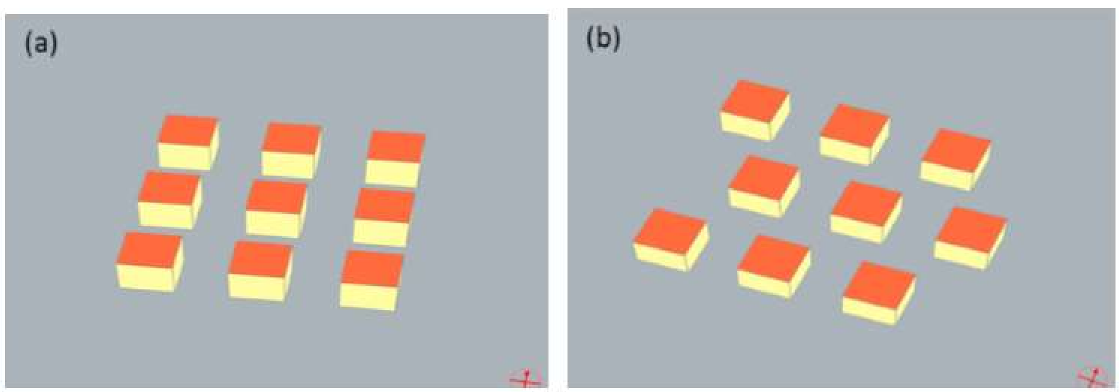


Figure 2.7: (a) Aligned and (b) staggered building scenarios

(Source: Energy Procedia, 2017)

An energy system is designed and analysed as per the two scenarios. The impacts of energy demand on the proposed solution are also evaluated in this paper.

2.3 PART 2: Case Studies related to energy consumption in residential sector

The consumption of energy is presented in this part second of the chapter. It provides the different case studies based on the estimation of energy used by the buildings. The consumption of domestic energy and several factors influencing the demand of that energy is presented in the second part of this chapter. It amplifies knowledge related to the usage of energy at household level and focus on reducing the usage of energy demand in the residential sector. In the coming decade, the expected rise of the energy demand is quite high and the possibility is that it will be amplified by the eight time by the year 2050.

2.3.1 CitySim Simulation: The case study of ALT-WIEDIKON, a neighbourhood of Zürich City

According to Perez, et al. (2011), While conducting the study in energy building demand simulation is realizing maturity and the requirement is assess the energy performance associated with improvement circumstances. On the basis of multiple physical models, the CitySim is invented at EPFL which is utilised by the urban energy as a simulator from past several years. The on-site utilisation of energy is estimated by the CitySim and the input required for this computation is the physical information of the buildings in XML file format. In order to simulate few buildings, the easiest approach is to enter the data manually with the help of GUI (Graphical User Interface) but when the need is to simulate thousands of buildings, then data should be handled using databases. In this study, the methodology utilised to take the benefits of PostgreSqL and QuantumGIS with an intention to handle the inputs required by CitySim for producing major outcomes. The database is linked with the CitySim using the Java principle that is applied for simulating a Zurich City neighbourhood in order to produce energy demand graphs.

It is predicted that the population of urban areas would be raised to approximately 70% by 2050 and it is same with the consumption of energy which is required to be controlled. The requirement is to determine the solution that can promote efficient resource consumption while maintaining the standards of life for the urban residents. CitySim is the computer modelling tool which is appropriate for simulation (Perez, et al., 2011).

PostgreSQL database: Geographical information systems (GIS) and database management systems (DBMS) facilitate in integration of simulation modules. It facilitates the management of data and provides several functionalities like access, edit and processing of the spatial information. With an intention to provide the representation mapping of any parameter associated with geometry, the software used is QuantumGIS.

CitySim: The multiple physical models are grouped together and contained in it, that involves the radiation model which initially measure the irradiation occurrence on every surface of the zone which identify the thermal exchange by the enveloped of the buildings and measure the energy requirements necessary for maintaining the inside situations of the predefined temperature. The physical information of the building in the XML file is provided and the envelope of each building is described using the building models.

Methodology

The data is stored in the database model, CitySim is used for estimating the energy-use and Java tool connects the CitySim and database model. The data source is required for estimating the consumption of energy used in the Alt-Wiedikon zone that contained 123 buildings (Perez, et al., 2011).

Following data sources used for this study are:

1. Cadastral map for 2-D representation of the footprints of the buildings. Digital Surface models (DSM) and Digital Terrain Models (DTM) facilitate in extraction of average and altitude height of each building.
2. The quality information of building like geographical location, main allocation, energy systems, main allocation, renovation data and many more is contained in the register that help in extrapolating the characteristics of the construction.
3. The computation of the total number of building's occupants is understood with the help of company census.
4. Through visual survey, the relevance for simulation and status for each building is understood.

These methodologies help in gathering the sufficient information significant for creating a rough idea of that particular zone. Further the data is organised using the simulation tool like database and data model.

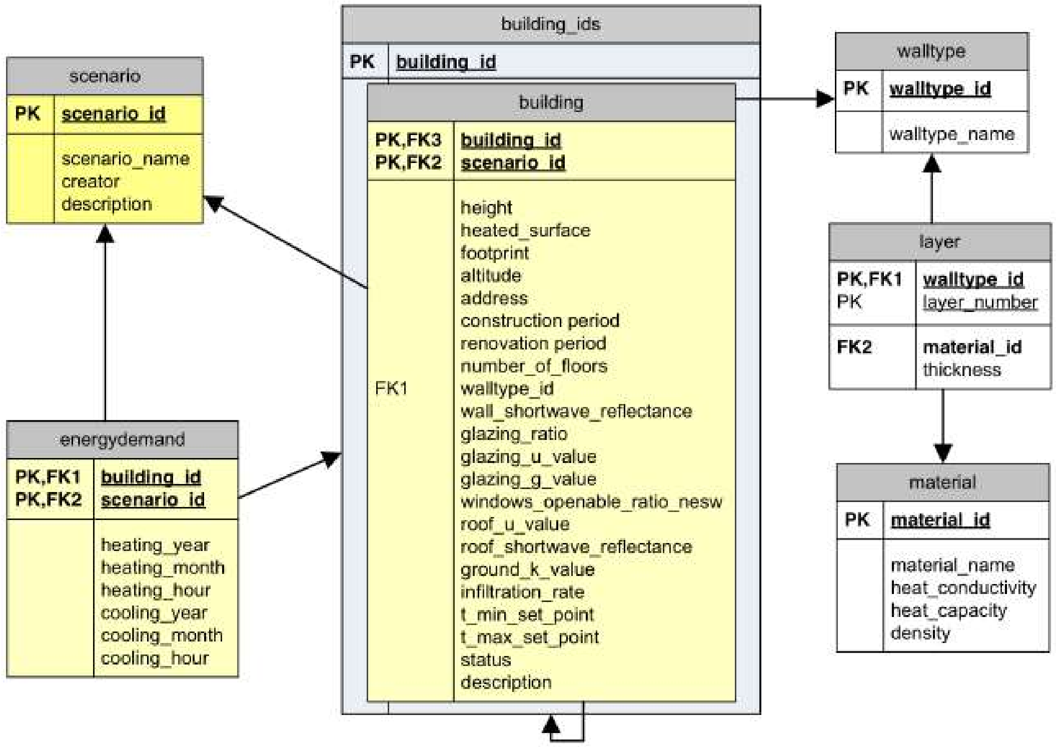


Figure 2.8: Schema of the CitySim database data model

(Source: EPFL, 2011)

For the purpose of simulation, the CitySim input file is created and that facilitate in storing the information in the database. The java program is written for database accessibility, data retrieval and converting it into the brief CitySim model. The 2D footprints of the building are extruded into 2.5D and exchange of heat is considered to be negligible between the buildings that touch each other. The infiltration rate , minimum and maximum set rate of every building is attributed which is added to the XML input file of CitySim. CitySim solver is called for launching a simulation with the help of Java program and when that simulation ends up, further the results produced includes the cooling and heating demand for every hour of the particular year is read, prepared and added in the database containing the “energydemand’ table. The SQL views join the two tables that are “energydemand” and “building” to produce the required outcomes.

2.3.2 A Comparative Study of Energy Consumption for Residential HVAC Systems Using EnergyPlus

Heating, Ventilation and Air Conditioning (HVAC) systems consume more than half of the building's energy. The resident as well as commercial buildings are heavily installing the HVAC systems that consume greater energy as compared to other buildings. The case study for the city Tripoli, Libya is considered. EnergyPlus is used for modelling the building and HVAC systems. It is the building simulation software which is utilised along with the OpenStudio software. This EnergyPlus software is simpler to be used but the problem with that it overestimate the consumption of energy than any other models (Samah, et al., 2017).

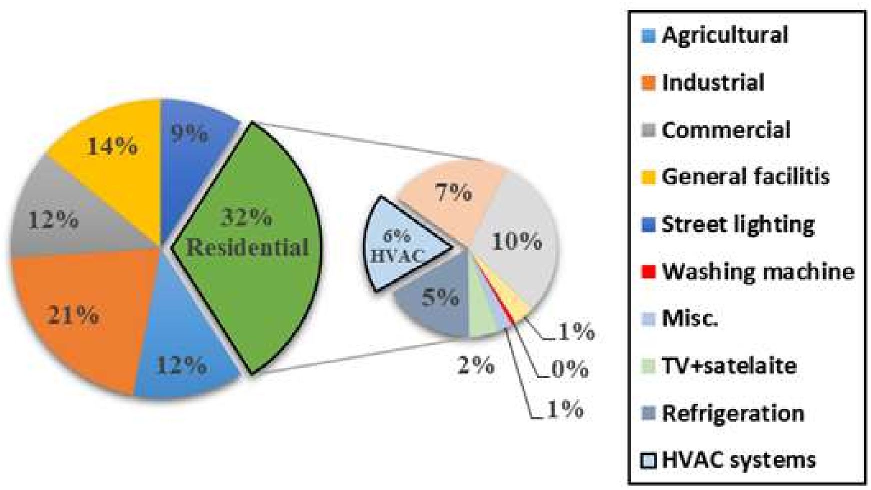


Figure 2.9: Percentages of electric energy consumed in Libya in 2012

(Source: American Journal of Mechanical and Industrial Engineering, 2017)

Methodology

- EnergyPlus is utilised for studying the consumption of energy, OpenStudio software is employed for modifying the properties of the model as the properties like schedule, internal loads, constructions,materials and manymore.
- The geometry of the model is created and modelled by the Sketchup. OpenStudio gives the result in SI units.
- It uses TARP algorithm for inside surface convention and DOE-2 for outside surface convention. The construction through walls is computed by the Conduction Transfer Function (CTF) solution algorithm (Samah, et al., 2017).

➢ Zone heat balance is carried out by the EnergyPlus for estimating the load which are classified into air and surface components. The heating and cooling loads are computed for maintaining the area at existing setpoints situations and thus annual energy needs of the complete building and the HVAC system is computed.

This study depicts that the HVAC system consumes great extent of energy. The computation of the virtual component "Ideal air loads" that is used in the EnergyPlus is simpler to be implemented. The two-floor building of the house located at Tripoli, Libya having the total floor area of 280m2. The guest room, living area, bathrooms and kitchen are contained in the ground floor while the bathrooms and bedrooms are available at the first-floor of the building which is considered to be the sleeping area.

Construction	Overall heat transfer coefficient, W/m^2K
External Walls	2.5
Roof	2.4
Single glazed window	5.8
Doors	1.8

Figure 2.10: Specifications of the building's envelope constructions

(Source: American Journal of Mechanical and Industrial Engineering, 2017)

2.3.3 Integration and Operation of Utility-Scale Battery Energy Storage Systems: the EPFL's Experience

The EPFL campus is selected for the study that covers 55 ha and having more than 10,000 students and staff members are around 5000 in number. The photovoltaic panels are incorporated with a 2-MW power plant. The definition of the energy model used in EPFL campus is given and it is validated using on-site supervision. The model is analysed on the basis of its thermal behaviour and microclimatic conditions contained by the urban surrounding. Carneiro gives the data related to geometry of the campus and with the proper understanding of the construction phase, the physical information of the buildings were presented. In the current study, the simulation of energy is performed to compute the influence of varying climate on the usage of energy of the built stock and the significance of considering the climate of urban surrounding (Sossan and Paolone, 2016).

Figure 2.11: The campus of EPFL, Switzerland

(Source: IFAC-PapersOnLine, 2016)

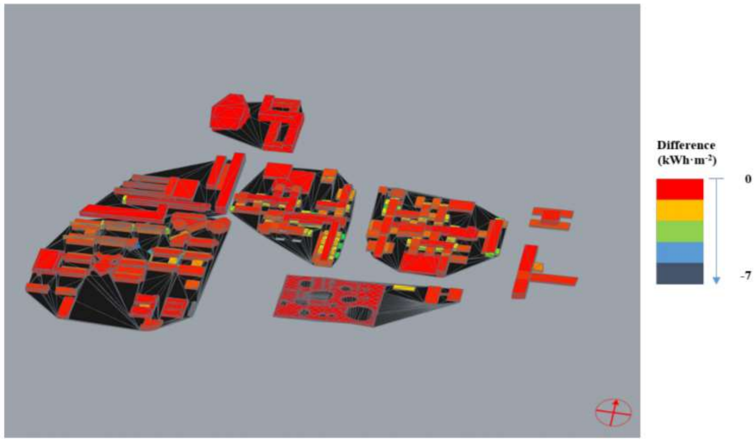


Figure 2.12: Heating demand difference for the campus of EPFL for 2009 (Without and with CIM)

(Source: IFAC-PapersOnLine, 2016)

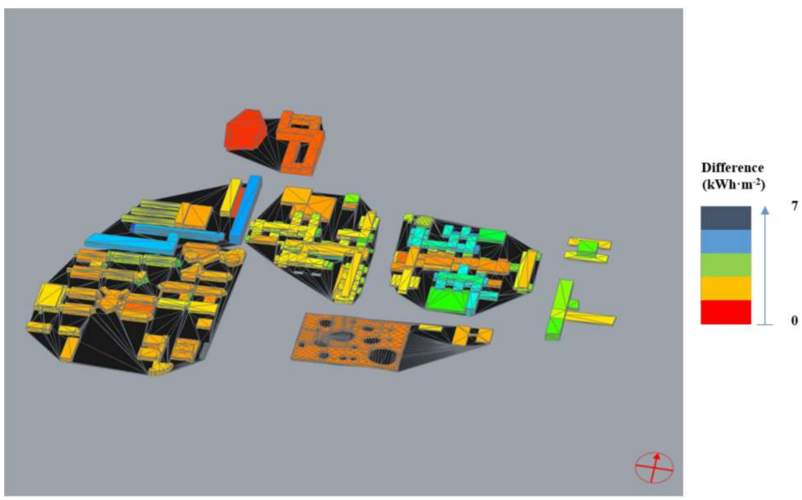


Figure 2.13: Cooling demand difference for the campus of EPFL for 2009 (Without and with CIM)

(Source: IFAC-PapersOnLine, 2016)

The replacement of gas turbines can be done with the solutions associated with the renewable and sustainable energy. The solution which is considered to be an efficient solution is the building of integrated wind turbines that have the higher extent of energy potential during the period of winters. The integration of renewable energy and campus site will be supported with the efficient storage of energy. Battery storage system of 720 kVA/500 kWh is hosted by the EPFL. In the period of cheap energy, the immensely essential segment of urban surrounding is climate-responsive passive design. The past patterns related to the passive design can be understood with the help of historic precedents that are useful in the today's urban environment (Sossan and Paolone, 2016).

The efforts are involved in development of green construction technologies which are applied to the surrounding for reducing the consumption of resources. With an intention to conserve the utilisation of resources, the requirement is needs to be attained the sustainability in consumption of resources.

2.4 Conclusion

The energy performance of the building greatly impact with the climate, geometry and non-geometrical information. The requirement is to fill the gap between the planning implementation and energy modelling approaches. The management of building's energy is necessary for attaining sustainability and reducing the consumption of energy. In the initial stage, the planning is made and decisions are taken related to the constituents of buildings and its site location. It is quite possible that the three would be the building orientation in a way so that there would be proper accessibility of the solar energy which facilitate in reducing the lighting and heating requirements. The cooling demand can be reduced with the optimized shading appliances.

In the residential sectors, the usage of electricity is majorly for the purpose of lighting, cooling, heating, cooking and entertainment. The reduction can be attained with the implementation of planning interventions. This thesis is related to the formulation of planning interventions for a locality in Jaipur named as Chitrakoot. The collected information related to methodologies and factors affecting the energy demand would be utilised for conducting this study.

Further, the study area for this research would be studied in the next section that will comprise of primary survey for collecting more relevant data for this study.

Table 2.2 Comparison of Literatue reviews

Article	Sector	Methodology	Case Study	Validation	Simulation Platform	Sensitivity analysis
Framework to Evaluate Urban Design Using Urban Microclimatic Modelling in Future Climatic Conditions	-	Microclimatic Modelling	Urban design	Yes	CitySim or Envi-Met	Yes
CitySim: Comprehensive micro-simulation of resource flows for sustainable urban planning	-	-	-	Yes	CitySim model	No
CitySim Simulation: The case study of ALT-WIEDIKON, a neighbourhood of Zürich City	Districts of Dublin	GIS-based residential building energy modeling	Dublin	No	Energy Plus	No
A Comparative Study of Energy Consumption for Residential HVAC Systems Using EnergyPlus	Neighbourhood of Zürich City	Methodology utilised to take the benefits of PostgreSqL and QuantumGIS	ALT-WIEDIKON	Yes	CitySim	Yes
Integration and Operation of Utility-Scale Battery Energy Storage Systems: the EPFL's Experience	The campus of EPFL, Switzerland	Integration and Operation of Utility-Scale Battery Energy Storage Systems	EPFL's experience	Yes	CIM model	No

(Source : Author)

3. Study Area profile

3.1 Introduction

Chitrakoot, Jaipur (26°54′ North, 75°44′ East, 424m altitude), a medium sized housing society in city Jaipur. The choice of this medium sized housing society is important as this region is not considered important for any kind of sustainable developments.

The Region came up in 1996 and has seen rapid construction since then mainly using clay bricks and Trabeated column structure. In the recent years with the introduction of AAC block. Builders are using AAC block in small numbers in this region, mainly because of lack of knowledge of AAC blocks and the training of proper techniques of construction.

The site area considered for simulation is 17 hectares and perimeter of 1.72 km. There are in total 320 individual Buildings, which include Detached Houses, Medium size Apartments, Row houses, Commercial Buildings and a park.

Total Population of the selected area is approximately 3200 in an area of 17 hectares. Person Per hectare are 188 pph.

3.2 Income-wise Distribution of Households

Income is an important socio-economic factor for better understanding of a society. Higher income group tends to consume more energy as compared to families with lower income mostly because of the difference in purchasing power. Income also dictates the source of energy. The higher the income the households uses more clean energy sources such as solar, LPG, Electricity, whereas in lower income household families use more traditional source of energy like wood, Coal etc releasing high amount of Carbon emissions on burning. Choice of appliances is also visibly different in different income groups, higher income household use more of electrical appliances which increase the use of electricity as compared to lower income household. With this information, the results were analysed by categorisation of household on income basis, such as monthly income of Rs. < 30,000, Rs. 30,000-90,000, Rs. 90,000-150,000, Rs. 150,000-2,10,000, Rs. 2,10,000-2,70,000 and above Rs. 2,70,000 for analysis. The results are presented in the following figure and Table. Majority income group is 30k-90k which is 36.6%, after that about 13.3% families have income of 1.5 Lakh to 2.1 lakh. So, mostly of the families are of middle-income group with a few families of higher income.

S. No.	Income–group	Households	
		Nos.	Per cent
1	< 30,000	2	6.6
2	30,000 - 90,000	11	36.6
3	90,000 - 150,000	9	30
4	150,000 - 210,000	4	13.3
5	2,10,000 - 2,70,000	2	6.6
6	> 2,70,000	2	6.6
	Total	30	100

Table 3.1 Income Wise Distribution of Households

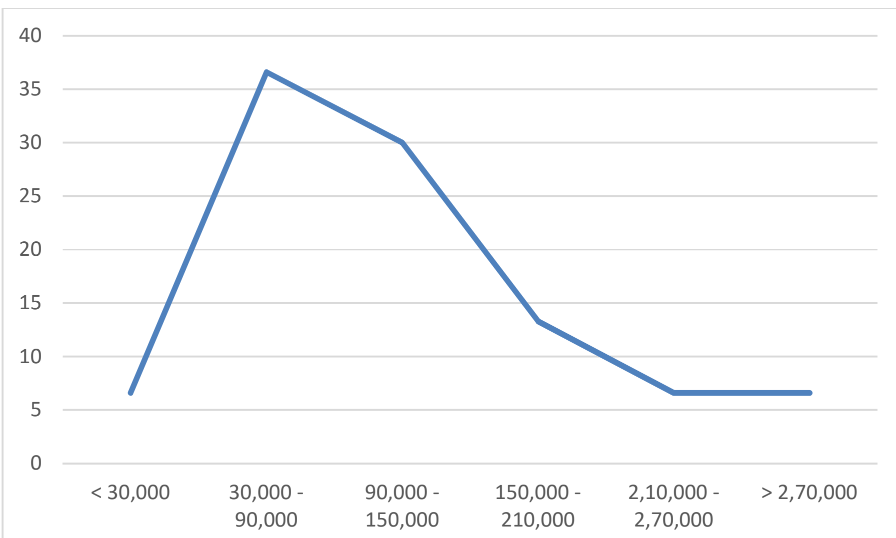


Figure 3.1, Income- Wise Distribution of Households

3.3 Housing Typology

Housing typology is important to understand the type to buildings in an area which also affects the amount of energy consumer in a neighbourhood. Based on the household survey, the houses were grouped into 3 types, namely Independent House, Apartment, and Rented House/Apartment. Results from the survey are presented in Table and Figure below. Mostly Independent houses are in the income group 90k-150k which is 23.3%, Lower income tends to have more of apartments and rented apartments, whereas higher income group have more Independent houses and less of apartments. In total half of the houses are independent houses in this region with one third of the houses as apartments and only 13 % of housing is of rented format. Since the share of independent house is more which also account to high use of electricity in the region. Independent house use more electricity as compared to apartments, as they have higher built up and also concentrated in the hands of high income group. Also, about one third of the houses are owned by middle income group 30k-90k, the number of higher income residents is less as compared to middle income.

S. No.	Income–group (Rs.)	House Type							
		Independent House		Apartment		Rented House/Apartment		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 30,000	0	0	1	3.3	1	3.3	2	6.7
2	30,000 - 90,000	5	16.7	5	16.7	1	3.3	11	36.7
3	90,000 - 150,000	7	23.3	2	6.7	0	0.0	9	30.0
4	150,000 - 210,000	2	6.7	1	3.3	1	3.3	4	13.3
5	2,10,000 - 2,70,000	1	3.3	0	0.0	1	3.3	2	6.7
6	> 2,70,000	1	3.3	1	3.3	0	0.0	2	6.7
	Total	16	53.3	10	33.3	4	13.3	30	100

Table 3.2 Housing Typology

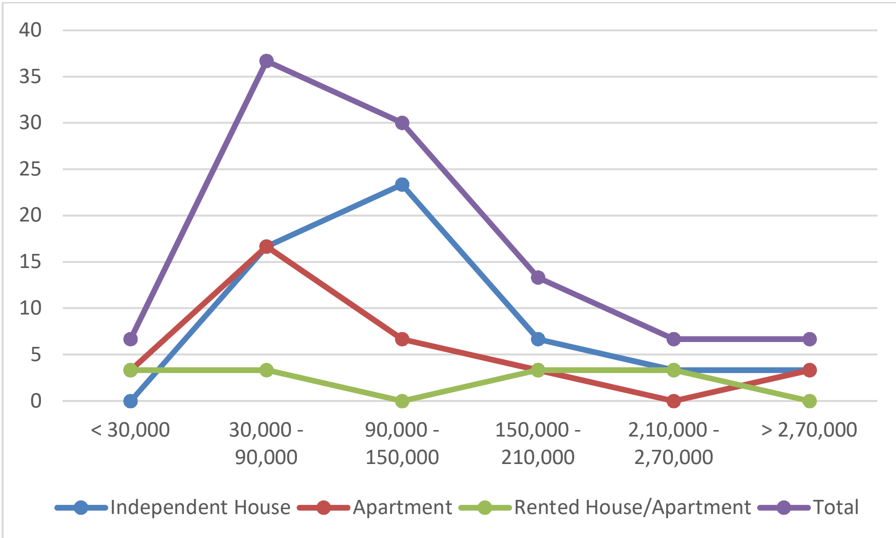


Figure 3.2 Housing Typology

3.4 Built-up Area of House (building)

Built up areas is analysed through survey to understand the area under construction. The houses with high built up area use more energy as compared to houses with low built up area as more cooling and heating is required to condition an area. To analyse built up area relations, the houses were divided into six category based on BUA, namely < 1000 sq.ft., 1000-2000 sq.ft, 2000-3000 sq.ft, 3000-4000 sq.ft, 4000-5000 sq.ft, 6000-7000 sq.ft, and > 7000 sq.ft. 43% of the houses are the range 1000-2000 sq.ft., 17% of the houses are of the range 2000-3000 sq.ft. 6.7 % of the houses area of the range 4000-5000sq.ft. and similar situation is for the houses of the built-up range 6000-7000 sq.ft. lower income group have houses of the lower built up area and high built up area is with high income group. 3.3 % of the houses which are in built up range 6000-7000 are all owned by high income group.

S. No.	Income–group (Rs.)	Built-up Area (sq.ft.)													
		< 1000		1000 - 2000		2000 - 3000		3000 - 4000		4000 - 5000		6000 - 7000		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 30,00	1	3.33	1	3.33	0	0.00	0	0.00	0	0.00	0	0.00	2	6.67

	0														
2	30,000 - 90,000	2	6.67	6	20.00	1	3.33	1	3.33	1	3.33	0	0.00	11	36.67
3	90,000 - 150,000	1	3.33	6	20.00	1	3.33	0	0.00	0	0.00	1	3.33	9	30.00
4	150,000 - 210,000	0	0.00	0	0.00	3	10.00	0	0.00	1	3.33	0	0.00	4	13.33
5	2,10,000 - 2,70,000	0	0.00	0	0.00	0	0.00	2	6.67	0	0.00	0	0.00	2	6.67
6	> 2,70,000	0	0.00	0	0.00	0	0.00	1	3.33	0	0.00	1	3.33	2	6.67
7	Total	4	13.33	13	43.33	5	16.67	4	13.33	2	6.67	2	6.67	30	100.00

Table 3.3 Built-up Area of House (building)

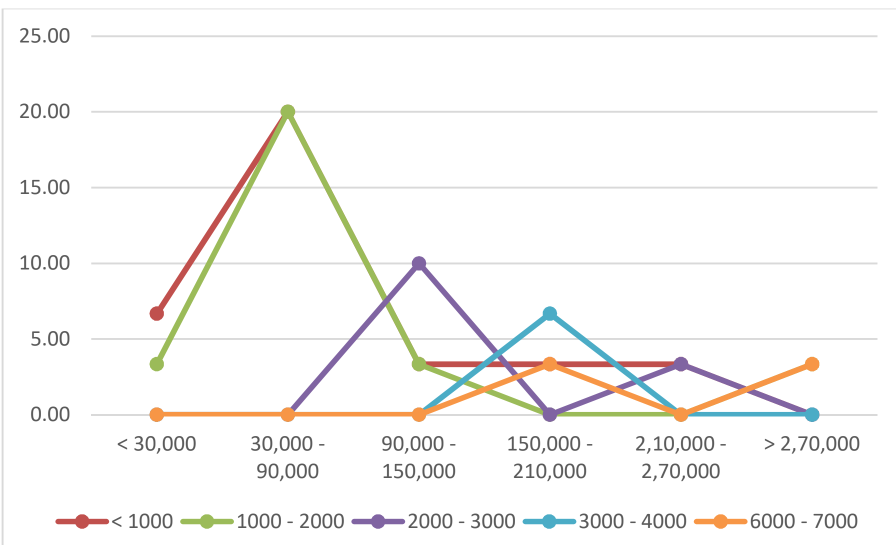


Figure 3.3 Built-up Area of House (building)

3.5 Household Having Trees in their Premises

Plantation are very crucial component of an environment. An environment with more trees and plants is more soothing and relaxing, plantation cools the environment and also brings rain, trees provide shade to buildings which help in bringing the temperature down and also decrease the cooling load. Considering the importance of plantation in an environment, the number of trees were observed in the survey conducted and the results have been presented in the table and Figure. In the table and figure, it can be observed that mostly trees are with middle income group 30k-90k. 90k-150k income group also have a good share of trees plantation about 18% considering there less houses as compared to house share of 30k-90k income group. Higher income group 150k-210k have a share of 21 % plantation. Chitrakoot has a good amount of plantation which cool the environment and bring shade during summer sun.

S. No.	Income–group (Rs.)	Trees	
		Nos.	Per cent
1	< 30,000	9	13%
2	30,000 - 90,000	23	32%
3	90,000 - 150,000	13	18%
4	150,000 - 210,000	15	21%
5	2,10,000 - 2,70,000	8	11%
6	> 2,70,000	3	4%
7	Total	71	100%

Table 3.4 Households Having Trees in their Premises

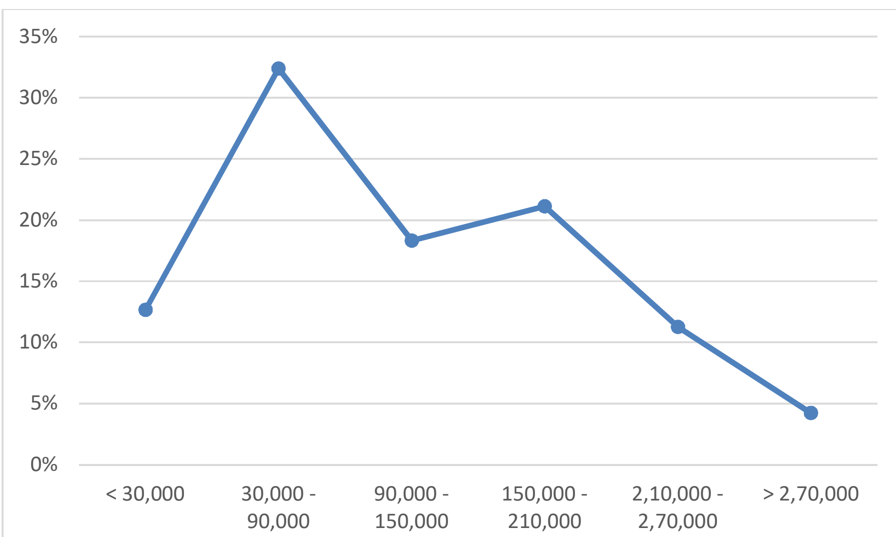


Figure 3.4 Households Having Trees in their Premises

3.6 Occupation

Occupation is an essential parameter to decide the functioning of a system. Occupation data helps us realise the education status, Income, time and services required by a society. A society with good education has better opportunities for employment and have a better living environment. The study area is a posh locality in Jaipur and have good education and employment status as compared to other neighbour areas. The income and status of job is directly linked to the education of an individual. With this understanding, occupation status of the household is analysed, the occupation has been classified as government service, private service, self-employed and retired personals, and their count in various income groups and the data is presented in the table and figure. It can be observed that 62% of the population is employed in private sector accounting most of the jobs to 30k-90k income group, 18% are self employed and 90k-150k income group make most of the self-employed, government service and retired constitute a low share of occupation in the region.

S. No.	Income–group (Rs.)	Government Service		Private Service		Self Employed		Retired		Total Population	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 30,000	0	0%	5	9%	0	0%	0	0%	5	9%
2	30,000 - 90,000	0	0%	20	36%	1	2%	1	2%	22	40%
3	90,000 - 150,000	4	7%	5	9%	3	5%	2	4%	14	25%
4	150,000 - 210,000	0	0%	2	4%	1	2%	2	4%	5	9%
5	2,10,000 - 2,70,000	1	2%	0	0%	1	2%	0	0%	2	4%
6	> 2,70,000	0	0%	2	4%	4	7%	1	2%	7	13%
	Total	5	9%	34	62%	10	18%	6	11%	55	100%

Table 3.5 Occupation

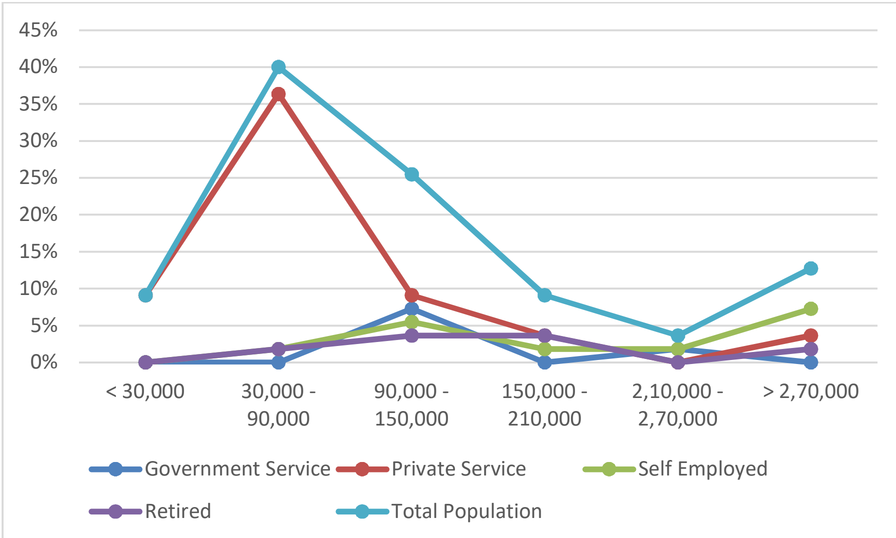


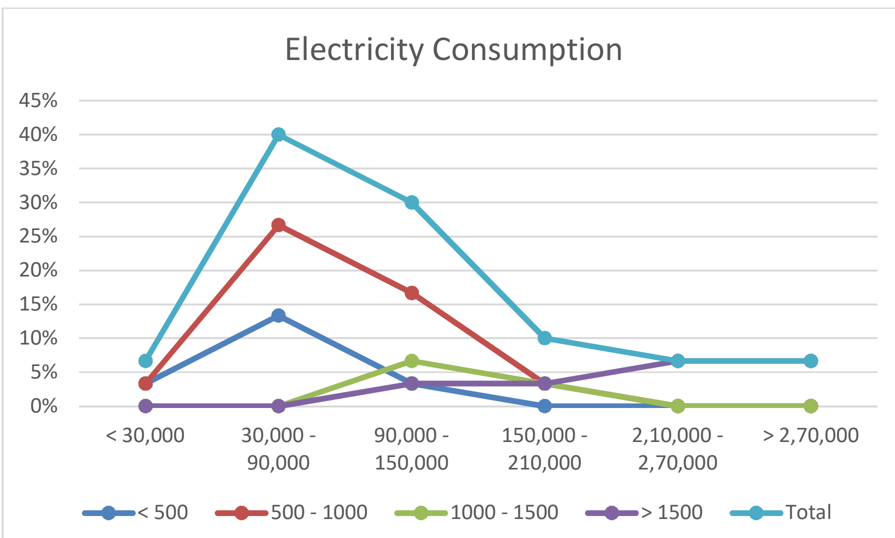
Figure 3.5 Occupation

3.7 Electricity consumption in Summer Season

Electricity is a very crucial element of modern settlements and one can't imagine a modern settlement without electricity. Electricity is used for various purposes like heating cooling, cooking, vehicles, lighting, pumping water, etc. Considering the importance of electricity, the consumption of electricity was analysed in the survey and the results have been presented in the table and figure. Half of the consumption is in the range of 500-1000 units per month. 20% of the consumption is in the range of > 1500 units per month, the Chitrakoot is a high-income group society and the consumption is high. As the income of the household increase the electricity consumption also increases and higher income group tends to use more electricity as compared to low income group. The number of electrical appliances in high income group is also very high and have higher number of air-conditions in use per person. Low income group have lesss electrical appliances and also high electricity usage devices like ACs is also less in lower income group. Lower income group tends to use dessert coolers in place of high Electricity demanding ACs.

S. No.	Income–group (Rs.)	Consumption (units/month)									
		< 500		500 - 1000		1000 - 1500		> 1500		Total	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 30,000	1	3%	1	3%	0	0%	0	0%	2	7%
2	30,000 - 90,000	4	13%	8	27%	0	0%	0	0%	12	40%
3	90,000 - 150,000	1	3%	5	17%	2	7%	1	3%	9	30%
4	150,000 - 210,000	0	0%	1	3%	1	3%	1	3%	3	10%
5	2,10,000 - 2,70,000	0	0%	0	0%	0	0%	2	7%	2	7%
6	> 2,70,000	0	0%	0	0%	0	0%	2	7%	2	7%
7	Total	6	20%	15	50%	3	10%	6	20%	30	100%

Table 3.6 Electricity Consumption in Summer Season



3.8 Domestic Cooling Appliances

Cooling appliances consist of fans, desert coolers, air conditioners. Cooling appliances are very important for comfortable living conditions in a house, since Chitrakoot is in Jaipur which is a hot and dry City and temperature during summers are unbearable without using cooling devices, cooling devices also impact the electricity usage in a house, cooling devices like ACs are high consumption devices as compared to Desert coolers. Also, ACs create a

more chilled and comfortable environment for users. Understanding the importance of Cooling Devices, the distribution of cooling devices is observed in the survey. Lower income group have higher number of desert coolers and higher income group have higher ACs. Data is presented in the table and Figure.

Table 3.7 Domestic Cooling Appliances (electrical)

S. No.	Income–group (Rs.)	Window Air Conditioner		Split Air Conditioner		Desert Cooler		Electric Fan	
		Nos.	Per cent	Nos.	Per cent	Nos.	Per cent	Nos.	Per cent
1	< 30,000	0	0%	1	2%	1	5%	2	1%
2	30,000 - 90,000	1	8%	13	22%	6	32%	46	28%
3	90,000 - 150,000	5	42%	16	27%	6	32%	51	31%
4	150,000 - 210,000	3	25%	8	13%	2	11%	19	11%
5	2,10,000 - 2,70,000	1	8%	11	18%	1	5%	27	16%
6	> 2,70,000	2	17%	11	18%	3	16%	22	13%
7	Total	12	100%	60	100%	19	100%	167	100%

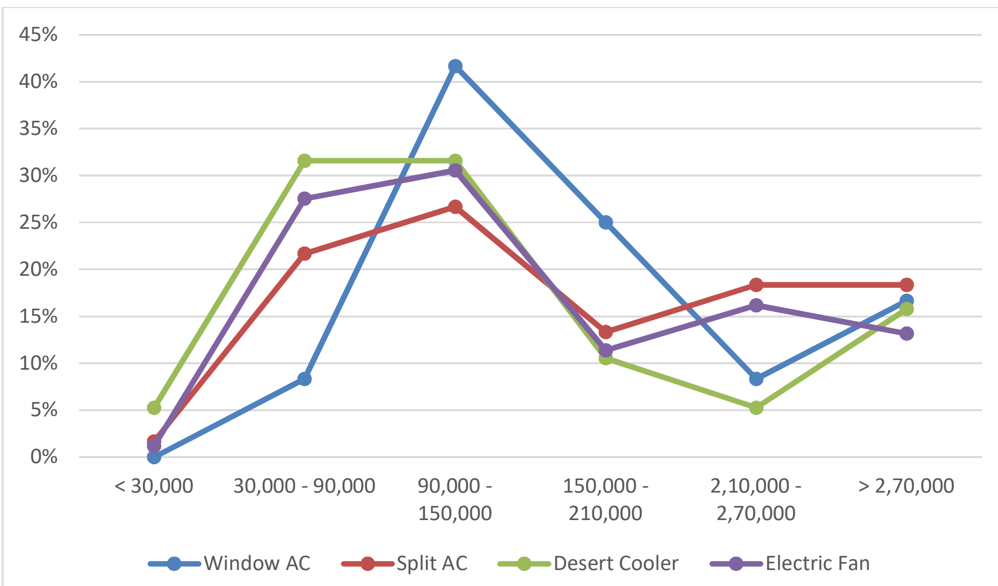


Figure 3.6 Domestic Cooling Appliance(electrical)

3.9 Findings of Survey Research

(1) Middle Income Group constitute the major population stake (36.6 %). And have an income of the range 30k-90k, 90k-150k also constitute 30 % of the population. Low income and high-income group constitute 6.6% and 12.6% respectively

(2) The average population per household is 4.6, The site area considered for simulation is 17 hectares and perimeter of 1.72 km. Total Population of the selected area is approximately 3200 in an area of 17 hectares. Person Per hectare are 188 pph.

(3) 40% of the employment is with income group 30k-90k, 62% of the total employment is in private sector, 11% are retired, 18% are self-employed, 9% is in Government Service. 90k-150k income group make most of the self-employed, government service and retired constitute a low share of occupation in the region.

(4) In housing typology, it has been observed that about two-third (60.97 per cent) of the surveyed households are confined in the row house, followed by about one-fourth (23.39 per cent) are confined in semi-detached and the rest are evenly distributed among the apartments and in the detached houses. In income group analysis, it has been observed that of the total row houses, more than half (53.24 per cent) of them are confined within the income range of less than Rs. 30,000, and more than one-fourth (28.78 per cent) are confined within the monthly income group of Rs. 30k-90k, which shows that the middle-income group are living in row houses.

4 Modelling and Simulation Process

4.1 Research Process

This thesis uses the CitySim software for energy simulation. This study is based on the particular location i.e. Chitrakoot, Jaipur, therefore the location is identified, primary and secondary data is gathered for outlining the particular scenario.

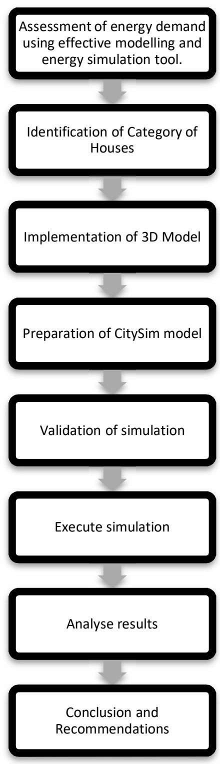


Figure 4.1: Research Process for Modeling and Simulation

(Source: Author, 2019)

4.1.1 Selection of simulation tool

It is essential to choose a perfect simulation tool for producing better simulation outcomes that are suitable for the model. The options available are Energy Plus, Visual DOE, Energy 10, eQuest, Energy Pro, CitySim and many more. CitySim is preferred over every other tool due to its effectiveness in computation of energy demand of the area of Chitrakoot, Jaipur and mirco-climatic conditions. CitySim is employed for simulating the energy utilization of the proposed archetype that represents the area of Chitrakoot. Therefore the computation of energy demand is done and the energy simulation is performed with CitySim software.

It is consisting of multiple physical models that are grouped together and estimate the on-site usage of energy for lighting, heating and cooling. It is based on hurly time steps and it requires the XML file and climatic situations file in order to perform energy simulation. The usage of non-renewable energy is minimized by effectively planning the use of energy. The objective of this software is to provide a decision support for reducing the use of non-renewable source of energy.

4.1.2 Methodology for using CitySim

Data needed for Input File

<u>Primary Data</u>

Site Survey is performed to check that solar panels are used in the locality or not.

Facade Window: The window ratio of every facade is referred as function of the period of construction within the range of 0.20 to 0.45 between the 1901 to 1920. According to the existing standards of residential building, the internal temperature set up at 20 degree Celsius.

Types of Houses: There are different types of Houses in the neighbourhood that are classified as single family house, multi-storey house and commercial buildings.

Occupants and Appliances: In order to define the internal gains, there should be the consideration of occupants and appliances in accordance to the Swiss normative SIA 2024. These are the functions of the hourly daily profile and livable surface region in the buildings.

Ground: It has been assumed for the simulation that ground is a flat surface however the methodology can also be applied to sloped grounds. The design of the ground is integrated in the geometrical model and slope is calculated as function of the construction design. This will result in declining the time of computation from 3h to 4s for an entire year of simulation.

Wall: The thermal insulation of wall is improved. It is comprised of opaque and transparent parts. The composition of the wall is gypsum plaster, stone and mortar masonry.

Secondary Data

Site Modelling by Satellite Imagery

Satellite imagery can be used for improving the severity mapping. From this source, the data is collected from the imaging satellites which are run by the government and businesses across the globe. It provides the images of the buildings on the earth or other planets for performing site modelling. It is an observational data source used for the purpose of performing diagnosis. It facilitates in building footprint extraction by which buildings of different shape and size can be detected.

Height of the building and model

Height of the building is the geometrical feature of the buildings which is analysed effectively. The building height matches up to the average height of the concentric layer.

Terminologies

- **Infiltration:** The unwanted air that accidently introduced into the buildings from outside due to the building envelope cracks or passage door is the process of infiltration that refers as air leakage. The rate by which an average winter air change per hours (ACH) as tightness functions of the envelope construction is termed as infiltration rate. The average ACH of tight envelope is 0.2-0.6 while a loose one of 1.0 to 2.0.
- **Shading Device:** By building elements, shading can be provided. These devices can be vertical, egg-crate and horizontal. The thermal condition within the building is greatly impacted by these devices. The application of these devices facilitates in reducing the consumption of energy. AC that uses extensive energy which can be reduced by using natural air with the help of architectural elements helping in reducing building heat. Its elements reduce the angle of solar heat that strikes the glass field. It blocks the direct rays of solar and therefore reduces the impacts of indirect illumination that includes ground level and sky reflection.
- **Cut off irradiance:** To amplify performance simulations, the irradiance is cut off. Irradiance is referred to as the computation and assessment of solar power which depicts the rate at which solar energy falls onto a surface.

- **G-value:** The glazing performance is improved as the current glazing is replaced with the triple glazing that has a U-Value of 0.7 Wm-2K-1. It reduces the energy consumption from 120-140kWh-2 to 75-100kWh-2.
- **Openable fraction**: There is a fixed pane and a sliding shutter in the window and the fixed one is a little above of the other that results in an openable bottom half. The fraction of openable part of the window is also considered for reducing the energy utilisation.

4.1.3 Category of House

The classification of house into different categories helps in identifying the building's compactness. In order to computes the compactness, the surface to volume ratio (S/V) of the buildings located at Chitrakoot is computed.

- **Detached House:** S/V of the buildings in case of detached house is greater than 0.8 m-1.
- **Terrace House:** S/V is within the range of 0.6 m-1to 0.8 m-1.
- **Multi-family House:** S/V is within the range of 0.4 m-1 to 0.6 m-1.
- **Apartment Block:** S/V is less than or equal to 0.4 m-1.

This household information is collected from the Cartographic technical map of the Municipality.

4.1.4 Base Analysis

Base is analysed on the basis of different values that will be discussed in this section. There are different situation occurred with the creation of renovation scenarios. It helps in effective assessment of the energy utilisation for building design in the neighbourhood.

Solar Potential: the optimized is performed for improving the solar energy potential for effective design of the building that can reduce the consumption of energy. It is a design parameter used for analysing the energy consumption in the neighbourhood locality, Chitrakoot. It will help in utilising the solar energy for heating, cooling and illuminating the buildings. The potential of solar energy within the buildings is maximised which is measured with the solar mapping. Solar potential of the facade can be assessed with the different tools like FASSADES, etc. It is influenced by the density, roof shape, orientation and design.

Surface Temperature: The use of electricity in the building is related to the surface temperatures within the buildings. The use of Expanded polystyrene (EPS) insulation helps in maintaining the surface temperature for the efficient utilisation of the electricity. The temperature of the surface is not in linear relationship with the electricity. The air tight envelope and insulation will help in eradicating the wastage of energy.

Photovoltaic Potential: Photovoltaics is an integral concept of building design in order to manage the consumption of energy. The potential of Photovoltaic is optimized for gaining the solar energy and effectively referring the thermal design of the buildings. It will give a significant supply of electricity by integrating into the architectural design of facades and roofs of the buildings.

Sky View Factor: It is an essential factor for the evaluation of thermal environment and spatial indicators of the neighbourhood. It quantifies the features of surface temperatures for managing the use of electricity. The highest radiation for surfaces is (100kWhm-2) for streets oriented WNE-ESE and for facades, it is (1400 kWhm-2) for facing SSW. Street surfaces gains the maximum monthly radiation is 80 kWhm-2.

Heating/Cooling demand and Indoor Temperature: There are different cases based on the heating/cooling demand and indoor temperature within the buildings. In this paper, the floor, walls, roofs are insulated with 0.35m EPS and Glazing replaced with 0.7W/m2K in the cooling demand base case scenario and indoor temperature base case scenario.

5. Results and Discussions

5.1.Simulation Process

Scenarios

A) Base Case Scenario
B) Case A- 0.35m EPS insulation Installed to the floor
C) Case B- 0.35m EPS insulation installed to the Roof
D) Case C- 0.35m EPS insulation installed to the walls
E) Case D – Replacing Glazing (0.7 W /m2K)
F) Case E- Case A + Case B + Case C + Case D

Data Inputs

Table 5.1.1 Data Inputs in Citysim Software

ID	Area	Volume	S/V	Height	Façade WR	Typology	Infilteration	T Min	T Max	Model Cooling May
A1	4270.52	64057.8	0.06667	15	0.22	Apartment Block	0.1	20	26	79859
A10	1140.54	17108.1	0.06667	15	0.22	Apartment Block	0.1	20	26	21328
A11	1093.46	16401.9	0.06667	15	0.22	Apartment Block	0.1	20	26	20448
A12	588.25	8823.75	0.06667	15	0.22	Apartment Block	0.1	20	26	11000
A13	378.77	5681.55	0.06667	15	0.22	Apartment Block	0.1	20	26	7083
A14	358.49	5377.35	0.06667	15	0.22	Terrace House	0.1	20	26	6704
A15	205.95	823.8	0.25	4	0.25	Detached House	0.1	20	26	3851
A16	8605.98	129089.7	0.06667	15	0.22	Apartment Block	0.1	20	26	160932
A17	1565.7	23485.5	0.06667	15	0.22	Apartment Block	0.1	20	26	29279
A18	393.8	5907	0.06667	15	0.22	Apartment Block	0.1	20	26	7364
A19	473.74	7106.1	0.06667	15	0.22	Apartment Block	0.1	20	26	8859
A2	315.62	2209.34	0.14286	7	0.3	Terrace House	0.1	20	26	5902
A2	845.66	12684.9	0.0666	15	0.22	Apartme	0.1	20	26	15814

0			7			nt Block				
A21	1988.14	29822.1	0.06667	15	0.22	Apartment Block	0.1	20	26	37178
A22	4115.25	61728.75	0.06667	15	0.22	Apartment Block	0.1	20	26	76955
A23	262.6	1838.2	0.14286	7	0.3	Terrace House	0.1	20	26	4911
A24	176.25	1233.75	0.14286	7	0.3	Terrace House	0.1	20	26	3296
A25	741.15	5188.05	0.14286	7	0.3	Terrace House	0.1	20	26	13860
A26	230.38	1612.66	0.14286	7	0.3	Terrace House	0.1	20	26	4308
A27	1456.98	16755.27	0.08696	11.5	0.26	Multi Family House	0.1	20	26	27246
A28	977.47	11240.91	0.08696	11.5	0.26	Multi Family House	0.1	20	26	18279
A29	1234.16	14192.84	0.08696	11.5	0.26	Multi Family House	0.1	20	26	23079
A3	693.58	7976.17	0.08696	11.5	0.26	Multi Family House	0.1	20	26	12970
A30	297.71	3423.665	0.08696	11.5	0.26	Multi Family House	0.1	20	26	5567
A31	1243.57	14301.06	0.08696	11.5	0.26	Multi Family House	0.1	20	26	23255
A32	2512.25	28890.88	0.08696	11.5	0.26	Multi Family House	0.1	20	26	46979
A33	266.3	3062.45	0.08696	11.5	0.26	Multi Family House	0.1	20	26	4980
A34	4515.21	51924.92	0.08696	11.5	0.26	Multi Family House	0.1	20	26	84434
A35	2538.35	29191.03	0.08696	11.5	0.26	Multi Family House	0.1	20	26	47467
A36	2538.35	17768.45	0.14286	7	0.3	Terrace House	0.1	20	26	47467
A37	22.86	160.02	0.14286	7	0.3	Terrace House	0.1	20	26	427
A38	633.19	4432.33	0.14286	7	0.3	Terrace House	0.1	20	26	11841
A3	1381.0	9667.49	0.1428	7	0.3	Terrace	0.1	20	26	25826

9	7		6			House				
A4	371.6	2601.2	0.14286	7	0.3	Terrace House	0.1	20	26	6949
A40	499.27	3494.89	0.14286	7	0.3	Terrace House	0.1	20	26	9336
A41	1061.24	15918.6	0.06667	15	0.22	Apartment Block	0.1	20	26	19845
A42	752.92	8658.58	0.08696	11.5	0.22	Apartment Block	0.1	20	26	14080
A43	312.67	4690.05	0.06667	15	0.22	Apartment Block	0.1	20	26	5847
A44	558.63	6424.245	0.08696	11.5	0.26	Multi Family House	0.1	20	26	10446
A45	1043.22	11997.03	0.08696	11.5	0.26	Multi Family House	0.1	20	26	19508
A46	838.12	9638.38	0.08696	11.5	0.26	Multi Family House	0.1	20	26	15673
A47	1346.06	15479.69	0.08696	11.5	0.26	Multi Family House	0.1	20	26	25171
A48	875.92	10073.08	0.08696	11.5	0.26	Multi Family House	0.1	20	26	16380
A49	1488.34	17115.91	0.08696	11.5	0.26	Multi Family House	0.1	20	26	27832
A5	374.83	2623.81	0.14286	7	0.3	Terrace House	0.1	20	26	7009
A50	141.64	991.48	0.14286	7	0.3	Terrace House	0.1	20	26	2649
A51	561.3	6454.95	0.08696	11.5	0.26	Multi Family House	0.1	20	26	10496
A52	363.47	4179.905	0.08696	11.5	0.26	Multi Family House	0.1	20	26	6797
A53	439.24	5051.26	0.08696	11.5	0.26	Multi Family House	0.1	20	26	8214
A54	280.6	3226.9	0.08696	11.5	0.26	Multi Family House	0.1	20	26	5247
A55	694.58	7987.67	0.08696	11.5	0.26	Multi Family House	0.1	20	26	12989
A56	743.14	8546.11	0.08696	11.5	0.26	Multi Family	0.1	20	26	13897

						House				
A57	673.32	4713.24	0.14286	7	0.3	Terrace House	0.1	20	26	12591
A58	326.46	2285.22	0.14286	7	0.3	Terrace House	0.1	20	26	6105
A59	1540.78	10785.46	0.14286	7	0.3	Terrace House	0.1	20	26	28813
A6	3451.12	51766.8	0.06667	15	0.22	Apartment Block	0.1	20	26	64536
A60	436.05	3052.35	0.14286	7	0.3	Terrace House	0.1	20	26	8154
A61	796.51	5575.57	0.14286	7	0.3	Terrace House	0.1	20	26	14895
A62	2015.61	23179.52	0.08696	11.5	0.26	Multi Family House	0.1	20	26	37692
A63	872.23	10030.65	0.08696	11.5	0.26	Multi Family House	0.1	20	26	16311
A64	781.59	8988.285	0.08696	11.5	0.26	Multi Family House	0.1	20	26	14616
A65	646.42	7433.83	0.08696	11.5	0.26	Multi Family House	0.1	20	26	12088
A66	934.34	10744.91	0.08696	11.5	0.26	Multi Family House	0.1	20	26	17472
A67	441.51	5077.365	0.08696	11.5	0.26	Multi Family House	0.1	20	26	8256
A68	368.4	4236.6	0.08696	11.5	0.26	Multi Family House	0.1	20	26	6889
A69	390.72	4493.28	0.08696	11.5	0.26	Multi Family House	0.1	20	26	7306
A7	360.65	5409.75	0.06667	15	0.22	Apartment Block	0.1	20	26	6744
A70	435.53	5008.595	0.08696	11.5	0.26	Multi Family House	0.1	20	26	8144
A71	1650.72	18983.28	0.08696	11.5	0.26	Multi Family House	0.1	20	26	30868
A72	2618.26	30109.99	0.08696	11.5	0.26	Multi Family House	0.1	20	26	48961
A73	7206	82869	0.08696	11.5	0.26	Multi Family	0.1	20	26	134752

						House				
A74	498.45	3489.15	0.14286	7	0.3	Terrace House	0.1	20	26	9321
A75	838.08	9637.92	0.08696	11.5	0.26	Multi Family House	0.1	20	26	15672
A76	3374.61	50619.15	0.06667	15	0.22	Apartment Block	0.1	20	26	63105
A77	1657.2	19057.8	0.08696	11.5	0.26	Multi Family House	0.1	20	26	30990
A78	1575.52	18118.48	0.08696	11.5	0.26	Multi Family House	0.1	20	26	29462
A79	905.75	10416.13	0.08696	11.5	0.26	Multi Family House	0.1	20	26	16938
A8	1574.49	23617.35	0.06667	15	0.22	Apartment Block	0.1	20	26	29443
A80	1458.09	16768.04	0.08696	11.5	0.26	Multi Family House	0.1	20	26	27266
A81	1128.17	12973.96	0.08696	11.5	0.26	Multi Family House	0.1	20	26	21097
A82	1186.78	13647.97	0.08696	11.5	0.26	Multi Family House	0.1	20	26	22193
A83	2136.24	24566.76	0.08696	11.5	0.26	Multi Family House	0.1	20	26	39948
A84	1999.66	22996.09	0.08696	11.5	0.26	Multi Family House	0.1	20	26	37394
A85	1806.76	20777.74	0.08696	11.5	0.26	Multi Family House	0.1	20	26	33786
A86	581.09	6682.535	0.08696	11.5	0.26	Multi Family House	0.1	20	26	10866
A87	4057.61	60864.15	0.06667	15	0.22	Apartment Block	0.1	20	26	75877
A88	619.34	7122.41	0.08696	11.5	0.26	Multi Family House	0.1	20	26	11582
A89	327.88	3770.62	0.08696	11.5	0.26	Multi Family House	0.1	20	26	6131
A9	362.28	5434.2	0.06667	15	0.22	Apartment Block	0.1	20	26	6775

A90	2011.54	23132.71	0.08696	11.5	0.26	Multi Family House	0.1	20	26	37616
A91	1712.47	19693.41	0.08696	11.5	0.26	Multi Family House	0.1	20	26	32023
A92	476.76	5482.74	0.08696	11.5	0.26	Multi Family House	0.1	20	26	8915
A93	1019.5	11724.25	0.08696	11.5	0.26	Multi Family House	0.1	20	26	19065
A94	1893.26	21772.49	0.08696	11.5	0.26	Multi Family House	0.1	20	26	35404
A95	3772.08	43378.92	0.08696	11.5	0.26	Multi Family House	0.1	20	26	70538
A96	5639.1	84586.5	0.06667	15	0.22	Apartment Block	0.1	20	26	105451
A97	500.58	5756.67	0.08696	11.5	0.26	Multi Family House	0.1	20	26	9361
A98	414.35	6215.25	0.06667	15	0.22	Apartment Block	0.1	20	26	7748

5.1.1. Base Case Scenario

Base case is situation calibrated to give results nearest to existing site situations. Various input parameter requires to calibrate the base case are Infiltration, U value of Glass, Wall-Roof-Floor Material Properties, Occupants, Occupant Profile, and the weather files obtained from meteonorm, the model was calibrated and compared with the existing survey results. Results are as in table and figure

Table 5.0.2 Simulation result and Measured Result

ID	AREA	VOLUME	S/V	HEIGHT	FAÇADE WR	TYPOLOGY	INFILTERATION	T MIN	T MAX	MODEL COOLING (MAY)	MEASURED COOLING	%ERROR
A 14	358.49	5377.35	0.066667	15	0.22	Terrace House	0.1	20	26	6704	5900	12%

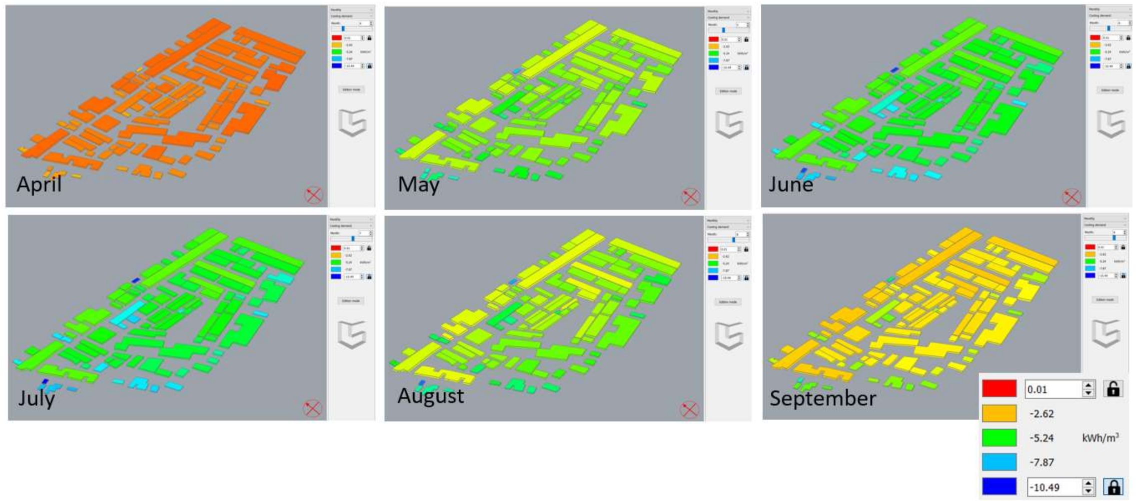
A 2	315.62	2209.34	0.142857	7	0.3	Terrace House	0.1	20	26	5902	4500	24%
A 23	262.6	1838.2	0.142857	7	0.3	Terrace House	0.1	20	26	4911	4350	11%
A 24	176.25	1233.75	0.142857	7	0.3	Terrace House	0.1	20	26	3296	2700	18%
A 37	22.86	160.02	0.142857	7	0.3	Terrace House	0.1	20	26	427	370	13%

The difference between the modelled and Measured electrical consumption is in the range of 11-24%, the difference in the socio economic factors is the main reason for the % errors as lower income group tends to use desert coolers and high income tends to use ACs which use more electricity for cooling. A14, A23, A37, were the situations where there was use of air conditioners in the house whereas A2 and A24 were using Desert coolers mostly for cooling purpose. The software Citysim Consider cooling Required when temperature reaches the set point which was set to 26 degree Celsius in calibrated model. In base case the walls were clay Brick walls with RCC for Roofing and ground was compacted Earth, there materials were selected from the material library of Citysim.

Cooling demand through simulation is presented in Figure 25 and Figure 26, the cooling demand

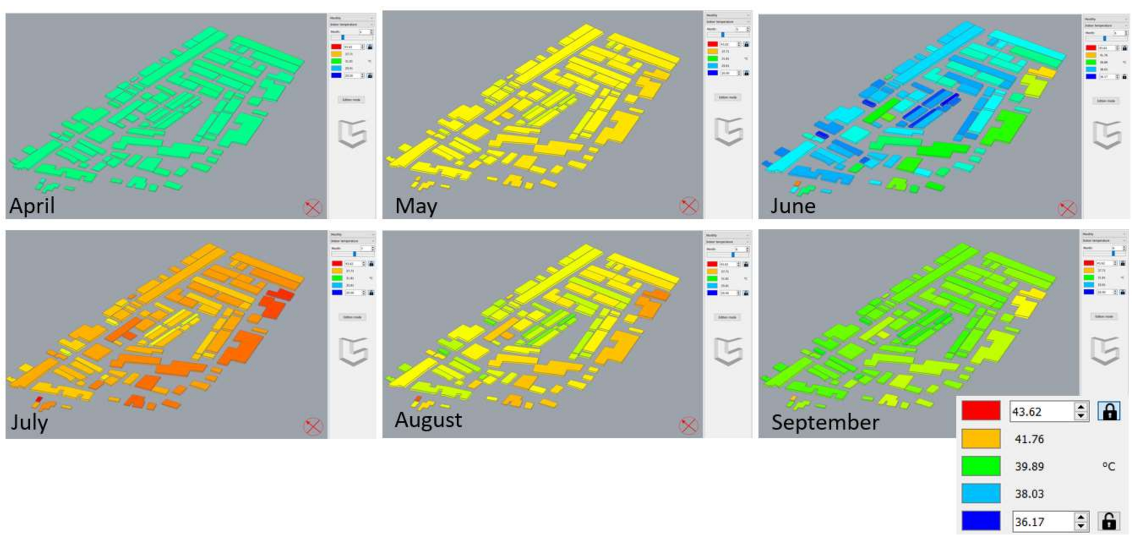
Cooling Demand

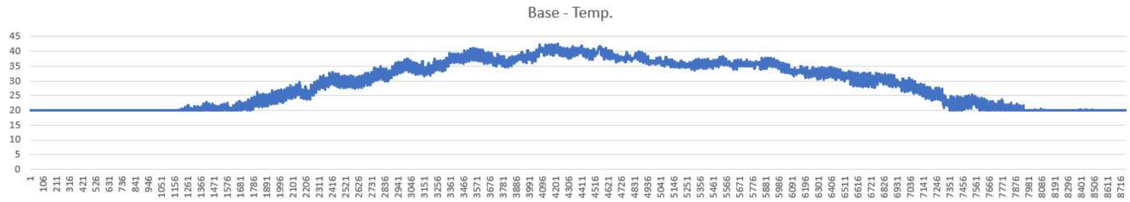
Cooling Demand in April is a as low as 0.01 kWh/m3 and reaches upto 2.01 kWh/m3 in the month of May and June

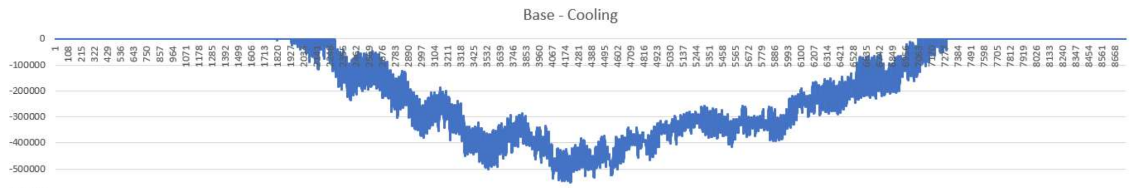


Indoor Temperature

Indoor temperature range from 36 degree Celsius to 43 degree Celsius in the month of May and june at some Blocks which can be seen in the figure.







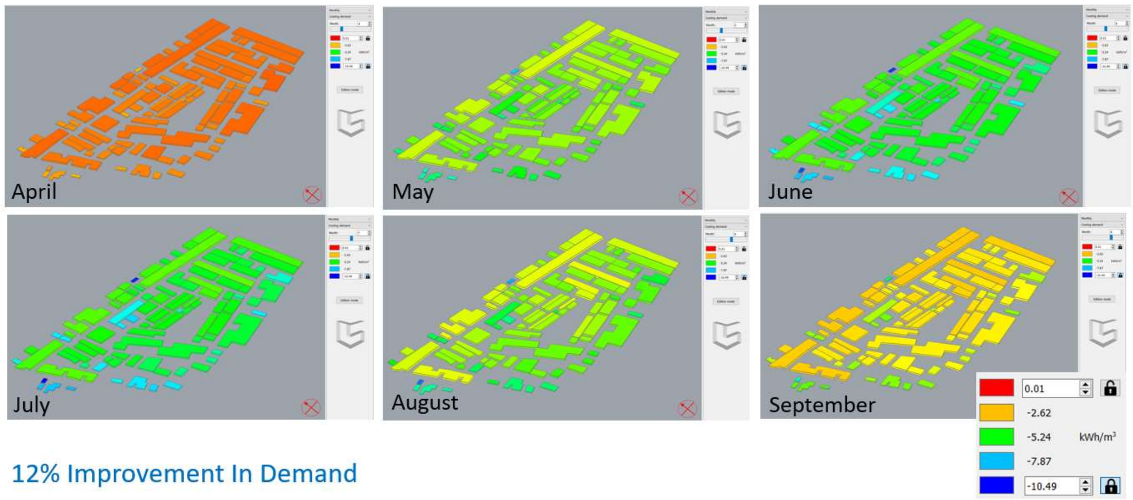
EPS Insulation Properties

EPS Thickness	:	35	cm
EPS Type	:	S	S = Standard, N = Neo
EPS Density	:	10	Kg/m^3
EPS Thermal Conductivity	:	0.0435	W/m.K
R-Value Insulation	:	8.05	m^2.K/W
U-Value Insulation	:	0.12	W/m^2.K

5.1.2. Case A – Floor with 0.35 m EPS Insulation

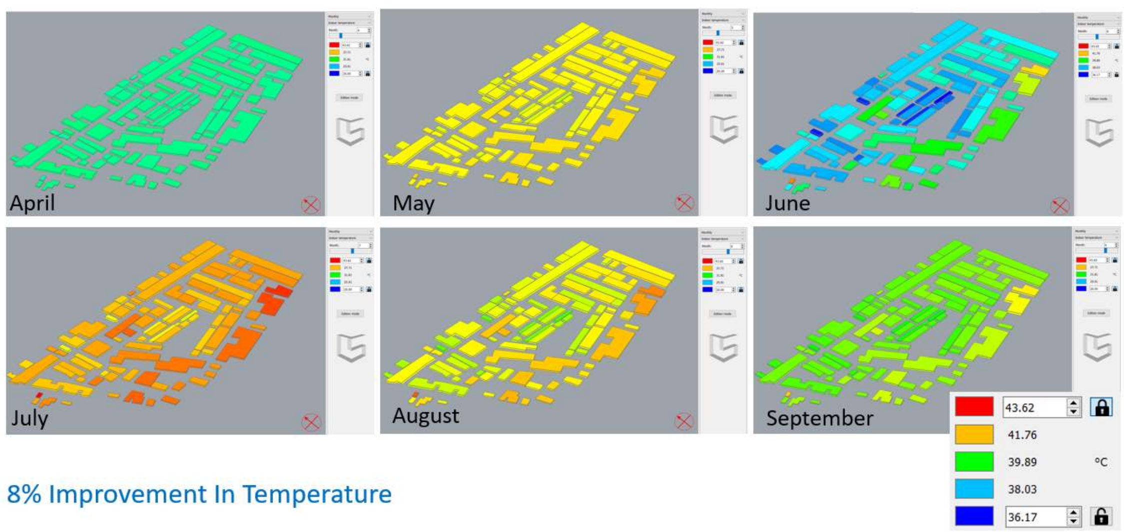
Cooling Demand

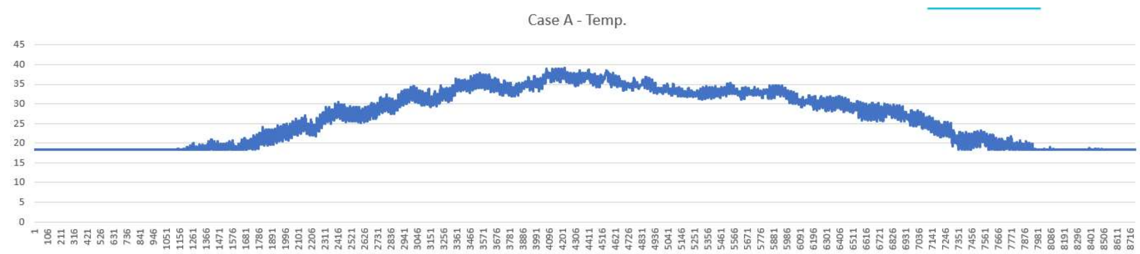
By providing 0.35m Thickness of EPS insulation to the floor of the building a 12% improvement in the cooling demand is observed through simulation

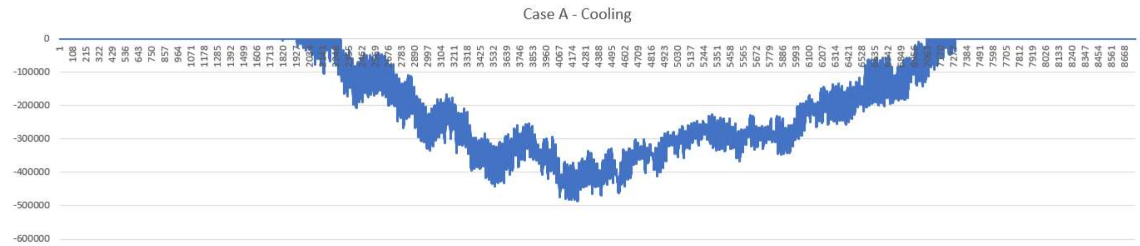


Indoor Temperature

By providing 0.35m Thickness of EPS insulation to the floor of the building a 8% improvement in Indoor Temperature is observed through simulation



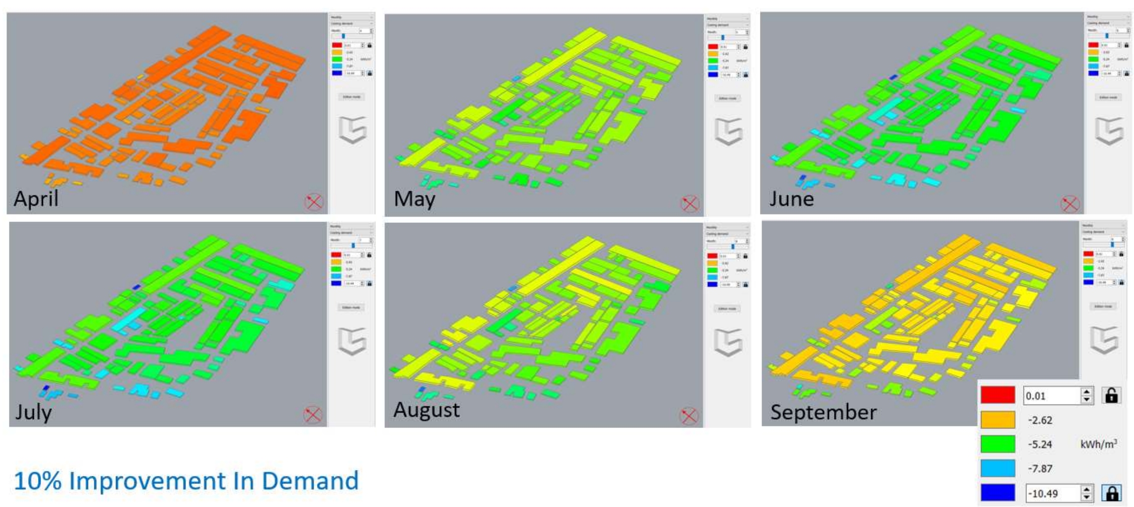




5.1.3 Case B – Roof with 0.35 m EPS Insulation

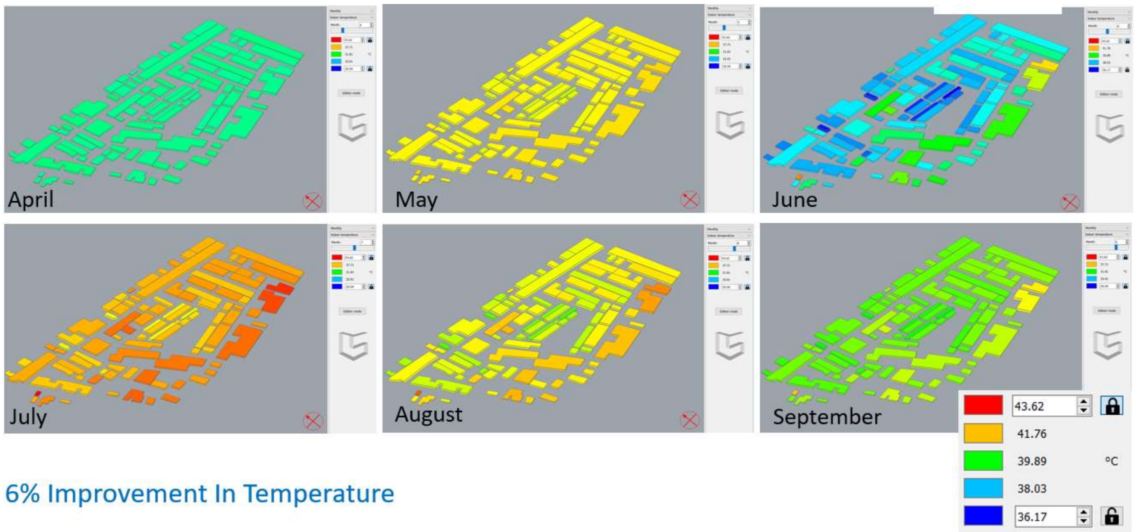
Cooling Demand

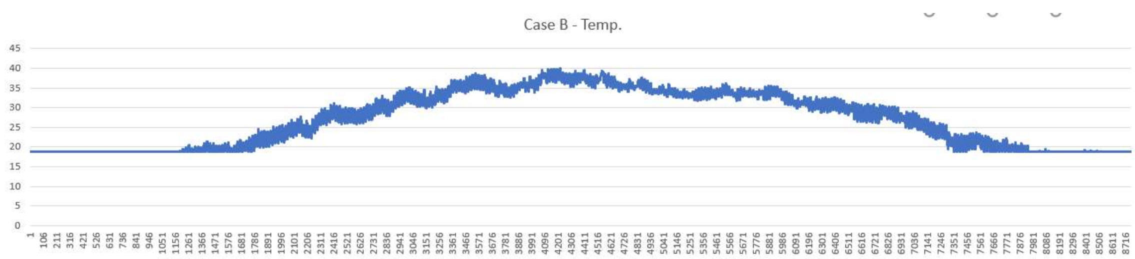
By providing 0.35m Thickness of EPS insulation to the Roof of the building a 10% improvement in the cooling demand is observed through simulation

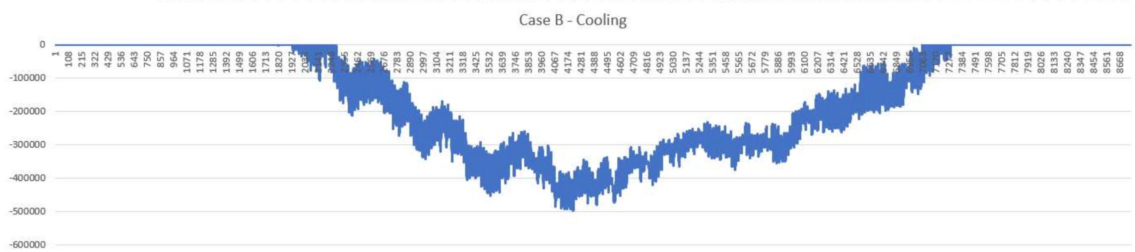


Indoor Temperature

By providing 0.35m Thickness of EPS insulation to the Roof of the building a 6% improvement in Indoor Temperature is observed through simulation



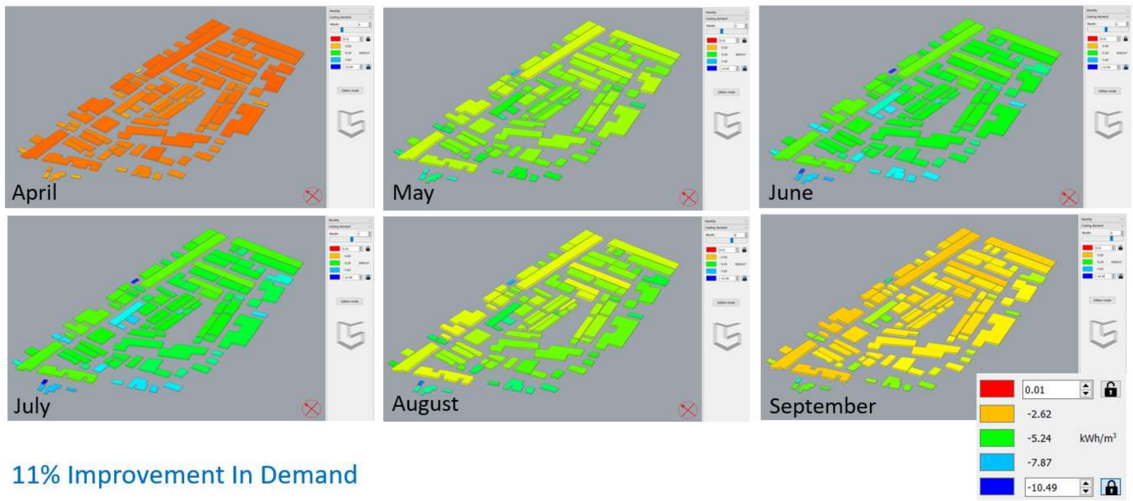




5.1.4 Case C – Walls with 0.35 m EPS Insulation

Cooling Demand

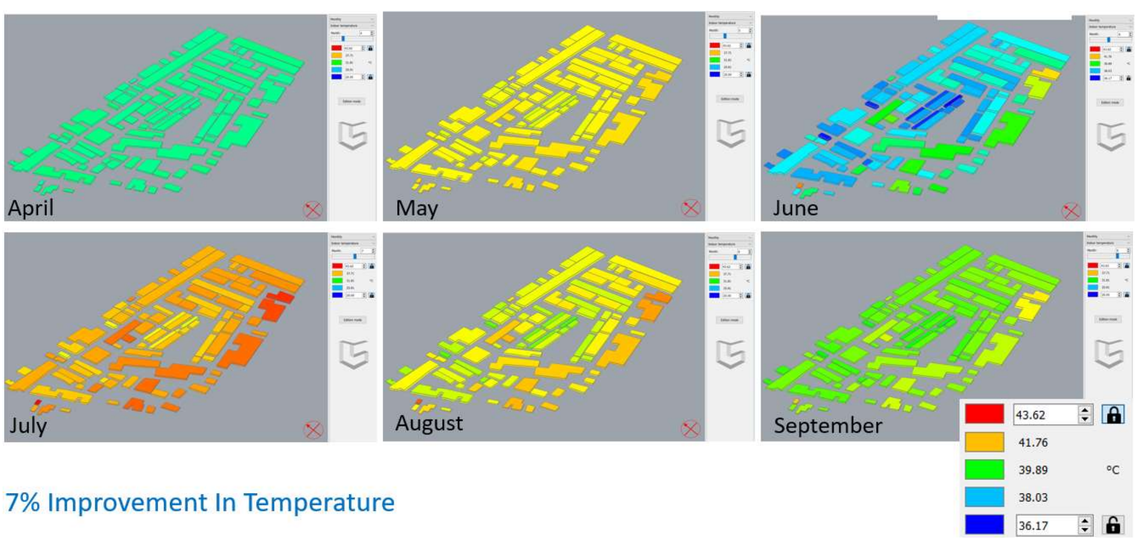
By providing 0.35m Thickness of EPS insulation to the Walls of the building a 11% improvement in the cooling demand is observed through simulation



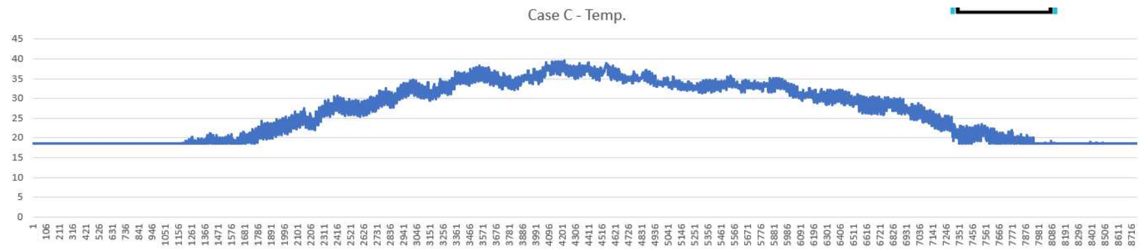
11% Improvement In Demand

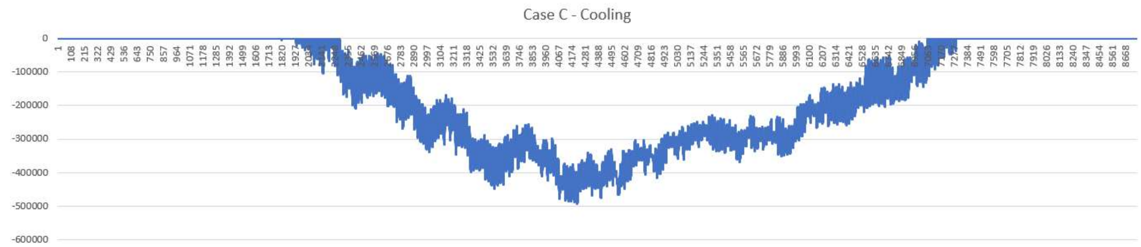
Indoor Temperature

By providing 0.35m Thickness of EPS insulation to the Walls of the building a 7% improvement in Indoor Temperature is observed through simulation



7% Improvement In Temperature

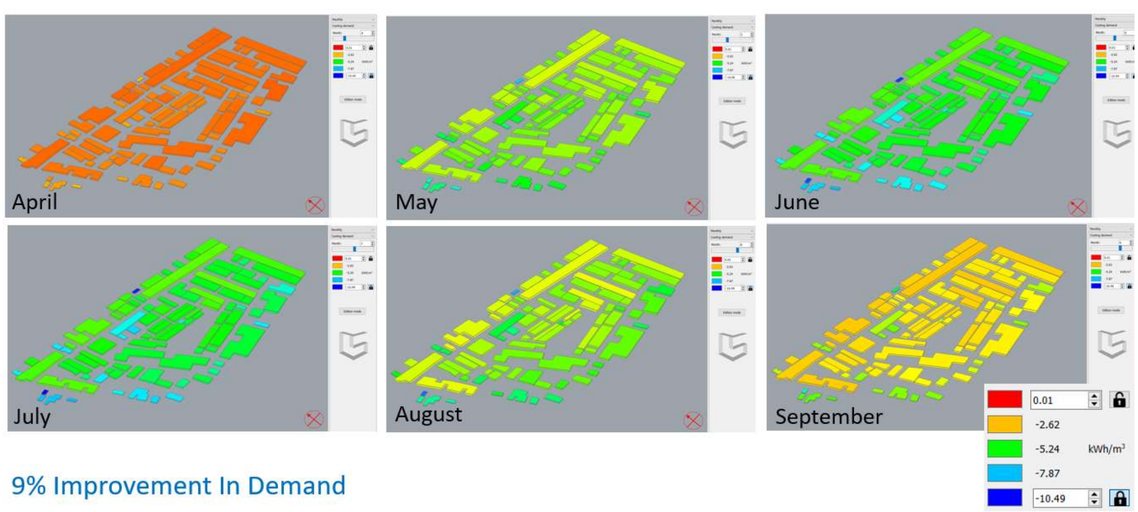




5.1.5 Case D – Replacing Glazing (0.7 W/m2)

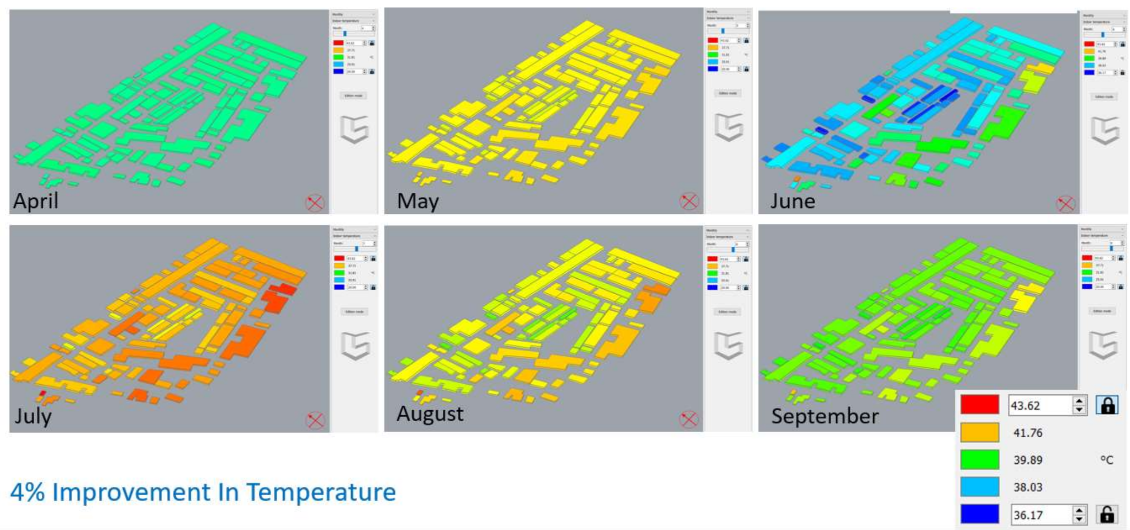
Cooling Demand

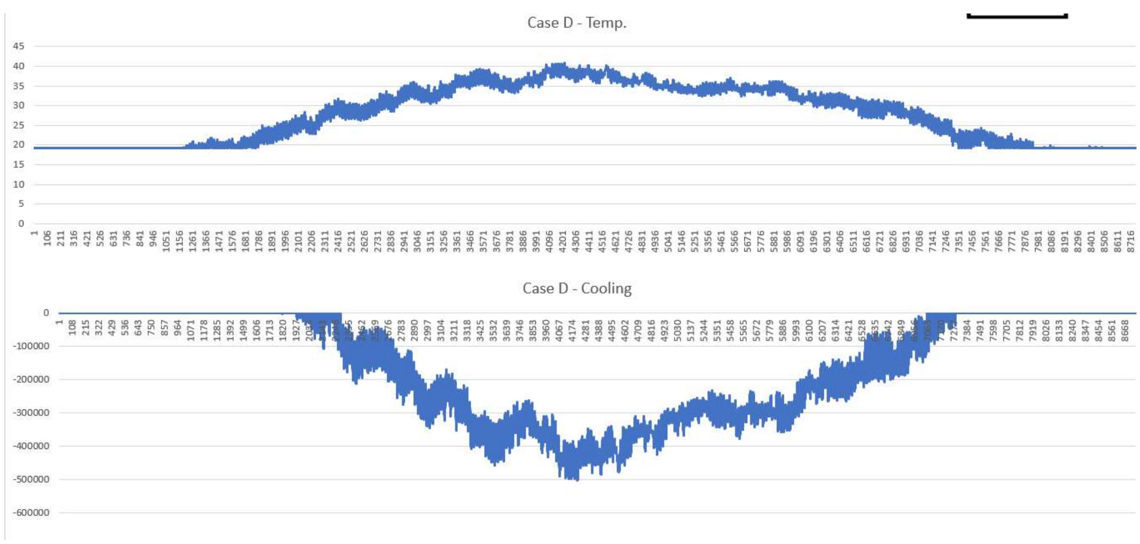
By replacing glazing with better performing glass materials having u-value 0.7W/m2 a 9% improvement in the cooling demand is observed through simulation



Indoor Temperature

By replacing glazing with better performing glass meterials having u-value 0.7W/m2 a 4% improvement in Indoor Temperature is observed through simulation

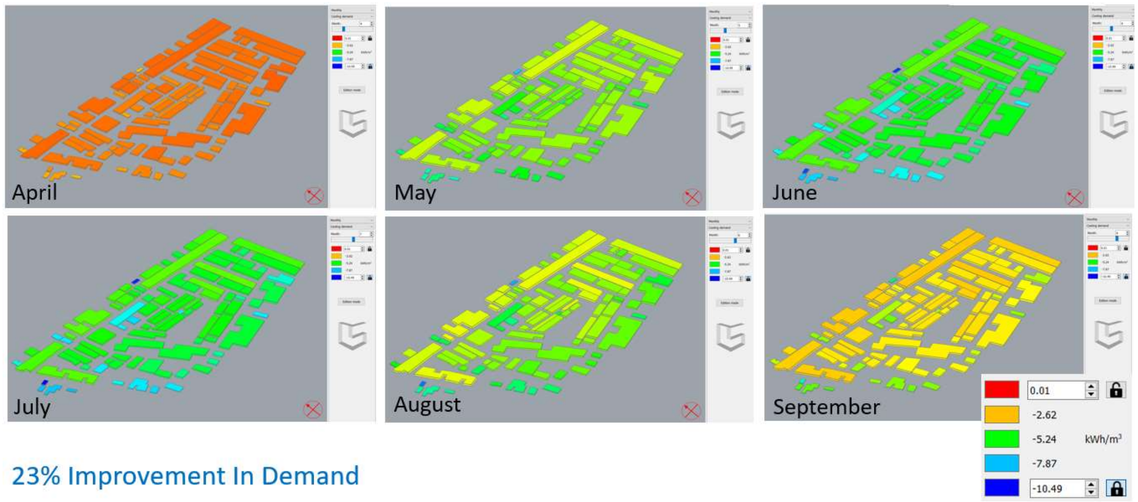




5.1.6 Case E – Case A+ Case B + Case C + Case D

Cooling Demand

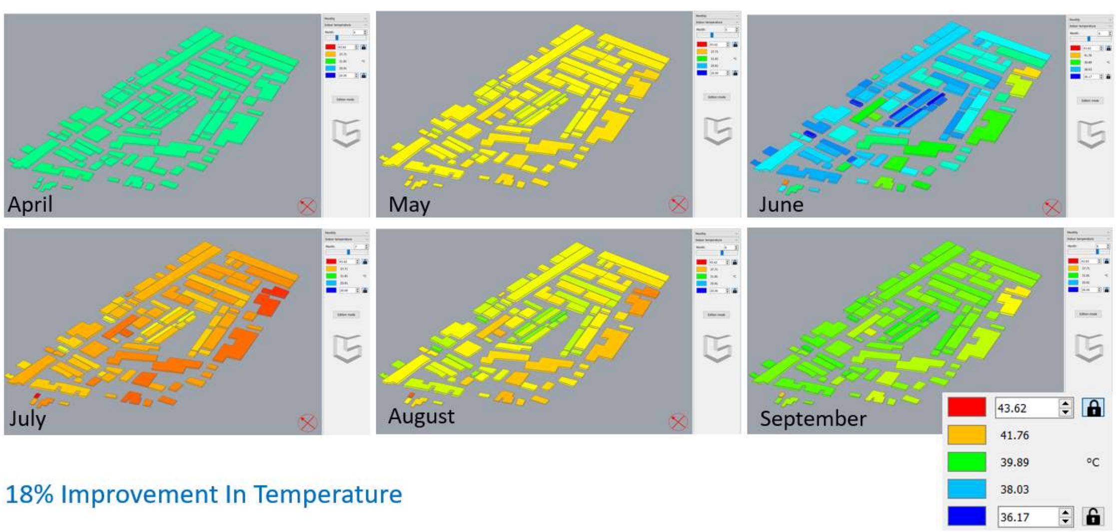
By combining the insulation in walls, floor roof and also replacing windows with better performing glass a 23% improvement in the cooling demand is observed through simulation



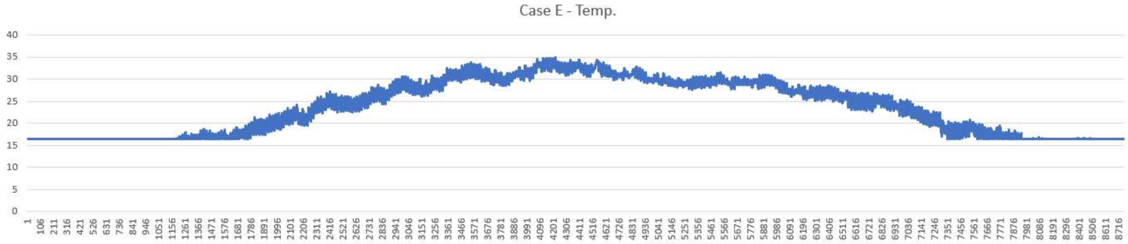
23% Improvement In Demand

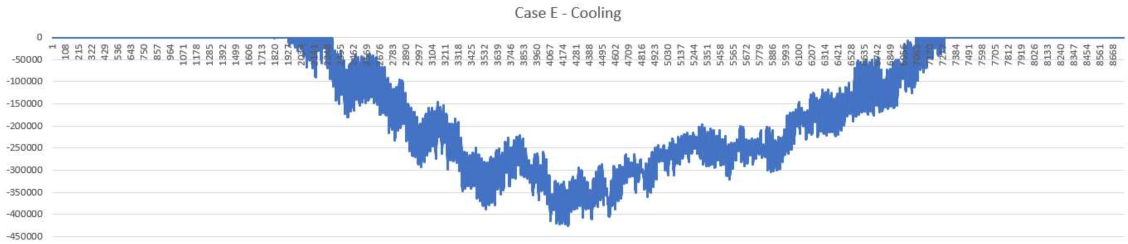
Indoor Temperature

By combining the insulation in walls, floor roof and also replacing windows with better performing glass a 18% improvement in Indoor Temperature is observed through simulation

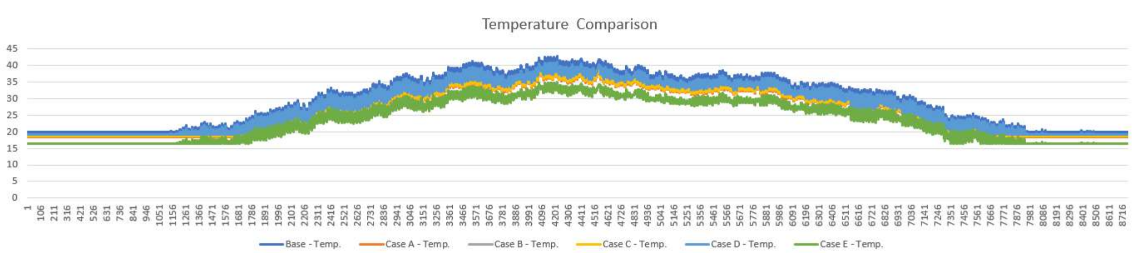


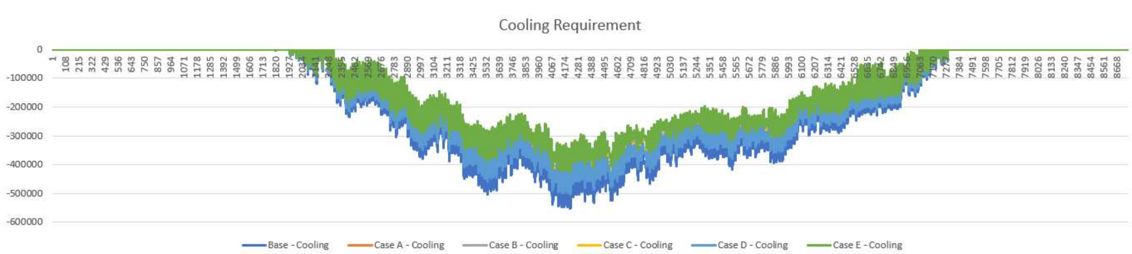
18% Improvement In Temperature





5.1.7 Comparison of Case A, B, C, D, E,





From the simulation of the model, in base case the cooling demand range from 0.01kWh/m3 to 2.7kWh/m3, a 12% improvement in cooling demand is observed by installing 0.35m of EPS insulation to the floor and improvement of 8% in indoor temperature is observed in the same case. An improvement of 10% in cooling demand and 6% improvement in indoor temperature is observed in Case B with 0.35 m EPS insulation installed to the roof of buildings. An improvement of 11% in cooling demand and 7% improvement in indoor temperature is observed in Case C with 0.35m EPS insulation on the walls. An improvement of 9% in cooling demand and 4% improvement in indoor temperature is observed in Case D with replaced glazing to 0.7w/m2. In Case E the EPS Insulation is installed to roof, floor, walls and also the glazing is replaced at the same time and then simulated, an improvement of 23% in cooling demand and 18% improvement in indoor temperature is observed.

6 Recommendations and Conclusion

6.1 Recommendations for Chitrakoot, Jaipur

A) Citysim software is able to simulate approximate cooling demand and indoor temperature. And it is recommended to use the software to make informed planning decisions during early planning stage.
B) EPS insulation is recommended to be used in houses in place of false ceiling designs as it can improve the cooling demand and indoor temperature of a building.
C) Insulation of appropriate specification should be recommended in policies and should be checked for during plan approvals as it will improve the indoor temperature and Cooling demand as a whole is a region.
D) Citysim Software has a few limitations, calibration to match survey results was difficult as the no of variables that can be changed are limited, other softwares like Energy Plus are better performers in case of single building performance analysis

6.2 Conclusion

A) Base Case Scenario

The difference between the modelled and Measured electrical consumption is in the range of 11-24%, the difference in the socio-economic factors is the main reason for the % errors as lower income group tends to use desert coolers and high income tends to use ACs which use more electricity for cooling. A14, A23, A37, were the situations where there was use of air conditioners in the house whereas A2 and A24 were using Desert coolers mostly for cooling purpose.

B) Case A- 0.35m EPS insulation Installed to the floor

By providing 0.35m Thickness of EPS insulation to the floor of the building a 12% improvement in the cooling demand is observed through simulation

By providing 0.35m Thickness of EPS insulation to the floor of the building a 8% improvement in Indoor Temperature is observed through simulation

C) Case B- 0.35m EPS insulation installed to the Roof

By providing 0.35m Thickness of EPS insulation to the Roof of the building a 10% improvement in the cooling demand is observed through simulation

By providing 0.35m Thickness of EPS insulation to the floor of the building a 6% improvement in Indoor Temperature is observed through simulation

D) Case C- 0.35m EPS insulation installed to the walls

By providing 0.35m Thickness of EPS insulation to the Roof of the building a 9% improvement in the cooling demand is observed through simulation

By providing 0.35m Thickness of EPS insulation to the floor of the building a 4% improvement in Indoor Temperature is observed through simulation

E) Case D- Windows with U value 0.7W/m2

By replacing glazing with better performing glass materials having u-value 0.7W/m2 a 9% improvement in the cooling demand is observed through simulation. By replacing glazing with better performing glass materials having u-value 0.7W/m2 a 4% improvement in Indoor Temperature is observed through simulation.

F) Case E- Case A + Case B + Case C + Case D

By providing 0.35m Thickness of EPS insulation to the Roof of the building a 23% improvement in the cooling demand is observed through simulation

By providing 0.35m Thickness of EPS insulation to the floor of the building a 18% improvement in Indoor Temperature is observed through simulation.

References

(1) Abdullahi, S., Pradhan, B., Mansor, S. and Shariff, A.R.M., 2015. GIS-based modeling for the spatial measurement and evaluation of mixed land use development for a compact city. *GIScience & Remote Sensing*, *52*(1), pp.18-39.

(2) Ali, U. Shamsi, M.H., Hoare, C., ODonnell., J. 2018. GIS-Based Residential Building Energy Modeling at District Scale. *4th Building Simulation and Optimization Conference*.

(3) Ascione, F., Canelli, M., De Masi, R.F., Sasso, M. and Vanoli, G.P., 2014. Combined cooling, heating and power for small urban districts: An Italian case-study. *Applied Thermal Engineering*, *71*(2), pp.705-713.

(4) Ascione, F., De Masi, R.F., de Rossi, F., Fistola, R., Sasso, M. and Vanoli, G.P., 2013. Analysis and diagnosis of the energy performance of buildings and districts: Methodology, validation and development of Urban Energy Maps. *Cities*, *35*, pp.270-283.

(5) Donkers, S., 2013. Automatic generation of CityGML LoD3 building models from IFC models.

(6) Hachem, C., Athienitis, A. and Fazio, P., 2012. Solar optimized neighbourhood patterns: Evaluation and guidelines. *Proc. of eSim*.

(7) Jusuf, S.K., Mousseau, B., Godfroid, G. and Soh, J.H.V., 2017. Path to an Integrated Modelling between IFC and CityGML for Neighborhood Scale Modelling. *Urban Science*, *1*(3), p.25.

(8) Keirstead, J., Jennings, M. and Sivakumar, A., 2012. A review of urban energy system models: Approaches, challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *16*(6), pp.3847-3866.

(9) Mauree, D., Coccolo, S., Kaempf, J. and Scartezzini, J.L., 2017. Multi-scale modelling to evaluate building energy consumption at the neighbourhood scale. *PloS one*, *12*(9), p.e0183437.

(10) Mauree, D., Coccolo, S., Perera, A.T.D., Nik, V., Scartezzini, JL. and Naboni, E., 2018. A New Framework to Evaluate Urban Design Using Urban Microclimatic Modeling in Future Climatic Conditions. *Sustainability*, *10*, 1134.

(11) Moghadam, S.T., Mutani, G. and Lombardi, P., 2016. Gis-based energy consumption model at the urban scale for the building stock. In *9th International Conference, Improving Energy Efficiency in Commercial Buildings & Smart Communities Conference (IEECB & SC'16), Frankfurt* (pp. 16-18).

(12) Mutani, G., Gamba, A. and Maio, S., 2016, September. Space heating energy consumption and urban form. The case study of residential buildings in Turin (Italy). In *11th conference on sustainable of energy, water and environmental systems, SDEWES2016* (Vol. 441, pp. 1-17).

(13) Perez, D., Kämpf, J.H., Wilke, U., Papadopoulou, M. and Robinson, D., 2011. CitySim simulation: the case study of Alt-Wiedikon, a neighbourhood of Zürich City. In *Proceedings of CISBAT 2011-CleanTech for Sustainable Buildings* (No. EPFL-CONF-174435, pp. 937-940). EPFL.

(14) Robinson, D., Haldi, F., Kämpf, J., Leroux, P., Perez, D., Rasheed, A. and Wilke, U., 2009, July. CitySim: Comprehensive micro-simulation of resource flows for sustainable urban planning. In *Proc. Building Simulation* (pp. 1614-1627).

(15) Robinson, D., Haldi, F., Leroux, P. & Perez, D., & Rasheed, A. & Wilke, U. (2009). CITYSIM: Comprehensive Micro-Simulation of Resource Flows for Sustainable Urban Planning. *Eleventh International IBPSA Conference*.

(16) Samah K. Alghoul. A Comparative Study of Energy Consumption for Residential HVAC Systems Using EnergyPlus. *American Journal of Mechanical and Industrial Engineering*. Vol. 2, No. 2, 2017, pp. 98-103.

(17) Sossan, F. and Paolone, M., 2016. Integration and Operation of Utility-Scale Battery Energy Storage Systems: the EPFL's Experience. *IFAC-PapersOnLine*, *49*(27), pp.433-438.

(18) Strzalka, A., Bogdahn, J., Coors, V. and Eicker, U., 2011. 3D City modeling for urban scale heating energy demand forecasting. *HVAC&R Research*, *17*(4), pp.526-539.

(19) Swan, L.G. and Ugursal, V.I., 2009. Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. *Renewable and sustainable energy reviews*, *13*(8), pp.1819-1835.

(20) Tavel, M., 2012. Climate Responsive Urbanism. Historic Precedents and Progressive Practice. *Fall 2011 International PUARL Conference: Generative Process, Patterns, and the Urban Challenge*.

(21) Thomas, D., Miller, C., Kämpf, J. and Schlueter, A., 2014. Multiscale co-simulation of EnergyPlus and CitySim models derived from a building information model. In *Bausim 2014: Fifth German-Austrian IBPSA Conference*.

(22) Moghadam, S.T., Coccolo, S., Mutani, G., Lombardi, P., Scartezzini, J.L. and Mauree, D., 2019. A new clustering and visualization method to evaluate urban heat energy planning scenarios. *Cities*, *88*, pp.19-36.

(23) Mohajeri, N., Gudmundsson, A., Kunckler, T., Upadhyay, G., Assouline, D., Kämpf, J.H. and Scartezzini, J.L., 2019. A solar-based sustainable urban design: The effects of city-scale street-canyon geometry on solar access in Geneva, Switzerland. *Applied Energy*, *240*, pp.173-190.

(24) Mauree, D., Perera, A.T.D. and Scartezzini, J.L., 2017. Influence of Buildings Configuration on the Energy Demand and Sizing of Energy Systems in an Urban Context. *Energy Procedia*, *142*, pp.2648-2654.

Appendix
Survey Questionnaire

1. **Household particulars**

S. No.	Name of all family members	Age	Sex	Married / Unmarried	Education	Employed				Income of each member per month (Rupees)	
						Govt.	Private	Self	Retired		
1											
2											
3											
4											
5											
6											
7											
8											
9											

2. **Residential building profile**

(i) Type of building: (a) Independent house (b) Apartment (c) Rented house/ flat

(ii) Building plot size (Sq. ft.) ……………

(iii) Year of construction of house/ apartment…………….

(iv) Building facing: North/ South/ East/ West direction

(v) Total number of floors in the building/ flat…………………

(vi) Total Height of the building/ apartment ………………………..

(ix) Setbacks (open spaces) of the building (feet).

(a) Front side (open space)…………….. (b) Left side (open space)……………

(c) Right side (open space)…………….. (d) Back side (open space)………….

(x) Number of trees in the plot……………

3. Electrical appliances being used in your household, at present.

Sl. No.	Appliances	Number of items	Capacity (watts or liters)	Average use (hours per day)	Total number of months use
1.	Refrigerator (small/medium/large)				
2.	Water purifier				
3.	Electric wet grinder (mixer)				
4.	Washing machine				
5.	Window air conditioner				
6.	Split air conditioner				
7.	Centralized cooling				
8.	Centralized air-conditioning				
9.	Desert cooler (small/ medium/ large)				
10.	Electric fans (wall/ ceiling/ table)				
11.	Exhaust fan				
12.	Electric geyser				
13.	Room heater				
14.	Immersion heater rod				
15.	Electric iron/ Press				
16.	T.V (Normal/LCD/LED)				
17.	Stereo system				
18.	Radio				
19.	VCR/ DVD player				
20.	Microwave oven				
21.	Electric oven				
22.	Electric chimney				
23.	Toaster oven				
24.	Dish washer				

25.	Coffee maker				
26.	Electric kettle				
27.	Computer				
28.	Laptop				
29.	Printer (A4/A3 size)				
30.	Fax machine				
31.	Electric water pump				
32.	Vacuum cleaner				
33.	Hair dryer				
34.	Cell phone				
35.	Elevators (lifts)				

4. Which of these energy efficient/ star rated/ energy labeling electrical appliances as such do you have in your house / apartment?

Particulars	**Yes**	**No**
Microwave		
Refrigerator		
Air Conditioner		
Television		
Computer		
Water heater		
Washing Machine		