The Sustainable Housing District

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Abstract

Global warming, dry outs of surface water bodies and descent of underground water resources, depletion of world's fossil fuel resources, unhealthy environmental conditions with increase of greenhouse gases emissions are dominating concerns of international communities around the globe. Fast urbanization of cities and uncontrolled expansion have made these problems worse. Buildings alone account for around 30% of global carbon emissions, and over one-third of final energy use and this share could double or triple by 2050. The question is what we need to do in terms of planning, designing and adaptation of new methodologies and techniques for building as well as cities, old and new?

Efficient and sustainable planning of projects from urban scale to building design is necessary to tackle these issues and the aim of this thesis is to collect and investigate the available data practical and theoretical on sustainable developments, that are trying to find solutions of these problems through innovative techniques and to apply these findings on our study area which is "*Porta Lucca"* area in "*Pisa Italy"* and develop a set of guidelines.

Methodology of thesis is to study the sustainable developments on two scales one macro (urban scale) and second micro level (Building scale) through research of theoretical data and then to learn further from working example about the implementation of those methodologies and their operational phase. Last part will describe the practical application of studied data on chose area.

Thesis consists of total seven chapters. 1st chapter elaborates the problem statement and explains the importance of sustainability and different issues we can handle through such developments. 2nd and 3rd chapters give elaborated description of available theoretical data on renewable resources and sustainable development on urban scale and analysis of chosen case studies of such sustainable/smart districts, respectively. Following the

same pattern 4th and 5th chapter comprises of investigation about buildings and their case studies.

6th and 7th chapters are focused on Analysis of study area and design guidelines. These chapters elaborate in detail all existing features of city from existing infrastructure of to demographical features and climatic conditions to distribution of resources. Design guidelines are based on research and practical examples and are recommended in accordance with analysis and commune di Pisa's compliance. Design guidelines address almost all issues explained in problem statement.

All the research of theoretical data and practical examples can serve as a source of knowledge in the field of sustainable development for future research.

Acknowledgement

I would like to extend my warmest thanks to my supervisor, Professor Carol *Monticelli* who made this work possible. Her friendly guidance and expert advice have been invaluable throughout all stages of the work. I have been extremely lucky to have a supervisor who has been so invested in my work and who responded to my questions and queries promptly.

I would also like to acknowledge the contribution *Miss Gabrielle Fernandez* made to my work. Her Suggestion and new approach towards certain parts have made my work more diverse.

I would like to thank my class mates and colleagues for helping me keep things in perspective and provided me with help I needed throughout the year. I would like to thank the faculty of Architecture and Urban Planning at Politecnico Di Milano for providing me with excellent working conditions and much needed research libraries.

Finally, I dedicate to dedicate this thesis to my parents. They will always be in my heart and their path, I will always follow even as I carve my own.

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Chapter 1: Introduction

1.1 What is a Self-Sufficient Community

Sustainability and self-sufficient developments of community is the important topic of discussion around the globe and a lot of research is being done regarding the technological systems, principles and how to achieve this specific goal. Different sustainable development around the globe has been done but it is very important to note that to what degree those developments are self-sufficient.

The definition of *being self-sufficient* is "being able to fulfill one's own needs without help from others" while the term *community* means "people living in one place, like district or city and considered, as a whole". (Oxford Advanced Dictionary, 2001). *Self-sufficiency* can be defined as autonomous community in an urban fabric, independent in term of all resources. These resources include mainly energy resources and food production. This kind of development also take into consideration the waste management water resources and zero emission of greenhouse gases (Eco-City Development—A New and Sustainable Way Forward, 2010).

Sustainability can be defined as "the ability to meet the needs of today without compromising the ability of future generation to meet their needs" (World Commision of Environment and Development Report, 1987) (Our Common Future, 1987). Self-sufficient community works basically on principles of sustainable development by combining many other concepts and eco-friendly practices to achieve the goal of self-sufficient community. There are specified requirements and certain set of parameters for such developments according to the five basic human needs, water, shelter, food, energy and community. *Being self-sufficient* means being independent of national energy grid system for the supply of electricity and natural gas, being able to produce enough of almost all kinds of domestic utilities like food supplies for example agriculture, dairy and meat products. *Self-sufficient eco-friendly communities* differentiate from traditional communities because they rely on renewable energy systems to meet electricity and heat demand instead of using conventional methods of energy generation and includes developing strategies for waste management in terms of recycling and reusing, drainage and treatment of waste water for reuse. One of the major differences between Model Eco-cities and fully self-sufficient community is that such communities also take into consideration the factor of food production. Such communities produce 90% of their basic food. This feature has not yet been part of worlds pioneer eco-cities from Tianjin china to Masdar city Abu-Dhabi. This whole concept of self-sufficiency can be categorized on two levels one on macro level which is on urban or community scale, this includes resource management and second is on micro level which mainly focuses on buildings their development process, materials and maintenance and human practices involved in all these actions.

1.2 Problem Statement:

Global warming, super-urbanization of cities with exponential population growth has been dominant concern and driving force towards sustainable developments depending upon renewable energy resources. Over population is the main and direct cause of many of these problems. Gaps between demand and supply from food supply to domestic utilities and from housing to health and education facilities. Depletion of natural resources and degradation of environment is also caused by over population (The real problem with over Population, 2009). In the Fig. 1, world existing and estimated population is shown till 2050. The world population will reach 9.8 billion in 2050, up 31 percent from an estimated 7.5 billion now. (U.S Census Bureau, International Data Base, 2015)

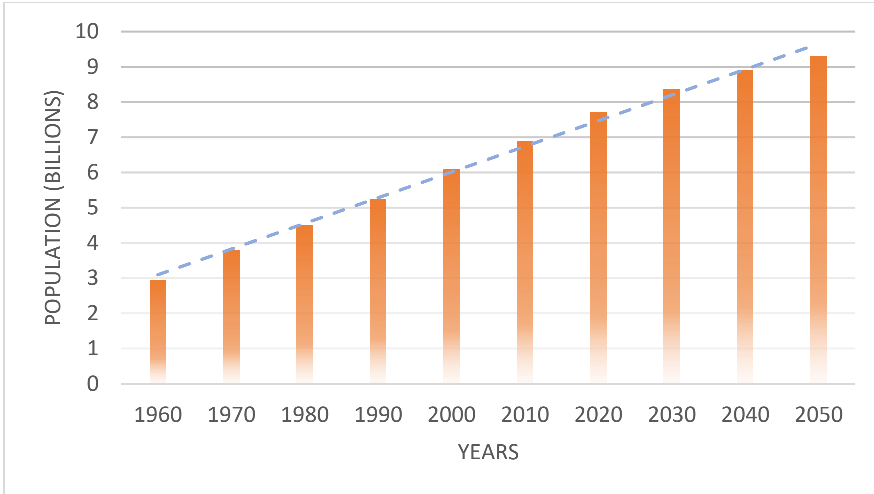


Figure 1: World Population Growth (Bureau, 2015)

Depletion in national fossil fuel resources has brought a lot of tension and discussion to the table that where we go from there or what will happen after these natural resources would dry out. What is the alternative because if we keep utilizing the non-renewable energy resources at the current rate we would run out of known fossil fuel resources in next seventy to hundred years.

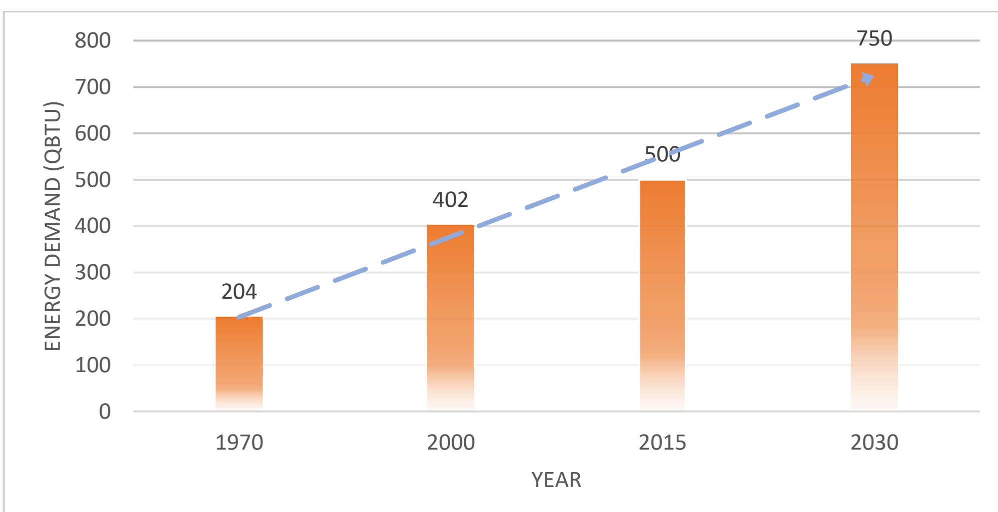


Figure 2: Energy Demand Timeline (Sodhar, 2011)

Above shown in Fig. 2 the energy demands with respect to years from 1970 to 2030 and exponential trend is clearly visible. (Sodhar, 2011, p. 4) Oil, natural Gas and coal are three main energy resources and they account for almost 85 percent of total energy demand.

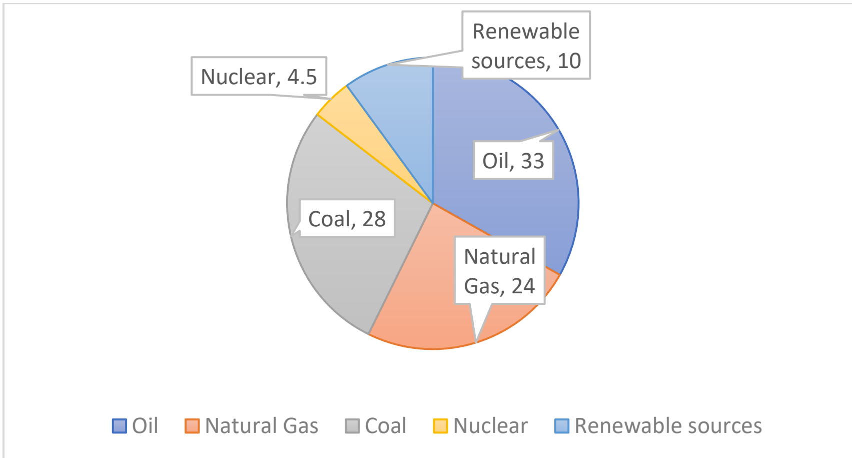


Figure 3:Energy Sources Division (Dudly, 2016)

It is clear from above that most of reliance in terms of energy production is on non-renewable resources which is more than 85 %. Only 10 % is being produced from renewable sources and 4.5% is nuclear energy. (Dudly, 2016)

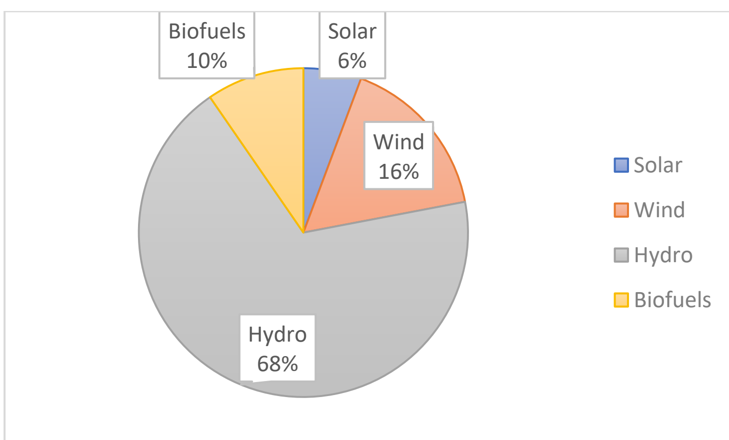


Figure 4: Renewable Energy Resources (Dudly, 2016)

Energy has emerged as critical economic issues worldwide. Difference in energy supply and demand in most of developing countries Buildings are the largest energy consumers in the world. They account for around 30% of global carbon emissions, and over one-third of final energy use. This share could double or triple by 2050 if we do not act.

The current worldwide demands of energy resources is depending on non-renewable resources like oil, coal, and natural gas. In addition to emitting greenhouse gases, they cannot be replaced as fast as they are consumed. Estimates regarding the remaining quantities of nonrenewable resources states that the current reliance on these sources is unreliable which can lead to escalating market prices and economic vulnerability. Accounting for approximately 30 to 40% of the total energy used today, buildings are significant contributors to these problems.

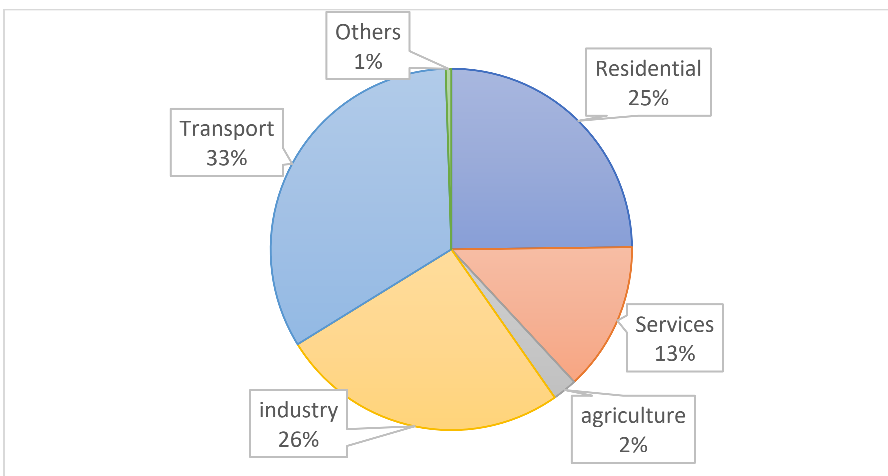


Figure 5: Energy Consumed by Household & Services (Dudly, 2016)

As Show in Fig. 5 the 38 % of total energy consumption is by Buildings in Europe out of which 25% is consumed by residential buildings. (Manuel Carlos Felgueiras, 2016, pp. 16-18). Looking at above data we can say that if new buildings are to be planned in a way that it complies with sustainable approaches we can save one third of the total energy but the problem with this is that 99% of building stock is made by operational building, this is the major issue in building sector that how to update all existing structure in term of sustainability and self-sufficiency.

The other most important issue we are facing is food crisis. If we look a decade back on the food price crisis of 2007-2008. It had limited the access to food for many people specially with low income in developing countries, but this crisis also had significant effects in developed countries. Because of 2008 food crisis 850 to 950 million people were food insecure. Such crisis creates significance socio-economic and political unrest because it undermines the basic humanitarian right. (Panitchpakdi, 2008, pp. 1-2)

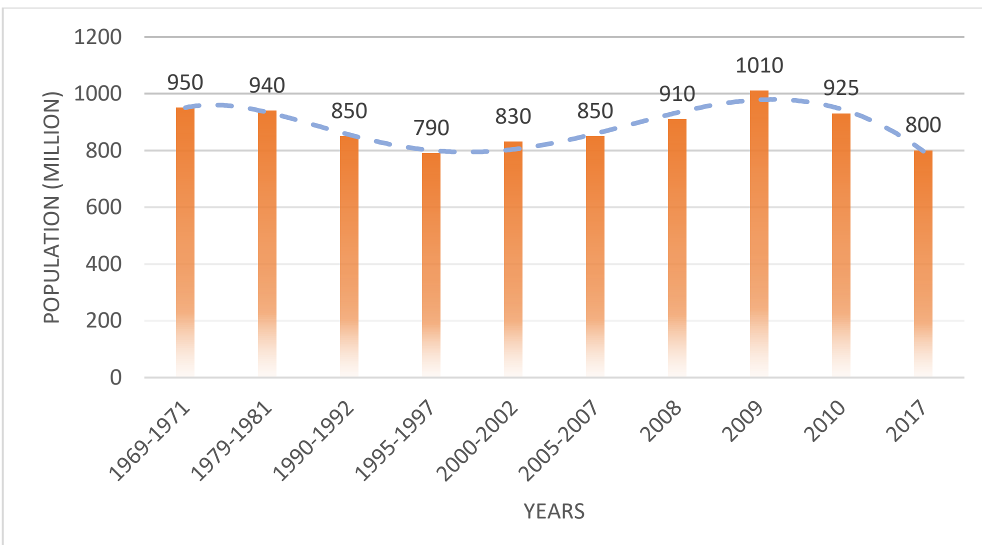


Figure 6: Undernourished Population (Baylie, 2008)

From above mentioned data by Food and Agriculture organization of United Nations shows that the huge portion of world population is undernourished which means that they either don’t have access to proper food supplies or access to substandard food which does not fulfil the common nutrition need of a human body. it is estimated that 1.1 billion people in the world lack clean water. The question is not one of comfort: water-related illnesses are the second biggest killer of children in the world. (Baylie, 2008, pp. 14-15)

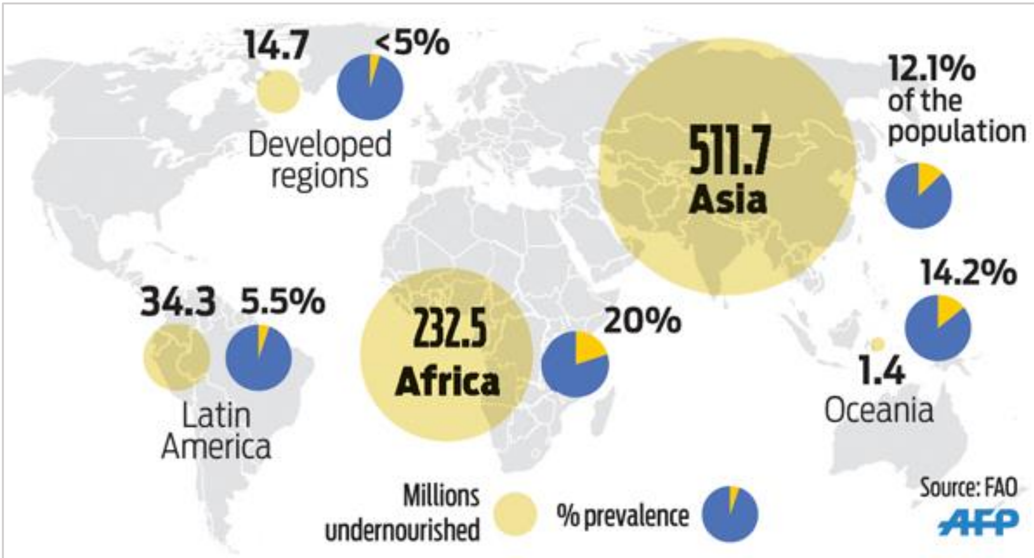


Figure 7: Undernourished Population in the world (Citizen Co., 2018)

There are many reasons for such crisis for example the difference between supply and demand is major factor in escalation of prices. High demand is due to increase in population and imbalance between production of food. Higher fuel and fertilizer prices also effect the cost of production and transportation of food products. Climate change rise in average temperature every year, uncertainty of weather conditions and natural disasters destroy more than one fourth of world crops. Scientist are now developing new technologies to grow edible agriculture products in a controlled environment which would reduce the risks of crops destruction by natural causes and with less land space requirements those methods can accommodate and produce large amount of need products to meet the demands of community. (Global Report on Food Crisis , 2017, pp. 18-25)

According to Mona Sahlin, former Minister for Sustainable Development, Sweden, Institutionalizing Sustainable Development “If everyone used energy and resources the same way we do in the Western World, we would need three more earths at least and we have only one.”

1.3 Background:

Demands of raw materials and its impact have been a long-lasting problem through human history even in early civilization as Egyptian, Mesopotamian, Greek and Roman civilizations, which today we refer to as sustainability.

Wood was both fuel and construction material up till the end of 18^{th} century but due to mass production, shortage of wood became real danger, and this led to new way of thinking with responsible use of natural resources for present and future generations. The term sustainability was first used by in German forestry circles by Hans Carl von Carlowitz in Sylvicultura Oeconomica in 1713. In 18^{th} century concern about population growth and stress on natural resources, were growing among policy makers and in 18^{th} century the focus of energy consumers shifted to coal and due to the amount of consumption it had people worried that in next hundred years coal reserves will disappear. In early twenty century the term “sustainability” started to appear in many publications and came into general use. (Sustainable development – historical roots of the, 2007, pp. 4-8)

G. P. Marsh’s book “ Man and nature” was published in 1965 and it is considered the front of conservation movement he stated that *“Man has long forgotten that the earth was given to him for usufruct alone, not for consumption, still less for profligate waste”* (Man and Nature, 1965) *.* Similar publications came after stressing the fact that human activities are disturbing the ecological equilibrium and exhaustion of natural resources. After coal, oil became the natural source of energy and there is drastic decrease in oil reserves. So, in the past we shifted from one source to another but in the late 20^{th} century the sociologists, scientist, and policy maker started think of new ways of production with the alarming increase in population and huge gaps between supply and demands.

In 1987 the Brundtland commission report on sustainability named as" *Our Common Future*". The report defined for the first time what does it means by sustainable development. It also discusses different factors like role of international economy, common challenges, food security, energy choices and urban challenges. (Our Common Future, 1987). it awoke the public to the idea that mankind had to think of the generations to come and the world they would live in. In 2012, as a result of world conference in Rio on sustainable development, UN publication "*The Future We Want*" has brought the critical issues of degradation of biodiversity and ecological system, depletion of non-renewable resources, waste, Water scarcity to light. (Towards sustainable development through the perspective of eco-efficiency, 2017)

The term eco-city was being used around 1970 because of US-based movement "*urban Ecology". Garden city movement* and *City beautiful movement* had previously worked on the same concept of urbanization. Self-sufficiency is the extension of concept of eco-city whose main objectives are zero-carbon emission, protection of biodiversity and ecological systems, waste-efficient technologies, water recycling and reusing with production of food utilities and renewable energy resources. (Kenworthy)

1.4 Significance:

Sustainable development is a practice that fortifies the future of human race by ensuring the safe and necessary use of resources. New methods and advancement in technological fields of production and development has brought us closer to achieve this goal but this advancement has had its downfalls. It has been argued that, in order, for future generations of both human and non-human species to persist, we must change the practices that have resulted in degradation of human and ecological systems. Eco-cities, self-sufficient communities and sustainable developments are answer to many problems world is facing.

From the problem statement and data presented human race is about to face the worst crisis from basic utilities to general commodities. Environment change and Global Warming, exhaustion of non-renewable energy resources, carbon emission of cities and industries, massive demands of consumer market of basic human needs, these are all few major issues which needs to be solved before it's too late and in this context the term Self-sufficient community seems like an answer to many of these problems if not all.

"Sustainable development"," Eco-cities" and now Self-sufficient communities are in focus of work on academic and policy making level for many years. Socialists, Planners, Architects, Politicians and Governments are taking keen interest to develop such cities. Many say that they are future of cities and even rural developments because they are independent of national grid in terms of energy resources, such developments have minimum carbon emissions, protection of ecological systems is key element for such communities, efficient transport systems, waste-efficient methods and technologies, high quality environmental conditions, production of food and dairy products with in the community for the community. Each element of such community addresses the certain issue from food crisis to water scarcity and from energy crisis to favorable living environment.

Important question is how to achieve these objectives and to what degree these targets can be attained. Now more than ever we need to think more about such development because we have resources and technologies at our hands. It is responsibility of planners and policy makers to make sure to achieve these targets because that is the only way forward which will secure our future and future of coming generation. Important question is how to achieve these objectives and to what degree these targets can be attained.

1.5 Aims of the Study:

In this thesis we will try to learn from the existing examples which have been working towards the solution of these problems and have been successful to some extent. Learning from their experience and in addition of new technologies we will implement the suitable solutions and preferred techniques to tackle the challenges at hand. In 21^{st} century where we are facing global crisis of this magnitude such studies and practices are very important as they provide a way forward.

- The Aim of thesis is to develop a better understanding of practices adopted by planner, developers and architects to take decisive steps for future sustainable developments.
- The aim is to take debate of suitable development to next level where not only new projects will be developed according to guidelines but also transforming existing cities into sustainable ones.
- The other aims include to help small cities with limited resources develop a set of key answer for such challenges, to attain smart and sustainable living without compromising the quality of living and to make and comprehensive study and analysis of technologies for people to learn and implement.

1.6 Objectives:

The main objective of this thesis is to analyze and study in detail, all the available technologies and planning tool to achieve the sustainable goals. Moving one step ahead towards self-sufficiency. Focusing specifically United Nation Sustainable Development Goals 2030 number seven, eleven, twelve and thirteen, affordable and clean energy, sustainable cities and Communities, responsible production and consumption of resources and climate action respectively. The following objective has been set according to above mentioned UN sustainable goals.

The main objectives of thesis are as follows.

- Detailed theoretical study of all technologies and practical interventions, existing and new which includes mainly renewable energy production, efficient use of water and recycling, waste management and environmental protection.
- Qualitative analysis of case studies of existing eco-cities and smart, sustainable buildings around the globe to learn and implement those intervention in our study area (City of Pisa) according to requirements of city.
- Setting a benchmark for future developments and to develop a set of toolkits comprises of key solutions to achieve the targeted level of sustainability in Italian urban context for the city of Pisa on urban scale and also on existing buildings which is adaptable for the rest of country.

1.5 Design Methodology:

Design:

Design phase will include different steps from site selection to analysis and implementation of studies techniques and planning strategies

Site Selection:

Suitable site where studied technological solutions are adaptable efficiently & needed and also replicable in other parts of region. Political willingness is important in this regard

Site Selection:

Study of demographical features to climatic conditions, air and noise population. city infrastructure, land-in use resource analysis & Comparison in Italian context. Problems identification in terms of resources supply and demand, planning, future policies with global Challenge

Recommendations and Conclusions:

Recommendation for future policies and projects and general guidelines in order to attain sustainable goals & summed up analysis of whole work and summery of design part.

1.6 Research Summary:

Literature Review:

Literature review will be done on two levels “*Macro Level*” (Urban scale) and “Micro scale (Building scale).

Problem statement:

Global crisis in terms of energy, agricultural production, water, waste landfills.

Aims and Objectives:

To develop knowledge of existing examples & technologies and develop guidelines for new projects

Literature Review:

Literature review will be done on two levels “*Macro Level*” (Urban scale) and “Micro scale (Building scale).

Macro Level:

Macro level investigation includes planning strategies and tech-interventions on urban scale in case studies and theoretical research.

Micro Level:

It includes technological interventions for buildings, study of sustainable materials, orientation, passive and active systems.

Chapter: 2 Research and Literature Review (Macro Level)

2.1 Introduction:

Eco-city and self-sufficient community are broader term and there are many definition and interpretation of these terms available, but it is collection of ideas and concepts about urban planning, health, housing, transportation, and economic development. (Roseland, 1997) while sustainable development and eco-city theories are practically been tested many analysis suggests that sustainable eco-city developments are subjective technical matter of institutional restructuring, traffic management, architectural design and the development of green technologies (Harriet Bulkeley, 2005) These developments can be categorized on two levels. First the macro level involves interventions on urban scale from policy making to protection of biodiversity and ecological system, dependency on renewable energy sources and local agriculture, waste management, water supply, recycling and smart transportation systems. (Kenworthy) In this chapter we will discuss these technological and Architectural town planning approaches which have key importance to achieve the goal of self-sufficient community.

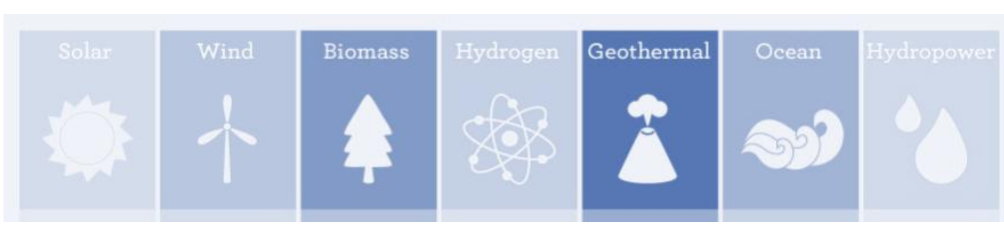
There are many conceptual ideas related to sustainability and a lot of analytical data and research is available. For example, *green urbanism started in* 1990 and it is conceptual model focusing on zero-emission, zero-waste urban design promoting energy efficient urban development's transforming cities. (Panagiotis Anastasiadis, 2013) Eco-city is also working on the same concept, but it takes one step ahead and approaches to achieve the goals are little different in both ideas. There are few built examples (Masdar City, Abu Dhabi, Dongtan, shanghai china). Self-sufficient district of city or town is also the conceptual idea based on such studies and academic practices. (Panagiotis Anastasiadis, 2013)

2.2 Principles/Parameters for a Self-Sufficient Community:

The Concept of self-sufficient in broader sense is subjective. What kind of city we need according to recent and future challenges, what kind of goals we set to achieve in certain amount of time and most important how to achieve those goal and in what capacity. There are certain set of objectives set out which are considered the most crucial and important to develop such system of urbanism. In this chapter we will analyze the scientific techniques and architectural planning and designing approaches on urban level, which help to acquire the status of self-sufficient community.

2.2.1 Energy Supply Resources:

Energy is one of the major concerns as discussed in problem statement briefly and it is one of the most important and first goal towards self-sufficiency. It's a common fact that non-renewable energy resources are not the way forward because not more than hundred and fifty years after industrial boom all fossil reserves are exhausted, and buildings spend 30 to 40 % alone the total amount of energy and we need to minimize the usage and supply energy for this sector as well as other through the means of renewable sources. There are many technologies available which are environment friendly and accessible.



2.2.1.1 Solar Energy:

Solar energy is the oldest source of energy known to men. Solar Energy Engineering-Processes and Systems. (Kalogirou, 2004) Everyday sun radiates huge amount of energy to the earth in form of heat. According to calculated estimate sun send 16,000 times more energy in a day than we use worldwide. Solar Radiation is the most fundamental renewable energy source in nature. The solar radiation reaching the earth can be used in many ways for example it can be converted into electricity directly through Photovoltaic cells and can be used for direct water heating purposes among others. (Omer, 2013) The feasibility of such systems depends upon on many factors like amount of sun radiation, number of sunny days, day time and latitude of place thus, these characteristics should be analyzed first before consideration of sustainability of site.

a) Solar Irradiance Resources:

The latitude of location effects the energy per unit surface area received from the sun thus different location have different sun radiation amount and different temperatures (Klaus Jäger, 2014) and solar power system to work solar irradiance is one of most important factor and used to drive the potential of solar energy system. (Zonnen, 2005)

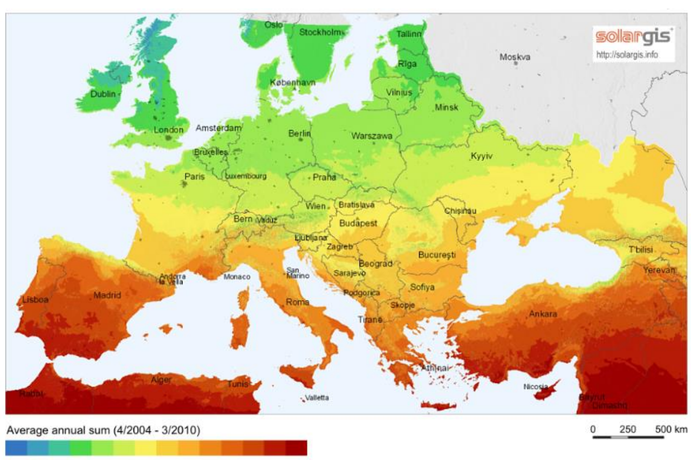


Figure 8: Solar Irradiance Map (Solar, 2018)

The average of 1100 watts/m^2 solar irradiance is needed for solar panels to work efficiently but other factors should also be taken into consideration. Following is the European map of yearly sum of solar irradiance.

From the Fig.8 it is clear the central and southern part of Italy are favorite for such intervention. Most part of Italy receives more than 1300 watts/m^2 which is more than required amount.

In the following section we will discuss types of utilization and conversion system available. They can be categorized into two, one is direct and other one is indirect. (Kalogirou, 2004)

b) Solar Thermal Collectors:

Solar Collectors are the devices which absorb direct solar radiations and convert it into heat and transfer the heat to fluids which are normally air and water, flowing through the collector. The most important application of this type of system is Thermal water heater which is used for domestic purpose. It consists of collector array, energy transfer system and a tank. (Kalogirou, 2004, pp. 175, 256) There are many types of collectors which can be used on large scale.

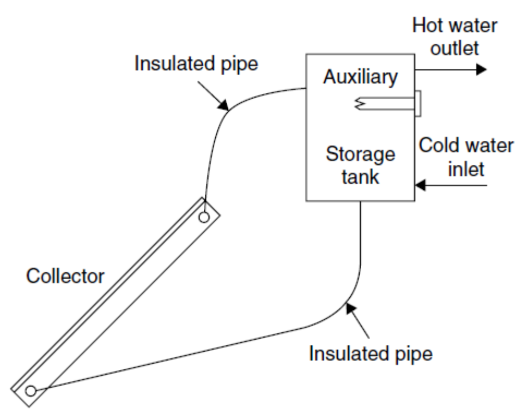


Figure 9: Solar Thermal Collector (Kalogirou, 2004)

c) Solar Photovoltaic Collectors:

Solar PV Collectors Converts directly sunlight to electricity. They produce electricity with any greenhouse or other gases making them environment friendly. PV panels are solid-state panels They have long life and very little maintenance. At present, panels based on PV cells can be produces into any size with average cost making it affordable since its one-time investment. Crystalline and polycrystalline silicon solar cells are the most common. "PV cell consist of two thin layers of silico and because of silicon atomic configuration, when its exposed to sunlight they electrons moves between the atoms producing electricity" which is called *Photovoltaic Effect.* Such materials are called *"Semiconductors*". (Kalogirou, 2004, pp. 473-480) (Council, 2013)

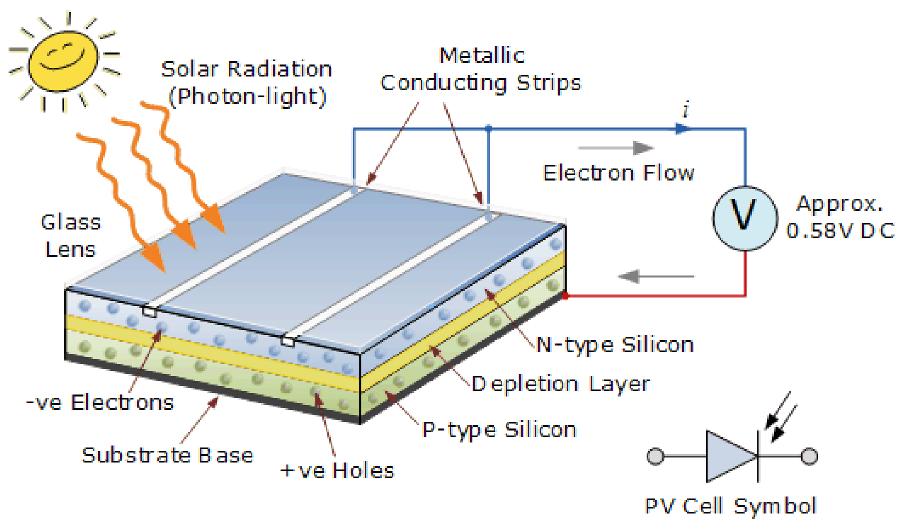


Figure 10: Working Mechanism of PV Cells (Kalogirou, 2004)

As we can when sunlight hit the surface of semiconductors because of valance bond electrons in outer orbit moves to the surrounding atoms and the moving electron produce electricity. (Energy, 1982)

PV Panels works during day, to supply electricity at night there are batteries attached to PV system which are charged during day and at night they provide electricity. The efficiency of PV panels depends on *Solar radiation, cell temperature*, *angle of incidence* and *load resistant*. Efficiency of PV cells can be increased by concentrating sunlight on specific part of cell which has been designed with reflective materials aiming high efficiency. (Kalogirou, 2004, pp. 500-517)

There are many ways to connect PV panels to load system depending upon the location and usage typology for example "*Direct Coupled System"* is used for system which are going to be used during day because it supplies directly electricity to system. "*Grid Connected system"* is common for application in urban areas or for small towns cutting down the energy demand on national grid system. (Kalogirou, 2004, p. 497) This type of system is very easy to adopt and it can flexibility to be used on both scales. Such panels can be installed for one housing or a small community. On urban level Governments can use hybrid systems and introduce electricity produced by PV panels into national grid system. Passive heating of inner space is also one of very important part of solar energy conservation which will be discussed in chapter three.

d) Evaluation of site:

There are two possible option for supply chain, either solar panels can be provided on each building creating a separated system or a common solar plant can be developed and through a connected grid system electricity can be supplied to each building. (Energy, 1982) The important questions to ask before designing the solar system are

1. Is the site having clear, free of shading, direct approach to sunlight at maximum possible times?
2. Can the system be reoriented for good performance?
3. If system is to be roof mounted, what kind of roofing system there is and is there is enough space on site (Either roof or ground) is available.
4. Does site receive enough average solar irradiance required for average efficiency?
5. For efficiency and maintenance in long term consider soil particle sizes

These questions are important because they directly affect the performance of solar PV panels. (Solar Electric System Design, Operationa and Installation, 2009) (Ramon, 2001)

e) PV Installation Area Requirements:

PV panels are available in different sizes with different output powers. The area required to install them important factor to decide the supply system. For single family house, normally the roof area is enough to install the PV panels depending on the roofing system (Flat or Pitched). Two of crucial components in this matter are amount of solar radiation reaching the roof surface and usable roof space for dedicated to PV panels. As a thumb rule 10 sq. ft is required for 1kw, so to establish 1MW solar power plant we need 100000 sq. ft (2.5 Acers or 1 Hector). (Sean Ong, 2013)

An average single-family house uses 700 to 900 kWh per month in Europe and USA. (Pablo Bertoldi, 2016) and 4 to 5KW solar kit can produce average of 850KWh per month and the area required for 4 to 5KW kit is 400 sq. ft and 38 sqm. (Ramon, 2001) These calculations are presented for normal house with very few provisions of sustainable development including mostly active systems. This amount can be reduced to only 30 to 40% of total average household usage now. For the area which has a lot of multi-story buildings a separate solar power plant is feasible because not enough rooftop space is available for PV panels. (Ramon, 2001)

f) Strengths and Weaknesses:

+ Flexibility with the scale of project ranging from few numbers of panels for one house to big solar parks for whole cities.
+ Long term renewable energy solution with very low cost in operational phase.

+ Abundance in resources as only natural source required is sun and most part of world receive enough amount of solar irradiance for efficient use of PV panels.
+ Almost zero carbon emission in operational phase.
+ No unexpected fluctuation of required resources.
– A lot of maintenance is required in operational phase.
– High Initial installation Cost.
– Low voltage special appliances are required for efficiency.

2.2.1.2 Wind Energy:

Wind power is considered the second most feasible form of renewable energy after solar energy. *Wind* can be defined as the "the moment of air masses in the atmosphere due to due to difference in air temperature." Air temperature causes difference in pressure which leads to movement of air masses from higher pressure points to lower pressure points creating wind movement. (Kalogirou, 2004, pp. 5 - 15) Air molecules are moving, they have kinetic energy and this kinetic energy is rotates the blades of turbine.

Extracting energy for wind is not a very new concept, ancient civilizations were using Vertical axis wind mill connected to grinding stones for milling in Persia. In the middle ages also, horizontal axis wind mills were common for grinding flour or to get water from underground

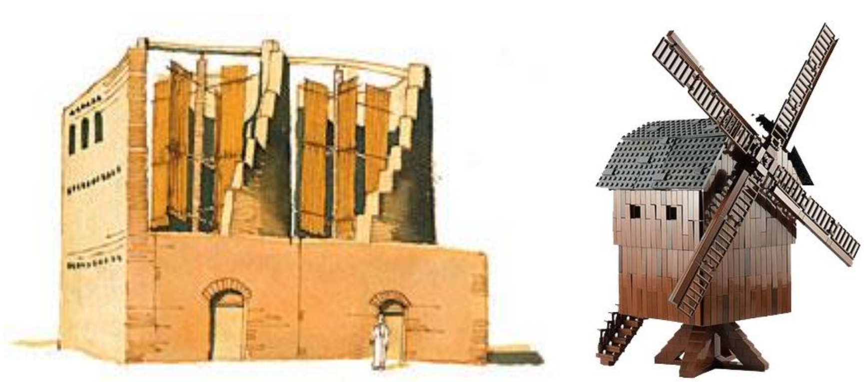


Figure 11 Persian Wind Mills (Solarpedia, 2018)

. In 19th century the Charles brush build first wind turbine which converted wind energy to electricity and in mid of 20th century most recent form of wind turbine with propeller and blade configuration. (Torey, 1976) Wind energy is renewable energy source and it has many advantages including no greenhouse gas emissions, Services and repaired individually without shutting down the whole plant, Windfarm can also be used for agricultural purposes, the cost of wind energy per KWh is less than that of solar energy. (Tong, 2010, pp. 6 - 10) For this intervention wind is the fuel and there are many factors on t=which the efficiency of wind turbines depends, the most important of all is wind speed. Wind speed is affected by uneven air temperature causing pressure difference, Coriolis effect due to earth's rotation and many local geographical features. (Tong, 2010, p. 4)

a) Wind Resources and Site Selection:

Wind is obliquities and to make the feasible choice of potential site there are many factors to be considered and most important of all is wind speed or energy density and there is minimum threshold value above which the energy that can be extracted is sufficient with respect to merits of wind farm. (Paul Gardner, 2006)

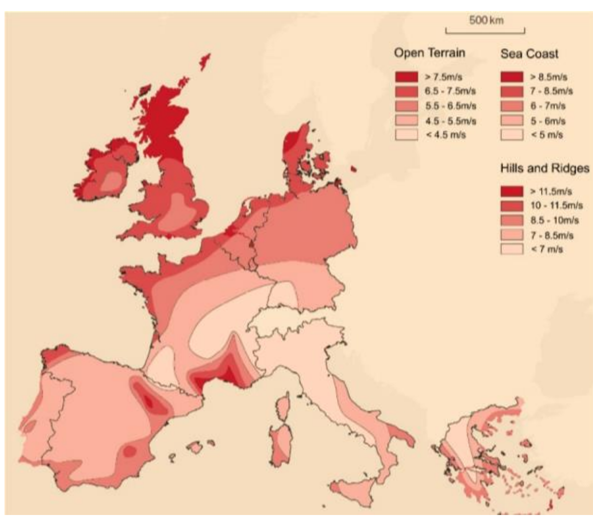


Figure 12:Regional Wind Resources (Paul Gardner, 2006)

Broad and regional wind resource maps are one of the important tools to find suitable site for wind farm. The Fig.12 shows different wind speed regions in Europe. Normally wind power is economical for the wind class 3 area or greater. Following the given glasses and their respective Wind power density. (Willian A. Edelstein, 2003)

Wind Power Class	**Wind Power Density (W/m^2)**	**Rayleigh Average Wind speed (m/s)**
1	0 - 200	0 – 5.6
2	200 - 300	5.6 – 6.4
3	300 - 400	6.4 – 7.0
4	400 - 500	7.0 – 7.5
5	500 - 600	7.5 – 8.0
6	600 - 800	8.0 – 8.8
7	800 - 2000	8.8 – 11.9

Table 1 Wind Power classes and their Respected Power Density, Rayleigh Speed (Willian A. Edelstein, 2003)

3.5m/s is the cut-in speed for wind turbines and cut-out wind speed is 25m/s, between cut-in and cut-our speed the wind turbine generates the steady supply of energy. After cut-out speed wind turbines shuts-off automatically to prevent themselves from damage.

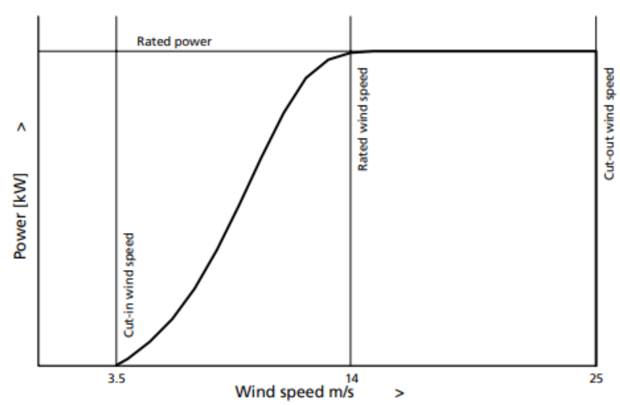


Figure 13: Optimum Wind Speed & Respective Power Generation (Alex Kalmikov, 2010)

The wind turbine can't take all of wind energy because then air would be stopped completely so theoretically maximum of 59 % energy can be extracted from wind turbines but it depends on wind speed, direction of wind, wind turbine size and topographical feature like latitude of site, Roughness of surface and obstacles. (Beyer, 2001) (Alex Kalmikov, 2010) but the singles most important factor to establish wind farm is wind speed and at the start of project development process the mean long-term speed is usually unknow so for that purpose analysis of existing projects with similar features would be taken into consideration for example the following table shows 10MW wind farm over the range of annual mean speeds. (Paul Gardner, 2006, pp. 30 - 38)

Wind speed (m/s)	Energy Production (MWh/annum)
5	11,150
7	24,534
10	41,386

Table 2: Wind Speed and Corresponding Energy Production (Paul Gardner, 2006)

It is clear from the table that when wind speed increases from 67% (from 6 to 10) the energy production increases 134%. So, very precise knowledge of site mean annual wind speed is necessary for such intervention. Other than wind speed few secondary influential factors which helps to analyze the long-term wind regime of site and production energy are air density, site turbulence intensity and gustiness of wind.

b) Wind Turbines:

The most common form of wind turbines is three rotator blades attached with one tower. Tower part is to achieve the height and it is designed according to requirements of site and wind speed. Rotor blades are the main functioning part which directly corresponds to the wind. There is gear box directly attached to rotors. When rotor starts rotating it also started moving shafts and then this shaft is connected to electrical generator which starts producing electricity. The tubular tower is to be adjusted automatically with the direction of wind to increase efficiency. Most of larger wind turbines rotates at speed of 20 to 40rpm and shafts rotates about 1500 rpm. There are two approaches to produce the electricity one produces DC current and other one produces AC current. It depends on the system operation, first one is steady rotation and second one is unsteady rotation at changing frequency. (Willian A. Edelstein, 2003)

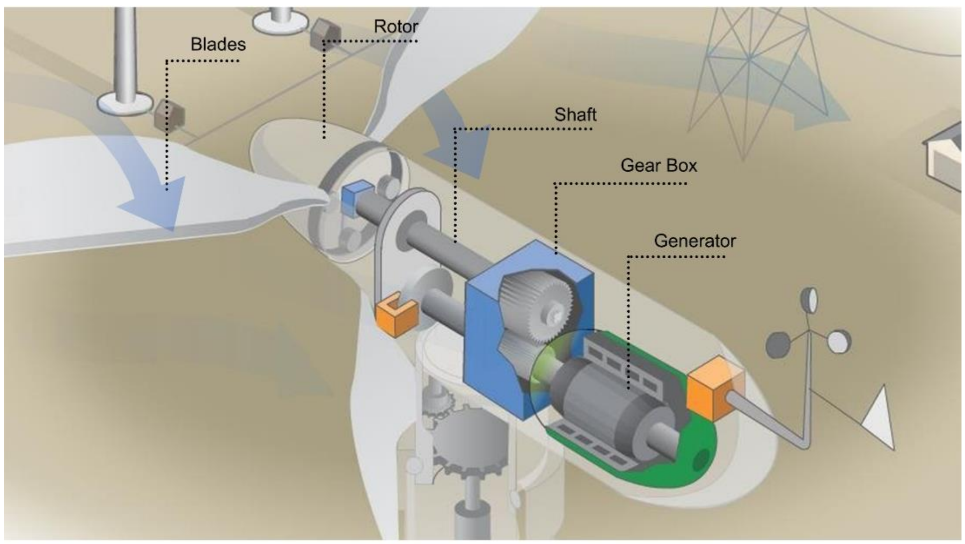


Figure 14: Wind Turbine Working Mechanism (Energy Gov., 2018)

In wind turbines the diameter of rotors has much significance in terms of efficiency, system economies, installation and maintenance. Bigger diameter and higher tower become more economic to achieve more efficiency as technology was advanced. In 1980 mostly, turbines have maximum of 15m diameter with 3 to 4 KW capacity in 1995 it expands to 50m and now 120m diameter wind turbine is being developed and it has 4.5MW capacity. (Paul Gardner, 2006, pp. 70 - 75)

The rotor blades are made of fiberglass composites with mixture of carbon fiber. These are expensive materials, but they have strength advantages. Wind turbines parts are designed for 20 to 30 years operating 120,000 to 180,000 hours of total operation. (Willian A. Edelstein, 2003)

c) Installation Area Requirements:

The selection and size of wind turbines comes after very complex designed process depending upon multiple factors. The most common turbines sizes which are being used from last two decades are more than hundred meters in diameter and the height is the 1.3 to 1.6 multiple of diameter. No of turbines depends upon the output power demands. For example, wind turbines with diameter 110 to 125 meter have output capacity of 10 to 20 MW.

But according to the thumb rule for wind farm 50 acers per MW is required. Out of this space only 5% area will be used by the wind turbine. 95% other area can be used for agricultural purposes. (Willian A. Edelstein, 2003, pp. 73 - 80) Other important factor in deciding the area or site for wind farm is to consider the factor of noise pollution. Wind turbines should be at least 300 meters away from residential areas, at this distance they can produce 45 decibels. (Kellner, 2014)

d) Strength and Weaknesses:

- + Low carbon emissions.
- + Natural resources required for production of energy.
- + No pollution generated by wind turbines (clean energy source) in operational phase.
- + Small land footprint, as they go high so their impact on land is minimum and the rest of land can be used for agricultural purposes.
- + Low running cost, the only cost associated with turbines is maintenance.

+ Wind turbines are considered relatively low maintenance.
+ Long term renewable energy solution. They wind turbines are expected to last more than 70 years and their life span is increasing with advanced technologies.
– There is huge fluctuation in wind resources.
– Initial cost is high as wind turbines are mostly huge and material used for them are expensive.
– Noise pollution created by wind turbines is high.
– Huge part of land is required although land can also be used for agricultural purposes.

2.2.1.3 Energy from Disposed Waste:

Waste and residue are result of human practices and disposition of this waste to proper site or landfills is a challenge in many developing and few developed countries. Recycling of used materials have positive effects on the amount of waste but in last decade with technologies and practices on the horizon the idea of "*Waste-to-energy*" has gained much importance because at the same time it solves two problems. The problems of excessive waste and sources of clean energy. Waste can be converted into heat and electrical energy.

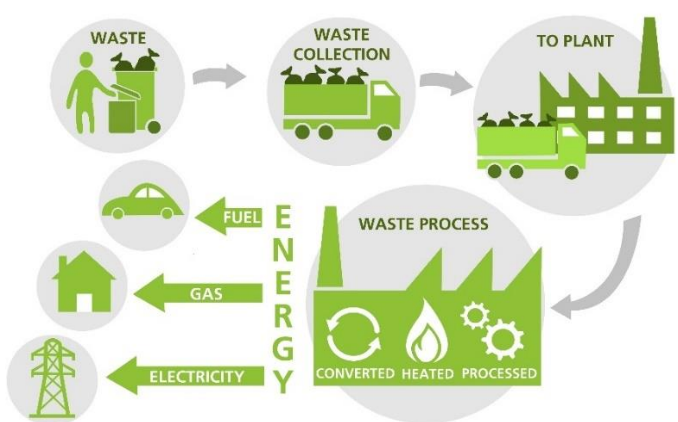


Figure 15: Waste to Energy Process (Regen Waste, 2018)

Its seems ideal to convert waste into energy but it's not just matter of buying few equipment's and installing them. The whole process works as a series of steps. The collection of waste to separation of Hazardous material, organic and inorganic, recyclable and non-recyclable materials is important. The awareness and education of people living in a community is very important for all these steps. (Taherzadeh, 2015) there are few disadvantages of this method like emissions of greenhouse gases if not checked properly. Initial fuel is required to start and maintain the process and skilled labor is required for this operation.

a) Incineration Process of Waste:

Incineration is one of the main technologies used to produce electricity and heat form waste material. The amount of water in waste decides either waste should be incinerated or digested because it directly effects the amount energy produces as result of that process. Dry wastes is normally go for incineration. (Taherzadeh, 2015) This process also produces residue and flue gas. Because of emission of gas and related environmental safety issues a certain amount of temperature is maintained. (Tore Hulgaard, 2010, pp. 363 - 392)

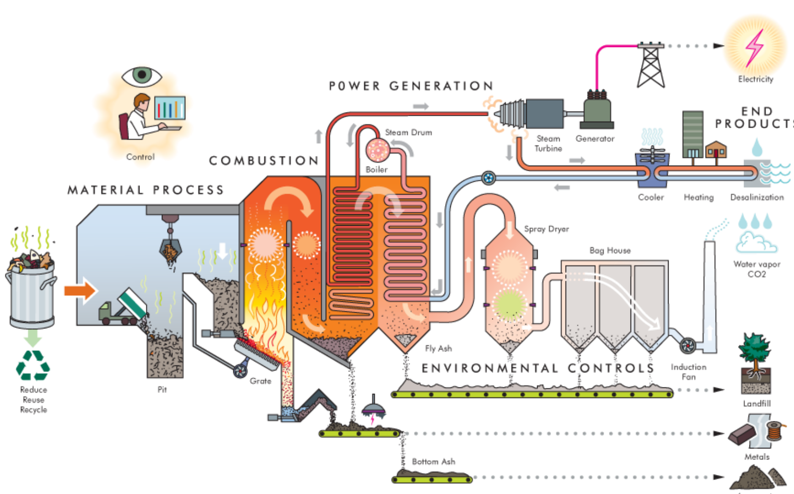


Figure 16: Waste to Energy Production Plant (Deltaway Energy, 2018)

The process starts when waste truck dumps all the waste from residential and commercial sources to the allocated site. This waste is then transferred to combustion chamber, here in burns at 800 to 1000°C. the boiler converts the heat from combustion into high pressure steam and the walls of combustion chamber are surrounded by water tube walls which is heated by radiation. Hot water can be supplied for domestic heating and other usage through supply pipes and high-pressure steam goes into turbine which drives electrical generator. Generally, 10% of electricity is used on site and rest of it can be supplied elsewhere. The residue waste after combustion is 15 to 20 % of original weight and 5 to 6% of total original volume which then used for ferrous metals. (Taherzadeh, 2015) (Tore Hulgaard, 2010)

b) Anaerobic Digestion:

Anaerobic digestion mostly happens with organic waste. There can be two possibilities, one if oxygen has access the digestion will result into CO_2 and water. But in deeper landfills (more than one meter where there is no access of oxygen, the digestion will result into not only CO_2 and water but also Methane Gas. In this reaction production of Methane Gas is important which is source of energy and can be used mostly for domestic purposes as natural Gas. Livestock waste has best use in this way that it reduces pollution and converts into Methane Gas. Special digesters can be set up for this purpose. There are two types of digestion process wet digestion and dry digestion depending upon their wet weight. Wet digestion is important because it results into more Methane Gas.

(Irini Angelidaki, 2010, pp. 583 - 600)

c) Area Requirements:

In Europe an average citizen produces 500 kg of waste each year and if 50 % of its non-recyclable waste residue can be used for “Waste-to-Energy”. So, for the community of

500,000 people the amount of waste to be treated is 125,000 tons/year. There are many sizes of plants are available, for the economic point of view 40,000 tons/year is the minimum threshold. The biggest plant available can treat 1 million tons/year. The amount of area depends on the plant size. (ESWET, 2015)

One plant which has a capacity of 25,000tons/year has to be set up in 4000 to 5000msq area but it depends on the design of the plant.

d) Strength and Weaknesses:

- + Reduced waste volumes and need of landfill spaces are reduced.
- + The energy obtained is cheaper.
- + Reliable source of energy as people always produces waste.
- + Less waste to landfills produces less methane gas which is very good for environmental quality.
- – Carbon emission because of incineration process is comparatively high and a lot measures are needed to ensure the responsible emission of carbon.
- – Initial Cost for incineration plant is high.
- – Skilled staff is required for operation of plants.

2.2.1.4 Energy from Tides and Waves:

Oceans contains a significant amount of energy resources in form of wave or tidal energy and thermal energy. (M. Teresa Pontes, 2006) Ocean waves are easy source of harvesting energy and it has higher outcome of energy as compared to wind and solar energy. (Marcus Lehmann, 2017) Tides are formed due to the gravitational fields of moon and sun and these tides can be exploited into harvesting energy in sustainable way. Oceans waves are generated by the wind blowing over ocean’s surface. Oceans wave are predictable, but they also have complex characteristics and because of that an extensive research work is needed to develop a feasible system. (M. Teresa Pontes, 2006)

a) Energy Resources:

Tides are produced by the rotation of earth in gravitational field of moon and sun. Due to this gravitational field the ocean's surface is raised and lowered periodically which then with the help of harvesting systems installed on site, can be converted into energy. There are two kinds of cycle half-day cycle which caused by moon gravitational field and 14-day cycle caused by moon and sun's gravitational fields.

Mean tidal wave anywhere is 0.5m but there are few places where it can go as high as 15m which the ideal example of high tidal wave is. The favorable conditions for which such plant is economical is if tidal wave is as high as 5m. this depends on many geographical conditions. The plant life of such systems is very long (120 years for barrage and 40 years for equipment) but the installation time is very long and complex. It is non-polluting sources and no initial decency on fossil fuels plus such systems provide barrier against flooding. (M. Teresa Pontes, 2006) energy Efficiency depends on many factors like tide rise and fall, ocean current (water circulation and flows), Tidal current (Ocean water mass response to tidal rise and fall). Currently there are not many plants are installed for example no plant is working in U.S and only few Megawatts Plant has been installed in Europe. China and Korea are leading nations in this regard. Investments and research are being done but industry is still in its initial stages. (Marcus Lehmann, 2017)

b) The Working Principle:

The work principle for tidal or wave energy is simple. There are two sides of barrage, both are called basins. One is high tidal basin and other is low tidal basin. High tidal basin is filled with water during high tide and it can be released during low tide which cause the rotation of generators. This is like wind energy system. (Marcus Lehmann, 2017)

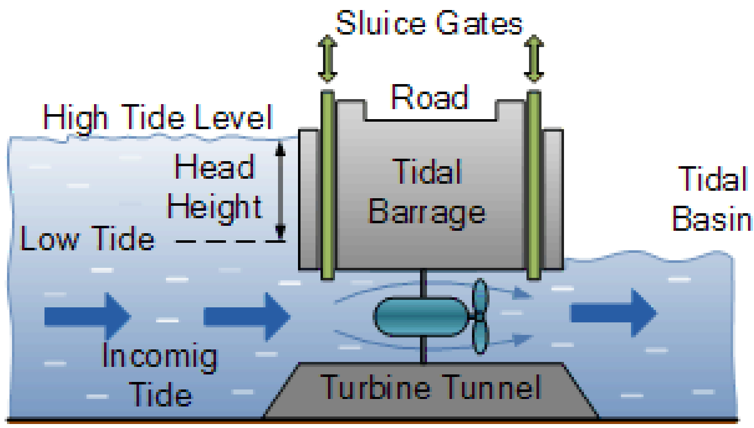


Figure 17: The working Principle for Tidal or Wave Energy (Marcus Lehmann, 2017)

For wave-energy conservation there few systems available for example oscillating water column and over-topping. In Oscillating water column as water rises the air inside column compresses and pushed toward outside which causes turbines to rotate.

Overtopping involves the collection of water on top of structure and then it runs down the structure with turbine attached to generators in lower portions. As water runs down it rotates the turbine and generates the electricity. (Rudge, 2005)

c) Strength and Weaknesses:

+ Renewable and environment friendly.
+ Widely available in coastal areas and no damage to land.
+ There are variety of ways to harness the energy which means the selection of methods can be in accordance with existing conditions and required efficiency.
+ Not huge fluctuation in term of resources and easily predictable.

- Tidal and waves energy harnessing plants have some effects of marine ecosystems.
- These technologies are suitable for only certain locations which limits their adoption.
- Maintenance is costly and difficult on an in-place unit.
- Relatively new technology which makes it little unreliable in term of efficiency and life span and the initial cost is also high.

2.2.1.5 Comparative Study of Renewable Sources:

Qualitative Analysis of different renewable resources is an estimated approach to determine the efficiency of energy resources with respect to different factors for example cost, Greenhouse gases emissions, adaptability, available resources, Scale of projects to maintenance of project in operational phase. The graph shows the comparative analysis of technologies. Solid bar shows comparative values and diagonal hatch shows the flexibility of resource from low to high. The graph does not depict the quantitative estimation because different technologies has different parameters with different Scope of work.


Initial Cost
CO2 Emmisions
Adaptability
&
Feasibility
Solar Power
Wind Power
Biomass &
Waste Energy
Wave &
Tidal Energy
Required
resources
Scale
&
Boundries
Maintenance
&
Repair

2.2.2 Agriculture Production:

The aim of establishing a model self-sufficient community is not only being self-sufficient in terms of energy resources but also food and agriculture products because the concept of self-sufficiency means living of the grid, independent of all kinds of resources so food is one of most important commodities as it is basic human need. In this part of chapter, we will discuss an unconventional and new way of agriculture production. It's called vertical farming. On other hand conventional methods of agriculture farming are also adoptable but here we will discuss vertical farming as main subject to evaluate its feasibility and its advantages and disadvantages.

2.2.2.1 Vertical Farming:

The concept of vertical farming has been on discussion table for quite a while and not very long ago after a long evaluation of economic feasibility, this concept has been brought to life. Because of requirements such as, controlling the environment within the buildings with regards to lighting, temperature, arrangement of plants, etc. and providing them with an insect free environment, the food production in a vertical farm has become a very expensive affair. (D.B, 2010)

This method of cultivation is more efficient than the conventional farming. All the food produced will be grown organically in a controlled environment, with no insecticides and pesticides. In order to keep the plants in a controlled environment, some certain criteria is required to be fulfilled while designing the structure and architectural details of these complexes. (Brayn, 2005) The designs of vertical farming units are made flexible enough to counter the plants needs and sun path all around the year. These projects combine urban agriculture with high scientific technologies.

2.2.2.2 Work Principles:

a) Hydroponics:

The technique selected to grow plants in "Vertical *farm*" is hydroponics. Hydroponics is a sub branch of hydro culture and is a method of growing plants using mineral nutrient solutions, in water, without soil. (Johnson B, 2010)

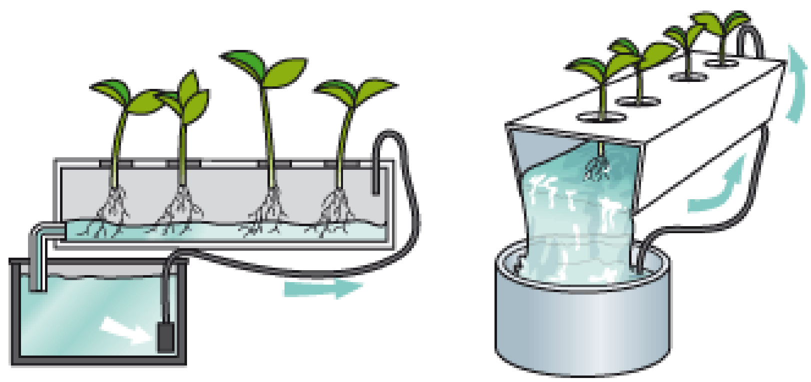


Figure 18: Hydroponics Working Methodology (Johnson B, 2010)

Hydroponics is a technology for growing plants in a nutrient solution with or without the use of artificial medium like sand, gravel etc for supporting the roots. The nutrients that the plants derive naturally from the soil are simply dissolved into the water instead, and depending on the type of hydroponic system used, the plant's roots are suspended, flooded with or misted with the nutrient solution so that the plant can derive the elements it needs for growth. (D.B, 2010) (Hydroponics, 2018)

Hydroponic systems are further categorized as open and closed systems. In open system, after the nutrient solution has been delivered to the plant roots, it is not reused where as in closed where surplus solution is recovered, replenished, and recycled. All hydroponic systems in temperate regions of the world are enclosed in greenhouses to provide a controlled environment to reduce disease and pest infestations.

Since the roots are either growing in water or growing through an inert medium, the nutrient concentrations and pH can be adjusted with great ease. (Brayn, 2005)

Hydroponics leads to high planting densities which minimizes the use of land area. Since Plants can be grown closer together so they take up less area than the field crop. Also, they need less space for roots growth as the plants are "spoon fed" with the nutrient and water they need. Yields are also greater due to better control over water, nutrition, pH, climate, sunlight and diseases. (Simply Hydro, 2018) In soil culture water may be lost from the surface through evaporation but In hydroponic culture, since the nutrient solution is enclosed in tube, there is no loss due to evaporation. (Hydroponics, 2018)

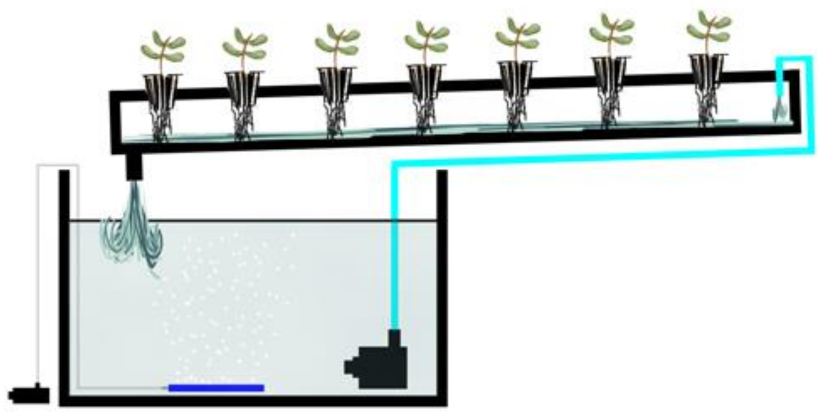


Figure 19: Mineral Distribution Mechanism through Hydroponics System (Simply Hydro, 2018)

b) Variable flow system (VRF):

Variable refrigerant flow (VRF) is a modified central system which has one main outdoor condensing unit and multiple indoor units. The system can control the amount of refrigerant flowing to the multiple evaporators of indoor units, thus allowing the use of many evaporators of multiple capacities connected to a single condensing unit. This arrangement provides an individualized and simultaneous heating and cooling in different zones. Like multi-split systems, in VRF the basic connection is between one outdoor unit to several indoor evaporators. But in contrast to split systems, VRF systems adjust the flow of refrigerant with respect to each indoor evaporator. This temperature control is achieved by continually varying the flow of refrigerant through a valve PMV "Pulse modulating value". The opening of PMV is determined by a microprocessor connected to the thermistor sensors in each indoor unit. (Corporation C. , 2010)

The outdoor unit is connected to a control wire to the indoor units, which enables the outdoor unit to respond to the demand from the indoor units by varying the compressor speed to match the requirements. The variable flow systems promise a more energy-efficient approximately range from 11% to 17% less energy compared to conventional HVAC units. (Bhatia, 2012)

The VRF system is further categorized as

i) Heat pump VRF system

ii)Heat Recovery VRF system

c) Heat Recovery VRF system

This system has the capability to operate simultaneously in heating or cooling mode. This system enables heat to be used again rather than getting wasted as it would be in traditional heat pump systems. Contrary to conventional split systems, the heat recovery VRF systems are equipped with distributed controls, inverter drives and pulse modulating electronic expansion valves. (Corporation C. , 2010)

Mostly, a three-pipe system is used but each manufacturer has its own design. In three pipe systems, liquid, hot lines are provided with suction line.

2.2.2.3 Importance of Vertical Farming:

1. Saves land up to 70% giving same quantity of agricultural products.

2. Seasonal vegetables and fruits can be available whole year.
3. Floods and harsh climate conditions can not affect the production process.
4. Controlled environmental condition produces better quality of crops.
5. Amount of water needed for vertical farming is less than used in conventional methods of farming.
6. Fulfils demand of food industry without compromising quality and nutrition requirements.
7. Integral part of community and brings job for the people. (Brayn, 2005)

2.2.3 Waste Management:

Waste management involves from collection to proper disposal of waste. Proper classification of Waste materials is very necessary based on their recycling and other uses. Basically, there are two kinds of waste materials.

(a) Organic Waste (b) Inorganic Waste

Inorganic waste can be further categorized into glass, plastics, metal and composites etc. (industrial waste is very different, and here we only consider civil waste collection). For this purpose, the proper awareness on community level is necessary and after this comes the collection and disposal part of waste to landfills, also after collection the separated recyclable materials will go to regarding industrial units and the material used for incineration (if there is a plant) can go there. (Chichester, 1994) Few of waste management techniques are as follows.

2.2.3.1 Underground Collection System (ENVAC):

In this system, collection of waste is done by manual and automatic means and dustbins are replaced by collection points directly connected to a system of pipes. (Wajeeha Saleem, 2016) Waste can be collected underground and sorted manually and through ***ENVAC*** system which is vacuumed based system. In this system Vacuum creates pressure and helps to transport the waste from collection points to designated spots. Collection points are already differentiated by typology of waste (Organic, Metal, Glass, paper, plastic etc.) and they are connected to separated pipes so sorting of waste in such systems is also easy. These solutions are preferred in hot climate and places where there are very narrow streets where waste truck access is limited. (ENVAC, 2018)

2.2.3.2 GIS Based Waste Collection Technology:

The combination of problem of the waste collection and the GIS systems has become increasingly used over the last years in Europe specially in Sweden and some of Italian municipalities. It is a structured and integrated application for, individual Municipalities or to Municipalities to manage the waste from production to collection and from collection to its transportation to landfills or treatment plants by automating and optimizing each step of the chain. The collection of data and optimization of system for better efficiency is one of many important goals of such systems. (Wajeeha Saleem, 2016)

2.2.3.3 Sorting Systems:

After the collection of waste, the next important step is to sort out the waste. For this purpose, there are many methodologies and techniques available depending on the final usage of waste either they are going to landfill or for incineration or recycling process.

a) Automated Sorting:

Everybody knows about the optical/manual sorting and compartmentalizing of bins but with the developing technology everyday there are many new techniques available for this purpose. Automated sorting plants are sensor-based plants to sort different type of waste, they sort waste according to set out system. Their efficiency is high at low cost and low carbon footprint.

b) Mechanical Biological Treatment:

The term MBT is used because of series of biological and mechanical processes. They are used for different type of segregation of waste. The main aim of MBT is the energy recovery from the waste and it can considered as pretreatment of waste before final use. Biological processes are used to minimize the water content and mechanical processes are used to separate inorganic content. (Wajeeha Saleem, 2016)

2.2.4 Water Management:

2.2.4.1 Water efficiency in buildings:

By the term **"*water* efficiency"** means" the minimum possible use of water without compromising the ease of process". In the building there are many ways can minimize the water usage and save up to 40% of water. For example, low flow fixture can reduce the water demand by almost half. The "*vacuumed flush toilets"* and "*dual flush toilets"* also helps a lot to save water. In many buildings around the world storm water harvesting is very common and that water can be used for different purposes. Some W.C also used grey water to flush toilets. (Sheth, 2017)

2.2.4.2 Water Recycling:

Water can be used and recycled again, maybe not for drinking purposes but for other usage bacteria and chemicals can be removed up to safe limit for reuse.

a) Grey Water:

Grey water is water which comes out of baths, basin Shower and washing machines. It has range of chemicals from detergents but after little treatments it can be used for purposes other than drinking, for example flushing toilets and watering the home gardens is good use for such recycled water. Flushing toilets with such water can save up to 15 to 20% water.

b) Black water

Black water which is sewage water and recycling it involves many steps. About reusing of blackwater there are divided opinions. (Nolde, 1999) Use of septic tank where hard organic particles settle down the chlorification and other procedure are done for reuse.

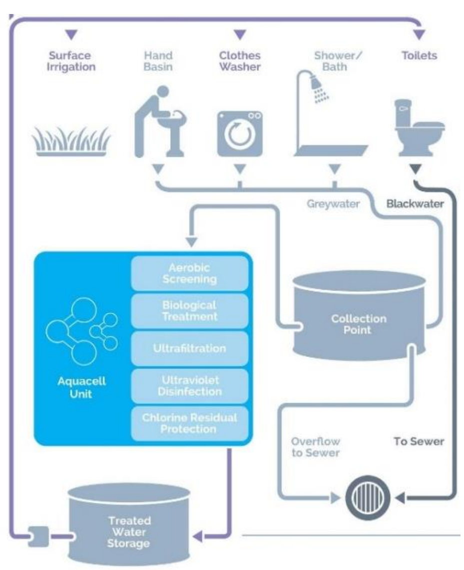


Figure 20: Water Recycling Mechanism (Green Buildings, 2018)

2.3 Conclusion:

Cities are the future and to plan our future we need to plan our cities better. The challenges human race is facing in terms of energy crisis, water shortage, global warming, rising sea level, waste from cities and industries are few of these. Cities are most affected and at the center of these problems. We as policy makers and urban planners need to adopt new ways of planning. Planning for the people rather than planning for money. Adaptation of new techniques with awareness among masses should be first step toward this and all stakeholders should work together. Political willingness is one of most important elements and policy makers should work towards making cities an efficient, sustainable machinery of system by using all planning techniques and technological solution at our disposal.

Chapter 3 Sustainable Districts | Case Studies (Macro Level)

3.1 Introduction:

There are many cities and parts of cities around the globe which are building new eco sustainable part into their urban fabric. Because of climate change, world population, energy crisis and rising average temperatures, Governments, policy makers, planners, architects and scientist are coming up with solutions to make existing cities sustainable and built new cities and part of cities on principles of sustainability.

In this chapter we will analyze different examples around the world new and existing which have been working towards the principles of sustainability. The purpose of such study is to learn from these case studies about the use of available technologies and urban planning strategies which they have used as experiment, how those strategies are working in terms of sustainability, how successful they are in order to achieve their goals and their strength and weaknesses. We have selected four examples after careful consideration of many examples. We chose "*Hammarby Sjostad"*, as it became the European pioneer in this field and it help earn Stockholm the title of *"The European Green Capital*". A lot of research and case studies have been done to analyze and learn from the project and a lot of projects have been developed on the same model. *"Royal Sea Port Stockholm"* project was based on the same idea and it was started after experimentation on *"Hammarby Sjostad".* Another important example of City of *"Vauban district"* in Freiburg Germany has been chosen as they followed systematic way of implementing an extraordinary strategy throughout many years to convert their abandon city districts into new sustainable urban area. All these three are in Europe and has lower to average temperature range, so one more very ambitious example of *"Masdar city"* Abu Dhabi was chosen to learn the sustainable strategies in hot climate. Both examples from Stockholm and Masdar city are coastal area as our study area of Pisa, Italy.

3.1 Stockholm – The European Green Capital:

Stockholm is the Swedish capital of 850,000 residents. City has developed itself into sustainable capital and city has also been focusing into reducing greenhouse gas emissions. The city has won the award titled "European Green Capital". The city has approved the plan to be target of zero fossil fuel by 2050. There are many building projects going on in the city, Hammarby Sjostad, Stockholm Royal Seaport are few of many sustainable developments going on in the city.

3.2 Hammarby Sjostad:

3.2.1 Fact and Figures:

Construction	New (1994 to 2018)
Area	200 ha
Population	26000
Dwellings	11,500
Distance from City Centre	3km
Population Density (city)	4069 inh./km^2

Table 3: Facts and Figures (Hammarby Sjostad) (Greenmatch, 2018)

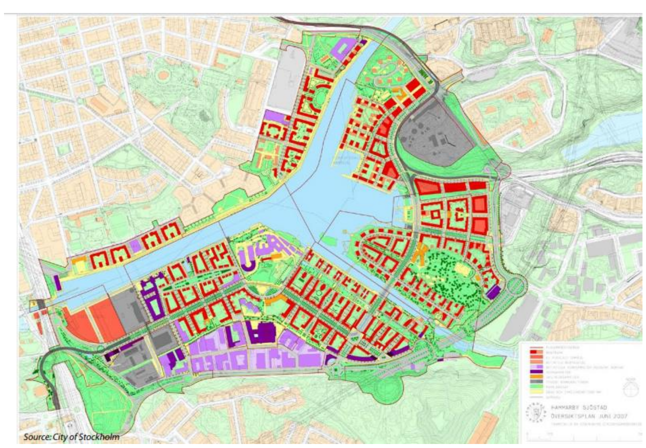


Figure 21: Hammarby Sjostad Masterplan 2007 (Greenmatch, 2018) (Hammarby Sjostad, Stockholm, Sweden, 1995 to 2015, 2018)

The Site is located on the south side of city. The district near inner city of Stockholm that was previously industrial and harbor area, has been converted into environment friendly sustainable living community. Originally the project was part of Stockholm Olympic summer games 2004 and city failed bid for Olympic games, but city officials continued with the project because of it proximity to city center and city need of housing projects. City acquire private land and develop the first draft of design. (Risén, 2018)

3.2.2 Design Objectives:

Construction Phase:

- Twice Reduced environmental impact than normal during construction and life cycle.
- Sustainable materials and eco-certified products for the development of project.
- Less than half of energy use in development phase than normal construction projects.

Operational Phase:

- Zero Impact energy consumption for its residents.
- According to Swedish standard of energy usage is 270 kWh/m^2/year but the goal for this development was set very low which is 60 kwh/m^2/year.
- All of energy was renewable energy and 80% of it would come from waste.
- 80% of travelling by cycle or on foot by 2010. (In 2007 survey 76% travelling was being done on foot or by bicycle)
- Provisions for public transit and limited Car use to save energy on transportation. (0.5 cars per unit)
- 5% of offices and 15% of household car usage would be carpool sharing by 2010.
- Mixed used development with all utilities in walking range of 500m to 700m. (Jonas Jernberg, 2015)

- Recycling of used Water and waste.
- All waste water will be recycled and reused and converted into renewable energy and water consumption was to be reduced by 60% per person.
- All storm water would be purified before going into lake.
- Not only environment sustainability but social sustainability (Social Equity) as well.
- 15% reduction in domestic Waste generation. (Andrea Gaffney, 2018)

3.2.3 Strategies to Achieve the Objectives:

"Closed loop Infrastructure" for waste water and energy, which feed each other thus reducing the amount of total energy. The closed loop system is the system in which the post-consumer waste is collected, recycled and reused and different elements of the system of depend on each other and work together. Here are few infrastructural elements which helped the project to achieve its goals. (Hammarby Sjostad, Stockholm, Sweden, 1995 to 2015, 2018)

- Most of Apartment blocks have solar Panels to produce enough energy for domestic usage.
- ***"ENVAC Waste system"*** (vacuumed waste collection system) In this method waste is transported using airflow, to the common point and then collected for final usage.

Figure 22: ENVAC Waste Collection Points (Jonas Jernberg, 2015)

- 100% of waste is sorted and only 0.7% of waste goes to landfill. 50% of waste is recovered as energy through the waste to energy system, 16% of waste is turned into biogas, 33% is materials recycling, and 1% is hazardous waste.
- Sewage of apartment buildings is converted into heat using Sharc system. Sewage water is already on 70^{o}F thanks to dishwasher and hot bathing water. Sewage water goes to heat exchanger and sewage water heats up the clean water and then it is heated more through the incineration of waste and through district heating pipes it is supplied to housing complexes.
- Solid waste from sewage is used for foresting and few agricultural purposes.
- Block sizes should be small to promote non-motorized transit.
- Two new inner-city buses which runs completely on Bio Gas and car sharing scheme with more than 25 cars as first installment around the neighborhood. New tram line connecting to the city center reducing the personal car usage.

Figure 23: New Tram Line in Hammarby Sjostad Area to City Center (Risén, 2018)

- 0.55 parking space for one household and 210 cars per 1000 residents
- The roads alongside the residential buildings are lowered 2m to decrease noise pollution.
- Strong connection between the residential complexes and nature through linear green spaces and strong water front facing design of buildings.

- Large roads (main boulevards up to 35m wide) with wide footpaths, public squares give loveable spaces to community. The amount of green public spaces is 19% of the total area which includes parks, quays, green spaces, plazas, and walkways.
- 40% to total area green/blue which includes courtyards, lakes and recreational grounds. Hammarby Lake occupied the 25% of it.

Figure 24: Green System and Water Bodies in Hammarby Sjostad (Jonas Jernberg, 2015)

- 25 m^2 per person of free space. For all residents in Hammarby this implies an area of 650,000 m2 of public space.
- The density of walking path is 25.8 km/km^2 and cycle path is 10.5 km/km^2. Total waking path is 45km and cycle path is 18.5km.

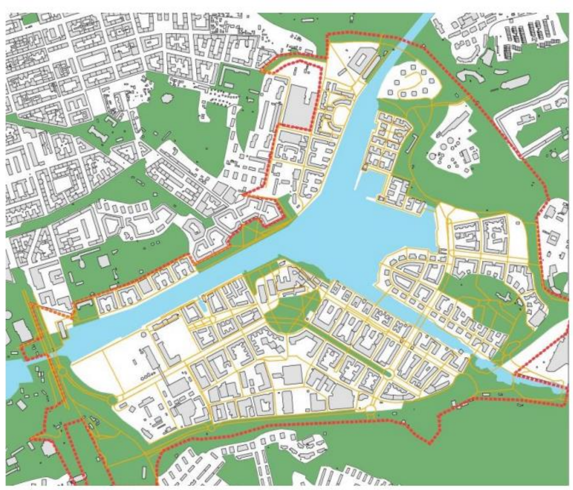


Figure 25: Cycle Track in Hammarby Sjostad (Risén, 2018)

- Multistory building from 5 to 6 story.
- 3 tons of CO_2 gas emission per capita per year (which is very low for developing countries)
- The ***"Hammarby model"*** model used to describe the new eco-cycle addressing the problems related to energy, water, waste and sewage. It was created by Stockholm water company. (Jonas Jernberg, 2015)

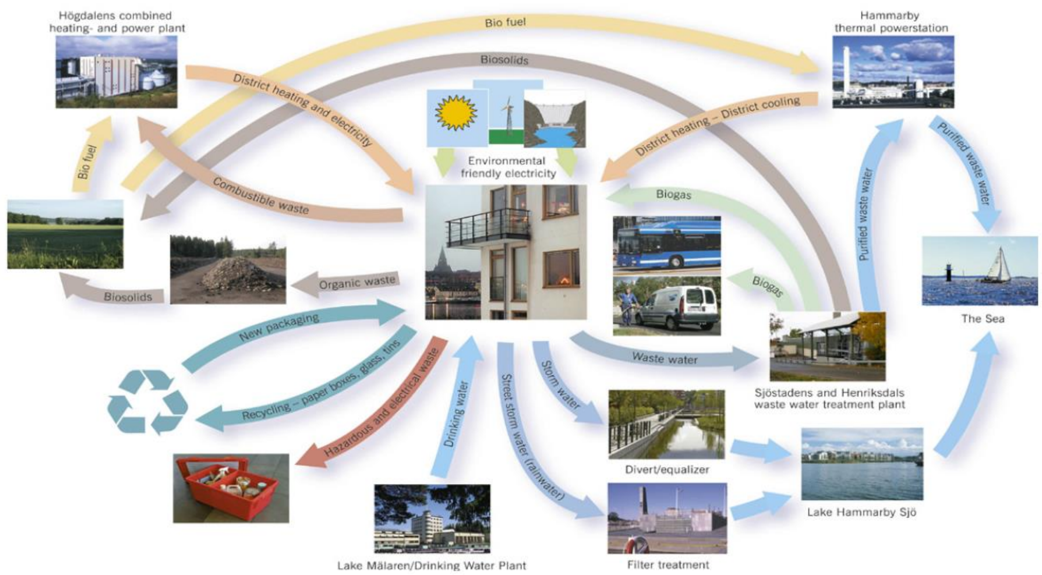


Figure 26: Eco-cycle Model (Risén, 2018)

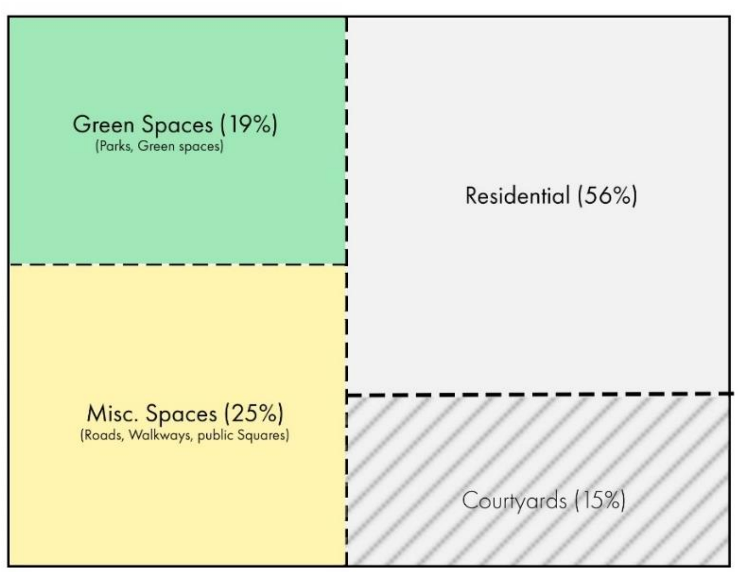


Figure 27: Distribution of Area (Hammarby Sjostad)

3.2.4 Lesson Learned:

- Comprehensive view of targeted goals and how to achieve them with available resources and set them up on early stages of planning.
- One important aspect to learn the adoption of ecological technologies with respect to needs and challenges of community.
- The set targets were focused on four main things Energy, water, waste and transit-oriented development. Each aspect has been handled through series of intervention and achieved according to set benchmarks.
- Energy resources are renewable (i.e Energy from waste which handle two problems at same time one, excessive waste and second is energy demand) The usage benchmark is also set low. Solar panels are installed on roof tops of buildings to gain more energy.
- Water efficiency is achieved through different steps. Recycling, vacuum flushed toiled and collection of rainwater are few of them.
- Central collection system of waste (ENVAC) at basement of each building and public areas, sorting of waste in accordance with their final usage are main strategies used for waste management.
- Development boundary is defined, and block sizes are conventionally small to make pedestrian access easy. All necessary utilities with in walking range.
- Carpooling and public transport rather than private cars, which runs on renewable resources and have direct connection to city center.
-

3.2.5 Conclusions

Hammarby Sjostad is very successful project in term of housing demand. Transit oriented development helped to achieve the targets of increasing use of public transport. The communities in this development use half of water and far less electricity than other parts of city. The strength of the Hammarby Model is its holistic approach to integration of infrastructure systems. The project would not have been this successful without coordination between all stakeholders. The one of few things this project lags in its integration of intra-generational equality in its design. The shift in political power also affected the project for example the reduction in community housing from 40% to 18%.

3.3 Stockholm Royal Seaport:

3.3.1 Facts and Figures:

Construction	New (2011 – 2030) & old
Area	236 ha
Dwellings	12,00
Distance from City Centre	3 km

Table 4: Facts and Figures (Royal Seaport) (Agency S. E., 2018)

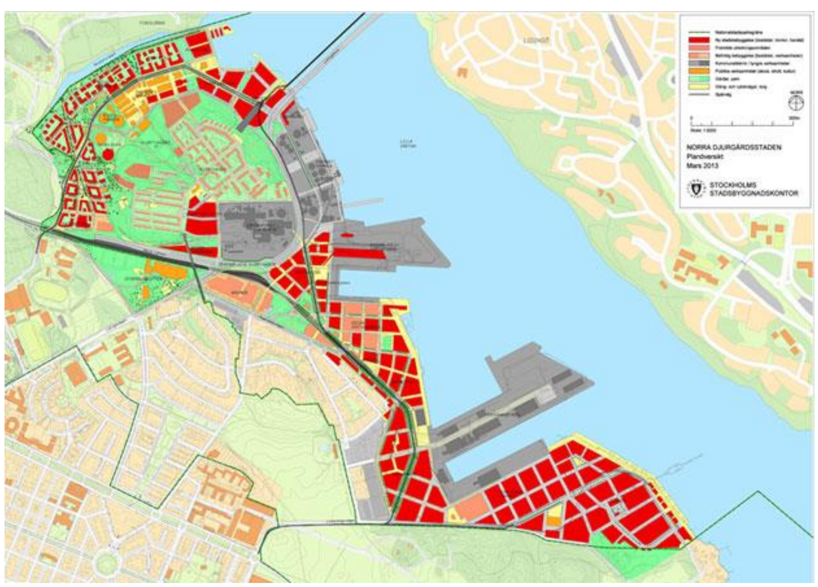


Figure 28: Stockholm Royal Seaport Masterplan (Agency S. E., 2018)

The Stockholm royal seaport is formal industrial area. It is located only 3km away from the city center and location's proximity to water front and nature is main factor developing into sustainable district. The development mainly consist of three districts and its planning is based on the experience gained from Hammarby Sjostad which internationally renowned sustainable project and it is also has the same goals.

The construction started in 2011 on more than 600 dwellings and by 2012 there were 2000 people living and 30,000 working there. The area includes almost 10,000 residential units and 30,000 workplaces. (Agency S. E., 2018)

3.3.2 Design Objectives:

Construction Phase:

- The aim of the project is to achieve the same targets as Hammarby Sjostad of sustainable districts with mixed used neighborhood of residential, commercial activities, services, industrial activities and sports.
- Sustainable and recycled locally produced construction materials
- Low carbon foot print of buildings in construction.

Operational Phase:

- Zero fossil fuel emissions and adaptable to climate change.
- CO^2 Emission in the area will be cut down by 1.5tons/inhi./year by 2020.
- Renewable energy sources, water efficiency and waste management are important points on agenda.
- Smart living to ensure the less energy consumption.

3.3.3 Strategies to Achieve the Objectives:

- Focus on smart electricity and regarding the development of smart grid an experimental project called "An Active house in sustainable city" was done with the family of four people. The house has equipped with House energy management system (HEMS). The includes motion and temperature sensors, dimmers and regulators managing the excessive consumption of electricity. The Royal Seaport Smart Grid Vision" includes
  a) Residential areas will have distributed energy systems with integration of renewable energy production from solar panels and wind mills.
  b) Installation of electric cars and charging points.
  c) CO_2 emissions will be reduced by ship electrical shore connection.
  d) Smart substations to monitor the data and efficiency of system.
  e) Smart grid lab to simulate and develop the smart grid technology.
- ***"Active House"*** focuses on household in smart grid system. It has lower CO2 emissions with higher level of comfort at cost of minimum energy consumption and it has following components to ensure such goals.
  a) Photovoltaic Generation
  b) Energy Storage batteries in case of fluctuation in production of energy (Day and night time, high and low wind speed).
  c) Control system for demand and supply.
  d) Home Automation with sensors and regulators to ensure the minimum consumption.
  e) Smart Appliances with low ampere demand.
  f) ENVAC Waste Collection system.
- LEED certified Green Buildings.
- Wind and solar power as main sources of energy.
- 55kwh/m2/year is estimated energy usage (according to 2015 repost the consumption has been below this level)

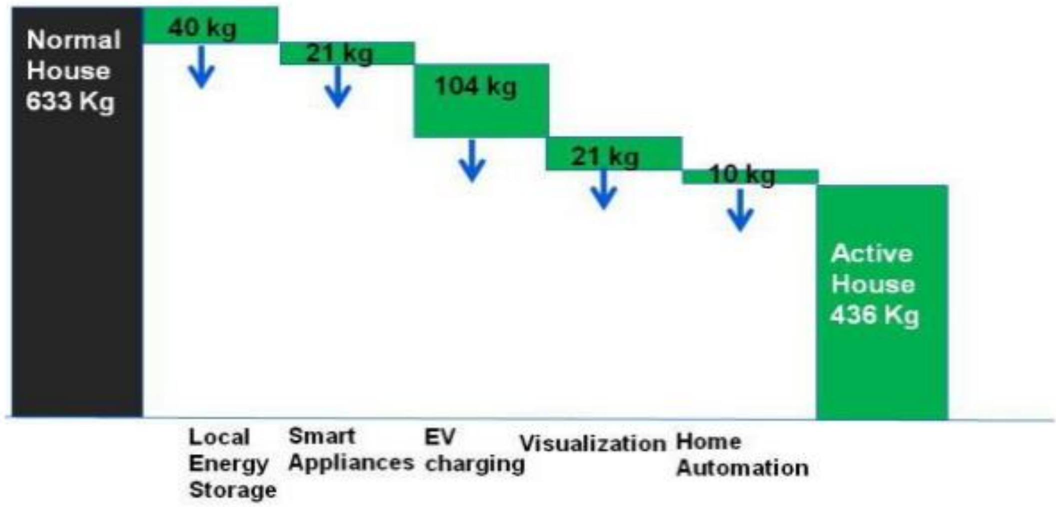


Figure 29: Comparison Between CO_2 Production of Normal and Active House (Juskaite, 2014)

- Closed loop system for waste management is also installed like Hammarby Sjostad
- Recycling rooms, green roofs and urban gardening are important steps taken to integrate the sustainable lifestyle.
- Nearby subway to connect to city, Buses operating on Biogas fuel, trams and boats. (Juskaite, 2014)

3.3.4 Lesson Learned:

- The most important things to learn from this project is to smart utilization of resources. Collection of consumer data to predict the quality and quantity of services provided.
- Smart appliances (less load and better efficiency) and Energy management systems to ensure the best possible usage at minimum expenditure is possible.
- Thinking of the challenges ahead of time and designing not only for present but also keeping in mind the future challenges is the only way to design and plan.

- Smart cars operating on electricity and their integration with in community is good approach towards "***clean energy vehicular system***".
- Mixed neighborhoods with cultural and commercial activities with decentralized development is better way to plan city neighborhoods.
- Adoption of technological solutions to achieve set targets is crucial because the selection of these available technologies based on feasibility and resources available in long and short terms is important.

3.3.5 Conclusions:

Royal seaport project is also another successful example of political willfulness and how integration and coordination with all stakeholder helps to bring together a holistic approach to achieve the targets. In terms of target achieved, the carbon emission and energy consumption are as low as set out targets. One of main features which take this project one step ahead is the smart active house system and collection of consumer data which will help to strategize for future development. In term of planning the large areas in Royal Sea Port project are industrial and port function which shows the lack of direction and continuity. The fragmented areas chosen to build on are not part of any overall idea but still in terms of sustainable goals this project shows remarkable results.

3.4 Masdar City, Abu Dhabi UAE

3.41 Facts and Figures:

Construction	New (2006 – 2025)
Area	60.387 ha (65M sqft)
Population	90,000 (40,000 Residents & 50,000 Daily Commuter)
Distance from main City	10 km
Population Density (city)	135 inhi./ha

Table 5: Facts and Figures (Masdar City) (Vidal, 2011)

A low-carbon, zero waste, eco-city in the dessert of Abu Dhabi, an integral part of economic diversification of Abu Dhabi (Reiche, 2010, p. 10). Part of sustainable vision for Abu Dhabi, this project set some precedents in the middle east for sustainable development in response to challenges of global warming and energy crisis. It is located 17 km east of Abu Dhabi. The site was originally plant sales area. Masdar's city Construction consist of two phases, two squares connecting the whole city. (Afkhamiaghda, 2015) After three years of working six main buildings, 101 small apartments, offshore campus of MIT, electronic library and Masdar city. (Vidal, 2011)

Figure 30: Masdar City, UAE Masterplan (Vidal, 2011)

3.4.2 Design objectives:

Construction/Planning Phase:

- Low carbon footprint during construction and in life cycle period.
- Sustainable materials and planning to encounter harsh environmental conditions and providing viable city life.

Operational Phase:

- Masdar City is aims to be less than 30 kWh per capita per day, an amount which is 9 times less than the energy usage in USA. (Afkhamiaghda, 2015)
- Completely dependent on renewable energy resources.
- Reducing waste to minimum amount as much as possible.
- Smart technologies to reduce the water use in households.
- Reducing the need of air conditioning and artificial lights to minimize the energy consumption.
- Zero vehicular and pedestrian friendly streets without road provisions.
- Thermal comfort indoors as well as outdoors by passive means as much as possible.
- Education and awareness programs to ensure the implementation of goals.
- Sustainability research centers for innovation and technology. (Reiche, 2010) (Urbanisation in MEDCs, 2018)

3.4.3 Strategies to achieve the Objectives:

- Designers acknowledged the importance of passive systems to ensure the sustainable goals of zero Carbon emissions and efficient use of energy resources. They based their design on following simple model.

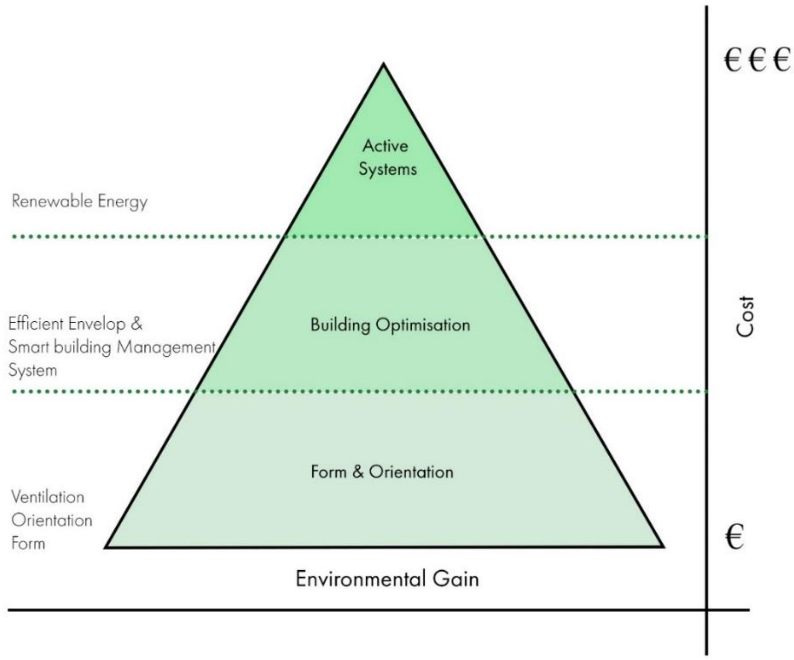


Figure 31: Relation between Environmental Gain and Cost (Jin, 2016)

- Narrow streets with low rise buildings are designed to provide maximum amount of shading in the street and extended building colonnades provide recess from sun.
- The orientation of city grid (all the streets) laid out south-east and north-thermal west axis to provide maximum shading in street during maximum time of day (scans of city has already shown that 20 degrees less temperature in the streets than average temperature). (Jin, 2016)
- No car zones to promote the pedestrian streets with underground subway connecting to city and ***"Personal Rapid Transit"*** is integrated into city's infrastructure which electrically operated cabin cars.
- All locally grown produce goods will be available and not more than 300m away. (Afkhamiaghda, 2015, pp. 10-15)
- There are sensors based smart light switches and taps reducing energy consumption and water usage by half.

- Urban Courtyards and streets are provided to create the loop of indoor outdoor spaces and in addition to this city grid is divided by two main green lanes bringing nature into the city. (Masdar Connect, 2018)
- To achieve the thermal comfort in public squares, A supersized wind tower is used for convection of a wind flow to mollify the heat, bringing thermal comfort for the people at the plaza. (Sona Nambiar, 2018)

Figure 32: Convection Wind Tower to Decrease the Air Temperature (Sona Nambiar, 2018)

- Masdar city has planted 1MW solar plant in phase one and in phase two 201KW plant will be installed producing 1.8GWh energy annually. (Sunpower, 2014)Renewable energy Sources distribution is as follows

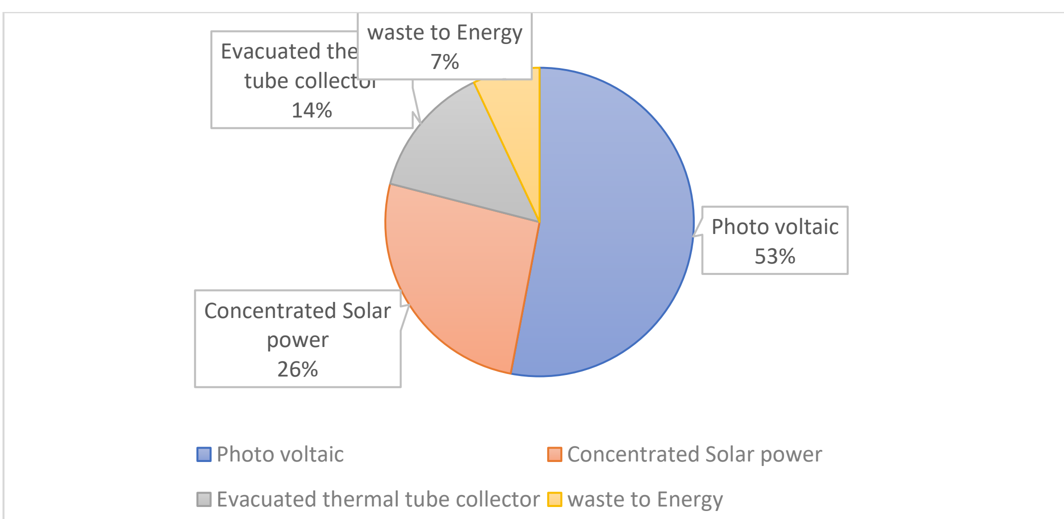


Figure 33: Renewable Energy Sources in Masdar City (Hassan, 2015)

- Sunlight entre from the skylight vestibules which prevents the direct sunlight and heat entering the building but gives illumination (indirect light).
- Glass reinforced concrete latticework is used on windows to avoid heat gain and glare inside the rooms. (Hassan, 2015)
- The wall design with Air limit heat radiation reduces the need of air conditioning and produce 10ºC cooler temperature indoors.
- Foster and partners paid a lot attention to sustainable materials.
  a) Materials with low VOC content.
  b) No use of EPS or Polyurethane insulation.
  c) Regional recycled materials.
  d) Low urea formaldehyde in wood products. (Afkhamiaghda, 2015, pp. 5-7)
- Following is the Land-in use of Masdar city, Abu Dhabi.

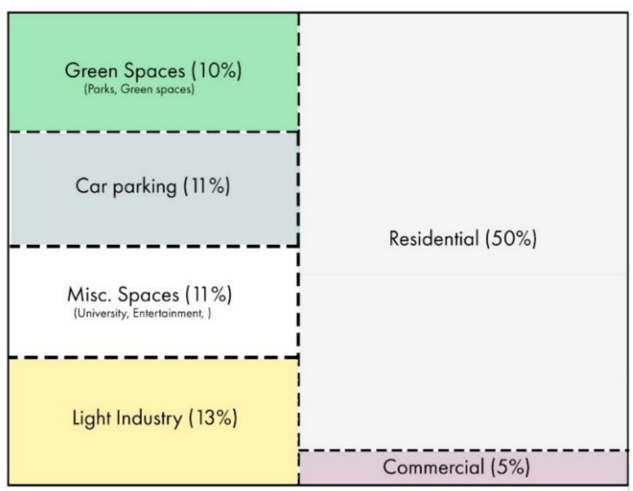


Figure 34: Distribution of Areas (Masdar City)

3.4.4 Lesson Learned:

- Policy making on Government and bureaucratic level is cardinal for such initiative.
- Environmental conditions and demographical features and local available resources should have key importance for design elements.

- Goals and targets should be set out with in achievable limits (Originally claimed to be zero waste but now it has shifted to low waste with 50% landfill diversion and city completion date has extend by almost 10 years).
- Making right decisions to have better quality of urban life, no matter what climate and design elements are.
- Right decisions to choose smart systems and technological interventions to achieve the level of efficiency required.
- Sustainable materials and advanced construction techniques to achieve the level of thermal comfort indoors and outdoors.
- Proper marketing and advertisement with clear vision is necessary to target the investors and consumers.
- Energy efficient transit systems at door step for projects like this to save the surpluses consumed energy.
- Academic and research centers for innovation in technology and to tackle challenges related to climate change, over population and energy crisis.

3.4.5 Conclusions:

Masdar city turns out to be very ambitious project as it had claimed to zero carbon and waste city but later the target seems un-achievable and now the goal is to become low carbon city with 50% landfill diversion. The city completion date has also been pushed forward by 10 years which also has negative effects on its attainable goals. One of biggest concern is city is empty and only 250 residents are students at local university. But despite deviation of original goals I think Masdar city is one step in right direction. It is one of very few pioneer projects in middle east, the area which is most affected by climate change.

3.5 Vauban District Frieberg, Germany:

Frieberg, solar capital of Europe has been leading the sustainable development for over two decades. It is a urban regeneration project is built on former army barracks. (Andy von Bradsky, 2018). The development was based on low-energy, ecological, low traffic and low car neighborhood concept to be “model sustainable district”. The Vauban district is located on the foothill of black forest. (Restrepo, 2018)

3.5.1 Facts and Figures:

Construction	(1996 – 2006)
Area	41 ha
Population	5,000
Dwellings	2,000
Population Density	122 inhi. /ha
Distance from main City	3.5 km

Table 6: Facts and Figures (Vauban District) (Andy von Bradsky, 2018)

Figure 35: Vauban District Frieberg Masterplan (Restrepo, 2018)

3.5.2 Design Objectives:

Construction/Planning Phase:

- Extensive use of Ecological materials and low energy buildings.
- Better integration with in city infrastructure.
- Involvement of all stake holder in development process to ensure the better integration of public interest and to create awareness.
- Diverse range of housing with private, community and corporate developers. (Ramos, 2010)
- All houses to be constructed according to low housing energy standard 65KWh/m^2/year.

Operational Phase:

- Efficient energy Consumption of district.
- High Quality building spaces for residents within the boundary of urban area.
- Priority to pedestrian, cyclist and urban transport in urban design.
- Walking distance to all services for example schools, shopping centers and work places. (Andy von Bradsky, 2018, pp. 20 - 23)
- Mix social spaces and involvement of residents in political decision making.
- Energy from Renewable resources, low waste production and water consumption. (Ramos, 2010)
- Passive heating in house and plus energy houses in the area to be constructed.
- Locally Produced electricity and district heating with renewable resources. (Restrepo, 2018)

3.5.3 Strategies to Achieve Goals:

- 65 % of energy is produces locally by Co-generative heat plants and solar panels. Efficient Co-generative plant producing heat and electricity operating on wood chips 80% (Ramos, 2010) and natural gas 20% reducing CO^2 emissions by 60% and this way it will contribute to the city's energy balance with a reduction in CO2 emissions by 3,000 tons per annum. (Andy von Bradsky, 2018)

- 15MW of Solar panels currently installed and 365kW linked with expressway. $450m^2$ of solar collectors and $1200m^2$ of solar panels.
- Natural shading in open and spaces and in building (specially in balconies to provide shading in summers.

Figure 36: Typical Housing in Vauban District Frieberg (Haghighi, 2010)

- 100 houses built according to the passive housing principles and 59 built by plus energy standard.
- Passive housing system includes:
  a) Insulated walls (Vacuumed insulation panels – two layers in walls)
  b) Operable windows for ventilation and heat gain with shading devices.
  c) Thermal shell glass window frames.
  d) Acrylic Glass on windows and facades and moveable plexiglass walls. (Haghighi, 2010)

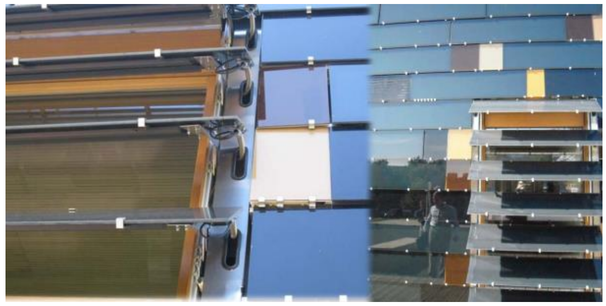


Figure 37: Acrylic Glass on windows and facades and Plexiglass Walls (Haghighi, 2010)

- Renewable energy usage is encouraged through feed-in tariff which enables small producers to invest in renewable energy resources.
- Buildings has limited height (max 12 m, 4 to five stories) which enable better air (cool air from mountains) circulation to lower the temperature the city in summer. (Andy von Bradsky, 2018, pp. 25 - 27)
- Two bus lines and new tram Connection with city center to promote local transit usage.
- 0.5 % car parking space per residence and 160 cars per 1,000 residents to (Field, 2018) discourage the car usage (Andy von Bradsky, 2018) and according to case study people in Freeburg use 16% cars 19% public transit and 64% cycling and walking. (Field, 2018)

Figure 38: Pedestrian Friendly Roads in Vauban District (Field, 2018)

- 500km long network of cycle tracks.
- The main principle is to avoid the production of waste; for instance, through returnable packaging. Residual waste is incinerated in a plant to produce energy. As a result, waste has been cut down to 114kg per resident a year.
- Rainwater is collected and recycled to use in household as well as other purposes. there are the green areas which enable 80% of water from rainfall to be filtered onto natural land. Strom water also used for flushing toilets in districts schools (Ramos, 2010)
- Community engagement in planning and designing phase to understand and ensure the inclusion of needs of residents.
- The general speed limit of 30km/hour to ensure safety of residents and the concept of play streets.
- There is a new ecological system introduced which transforms part of sewage into biogas which then used for cooking in houses.
- Green roofs to minimize the heat gain in summers.
- Planning is done as loop off systems where tram runs giving pedestrian only in most streets.

Figure 39: Traffic Plan for Vauban District

3.5.4 Lesson Learned:

Community integration and involvement in decision making as well as implementation of new strategies has core importance for the success of any project. Innovative solutions like turning sewage into biogas which then be used for cooking helps to save dependency on fossil fuels, such solution should be integral part of design process as well as should be given importance in operational phase. Car free pedestrian streets helps to save energy, reduce carbon emission but also helps to create livable streets for residents. Selection of suitable, innovative materials is right step to achieve the sustainability goals.

3.5.5 Conclusion:

The redevelopment of old army barracks into new sustainable district and remodeling the whole policy making about the development of city has been done quite successfully in German city of Freiburg. Use of passive housing strategies is not new in such projects but how efficiently the architects have handled all the materials and their installation, but minimum active systems intervention is impressive. From use of renewable energy resources to cutting down car usage and dependency on public transport are few of very important steps in right direction but the most important part is all the changes and policy development has not been done in one day. Step by step through years of planning and community involvement has brought these tremendous results. It is very successful project because community living there is part of decision making process.

Chapter 4 Sustainable Building | Literature Review

4.1 Introduction:

We have discussed already about what sustainability means and when we talk about development of sustainable, smart or green buildings the definition remains the same. To elaborate sustainable buildings are based on the principles of resource conservation and efficiency, cost effectiveness and design for human adaptation. (Peter O. Akadiri, 2012) Resource conservation is the most important and crucial objective of sustainable development.

Selection of suitable materials (low residual energy, recycled material, low carbon footprint, locally available) and building construction with best available technologies to achieve the set out sustainable goals play an important part not only in construction phase but also in operational phase because the decisions made in planning and construction phase effect the performance of building in operational phase.

Resource conservation is very wide subject and as there are many resources involved during construction and lifecycle of building, researchers and architects have divided them accordingly and how to achieve them. In this chapter we mainly focus on this objective keeping in mind the second and third objective mentioned above.

The most important resource in construction is materials and sustainable technologies which we will discuss in the first part of this chapter and other resources which are related to operational phase of buildings are Energy and water. For efficient and minimum use of energy there are many approaches which we will discuss in detail and also in the previous chapter we have discussed renewable energy resources but now we will analyze them on micro level. Same goes for water where we will study how we can make water usage as minimum as possible. Other important thing to discuss is waste management of building and how we can minimize it.

There are also many factors like orientation of building, shading devices, different efficient active systems, suitable material, green roofs, glazed windows, insulated envelop of building, pre-construction site conditions, optimum design to achieve targeted goals and these factors will be part of this chapter and we will analyze how these factors contribute to buildings sustainable.

4.2 Sustainability and Materials:

The most important question to ask in this regard is what it means to be a sustainable material, what kind of characteristics, a material should possess to achieve that title. In this section we will discuss these characteristics and available sustainable materials for construction. There are conventional materials and with special treatments they can act as sustainable materials, or they can have better performance than before and there are also unconventional materials which are being used now days more frequently because of new innovations and improvements in their performance.

4.2.1 Characteristics:

There are not hard and fast defined characteristics for a material to be sustainable but set of guidelines drawn from experience and practices based on their origin, effects on environment, lifecycle performance, ability to be recycled and reused, carbon footprint, and environmental endurance to name a few. To elaborate in detail a sustainable material should elaborate following characteristics.

- The material should be resource efficient meaning it should be available in abundance and preferably locally available.
- The material should not compromise the indoor air quality for example their materials which have toxic fumes and VOC's. Sustainable materials should have no or minimum emittance of volatile organic compound.
- Sustainable materials are free of toxic materials such as chlorine, lead, chromium, asbestos, cadmium, mercury and formaldehydes. (N. Sunke, 2018)
- Sustainable materials are rapidly renewable materials and have harvest cycle under 10 years. (Sheth, 2017, pp. 3-6)
- Minimum carbon footprint is one of the most important sustainable features and it can be assured by many factors for example naturally available materials have low carbon footprints because no energy is needed in their manufacturing and locally available materials preferably within the distance of 500m by LEED's also make carbon footprints value more less as minimum energy is needed for their transportation. The example of rammed earth is best in this regard. (Peter O. Akadiri, 2012) (Usman Aminu Umar, 2014)
- Sustainable materials are recycled or to be in future to reduce consumption and carbon footprint. (Usman Aminu Umar, 2014)
- Low thermal conductivity of materials is important to achieve thermal comfortable temperature. Indoor emissions will be decreased, and cost of heating or cooling will eventually decrease. (N. Sunke, 2018)
- Materials which are produced by using "resource efficient manufacturing" for example consider that how much energy, water and other resources we have consumed to manufacture the product till its final stage of installation and during its life cycle the amount of maintenance and repair.
- Materials that maximize the energy efficiency in the building to decrease the consumption of energy resources. (Morsella, 2018)

4.2.2 Available Materials:

The most important decision regarding materials are usually done in schematic design phase and it consist of three main steps Research, evaluation and selection. There are many materials available in the markets and simple derivative materials which are considered sustainable materials. In the following part we will look at few of those materials and their properties.

4.2.2.1 Rammed Earth:

Rammed earth or formally known as earth-built architecture was huge part of construction in old civilizations. UNESCO 10% sites are made of earth materials and 30% of world population (billion) lived in houses made of earth materials. (Quagliarini, 2018)

As far as the strength of rammed earth material is concerned it is not recommended for tall buildings but for buildings for two to three stories, rammed each provide satisfactory load bearing structure. One of main advantages of rammed earth is that it provides thermal comfort inside because of mass effect and its has minimum impact on climate. Almost all the times it is available on site

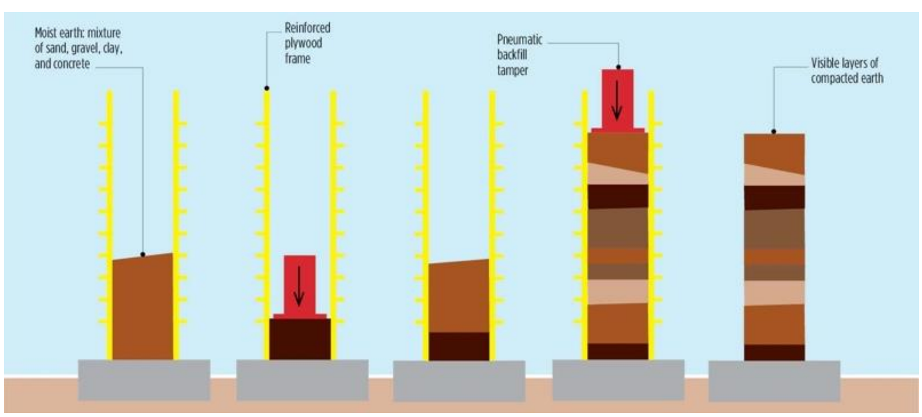


Figure 40: Rammed Earth Construction Process (Ochikatana, 2018)

Rammed earth raises concerned because it is sensitive to water but at the same time its salvageable and reusable increasing it sustainability and there are examples of Horyuji temple in japan which is 1300 old and still is in good condition. (Q.B. Bui, 2008) Keeping in mind soil properties and with new additives and admixtures, now days a lot of properties of rammed earth like moisture resistant can be increased.

4.2.2.2 Wool Bricks:

Wool bricks are made of locally available and abundant clay or soil with wool as reinforcing material. Wool fiber is added using alginate conglomerate, a natural polymer found in the cell walls of seaweed. Mechanical tests show 37% more compression strength as compared to normal bricks. These bricks are made without firing which ultimately saves a lot of energy make them more sustainable than conventional baked bricks and concrete blocks. (Sharma, 2018, pp. 15-20)

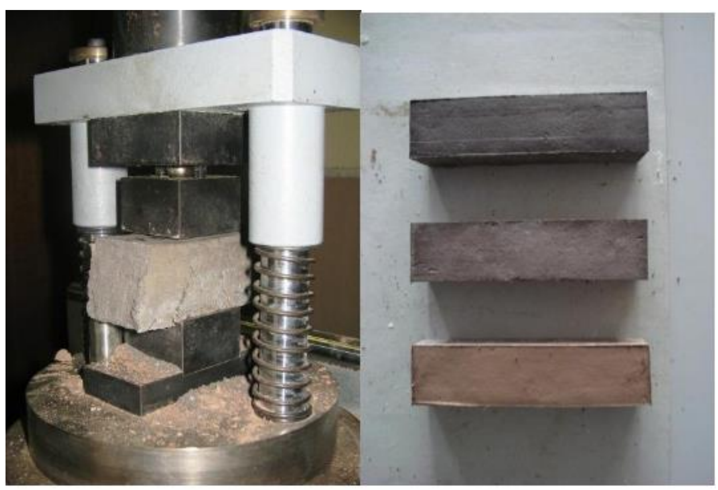


Figure 41: Wool Brick (Sharma, 2018)

4.2.2.3 Fly ash Bricks:

Fly ash bricks are another alternative for brunt clay bricks mainly being used in India these days. The raw materials of these brick are 45% fly ash 40% stone dust or sand and rest is 10% lime and 5% gypsum. These bricks are three to four times more durable than burnt clay bricks and have less moisture absorption. They have low energy consumption and zero emission of Co_2. They are not sensitive to water and high strength of bricks ensures longer life for structures. They can be used in load bearing walls in interior or exterior applications.

In fly ash bricks we use fly ash instead of clay. Some manufacturing processes use pressure instead of heat, reducing the amount of energy required to manufacturing. Fly ash bricks are eco-friendly because they use waste products of coal or lignite based thermal power plants. (Sharma, 2018, pp. 40-45)

Figure 42: Fly Ash Bricks (Sharma, 2018)

4.2.2.4 Sustainable Concrete:

Concrete is widely used in construction industry but when used in its conventional form it emits 7 to 10% of Co_2 of total by building. Now day researchers are doing experiments to decrease Co_2 emissions. (Greenmatch, 2018)

AshCrete is the first example of this sort in which we use fly ash instead of cement. This way waste material is used because fly ash is by product, decreasing waste and Co_2 emissions.

TimberCrete is also experimental example of sustainable concrete which is composed of sawdust and concrete, making it lighter than conventional concrete. sawdust both reuses a waste product and replaces some of the energy-intensive components of traditional concrete.

Ferrok is also new researched material which uses steel dust form steel industry waste to create a material like concrete which can shaped into block and bricks. The most interesting feature in this material is that during its hardening process, this material absorbs Co_2 making it carbon neutral material. (Peckenham, 2018)

4.2.2.5 Cork:

Cork is bamboo like material and it is very important sustainable material because it has ability to regrow very fast and it can be cut from live tree. Cork is flexible material and it can sustain adequate amount of pressure. It has amazing noise and heat absorption properties for which it can used in partition walls. Its resistance again loading and wearing makes it perfect material for floor tiling. Cork is impermeable, so it does not absorb water and it does not rot. (Pyzyk, 2018)

4.3 Smart Buildings:

A smart building is a structure which have automated controlled building systems for internal operation like heating, cooling, ventilation and lighting system. The integrated system consists of sensors and regulators connected to automated controlled system to adjust everything according to the needs of occupants. There are many updated versions of systems available with targeted goals to achieve. Custom systems by different companies are also available designed according to the needs of clients. (SIEMENS, 2018)

4.3.1 Smart Grid System:

Smart grid system on urban level is one of its practical examples. It is multi mechanism system with integrated smart thermostats, meters, sensors and data collection points.

Figure 43: Smart Grid Connection System (Yaser Soliman Qudaih, 2011)

Smart grid system collects user data and monitor consumption activity to modulate the pattern for future needs and supply systems. It is two-way flow system of electricity and information. (Yaser Soliman Qudaih, 2011) Renewable sources supply energy in such systems they are resilient to blackouts and overheating because they use smart thermostat and sensors to detect and predict the problem. Consumer data with respect to weather and time helps to predicts the peak load trends.

4.3.2 Building Management System:

The goal is to design and construct buildings with maximum comfort and ease of occupants utilizing minimum energy possible. The efficient use of energy and other resources is very crucial and that where "*Building Management System"* come in and it has been around since 1970 but it has gained importance recently with the development of new and advanced techniques. (Waqar Tariq, 2012)

Building management system has three main working principles first is automation and optimization, second is monitoring and third is controlling. First one comes during the design and construction phase and other two comes in operational phase of building.

Building management system is an integrated single interface which collect and exchange data for easy interactive control. BMS facilitates us to control and monitor each and every electrical and mechanical appliance connected to the system that are designed and installed according to the set-out goals to achieve the level of maximum efficiency to form a sustainable environment. (Advanced Control Crop, 2018).

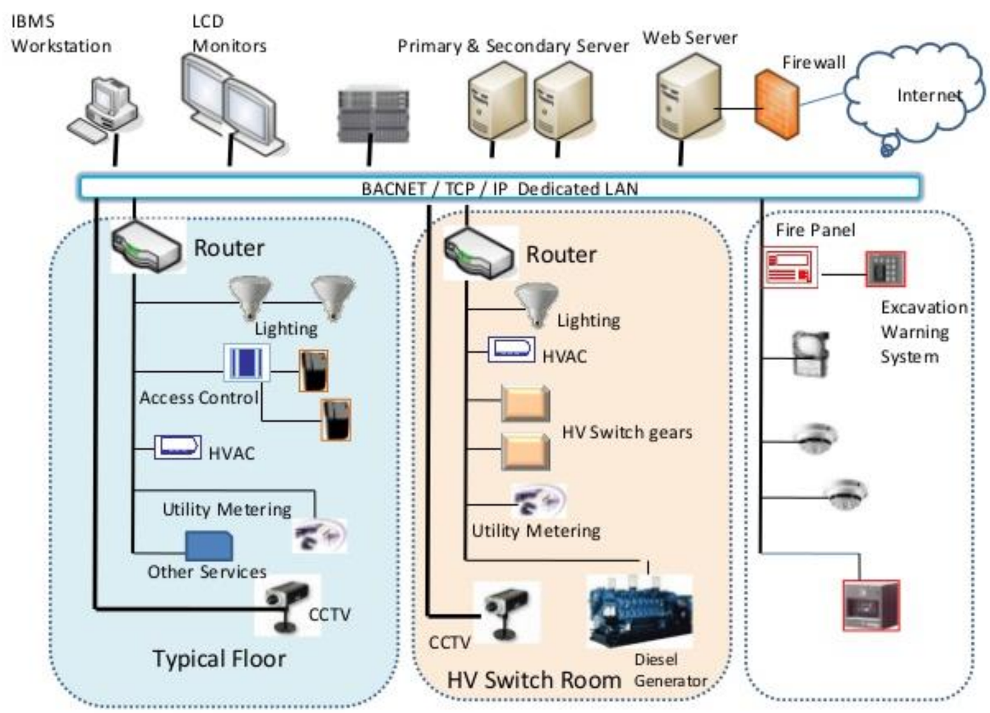


Figure 44: Building Management System (BMS) Operational Mechanism (Advanced Control Crop, 2018)

By control and monitor it means that BMS systems with the help of many sensors and regulators adjust systems installed according to the needs of occupants while ensuring the minimum consumption of energy. For example, during daytime BMS will adjust the lighting fixtures to their minimum luminous value needed because indoor space is getting enough light from outside. Whereas normal manual system has single handling point and consume more energy than needed but BMS ensure to save energy without compromising the comfort of users. Same is the case with heating, cooling and ventilation, BMS connected sensors adjust the appliances according to needs or set out desired conditions according to standard given timings. Now days with more advanced technologies, mobile apps have also been integrated with such system to maximize the user interaction while ensuring the efficient use of energy.

Every lighting fixture, heating and cooling units and electrical sockets are intelligent point of information collection and supply chain.

4.4 Sustainable Buildings & Passive Design

Building's planning phase is the most important part because in this phase the fate of building is decided. Architecture of building is crucial part in which architects make decisions about shape, orientation, materials, passive and active systems of buildings, nature of envelop for building. In this part building working mechanism of building is finalized according to the client's vision meaning what kind of building its going to be, if its is going to be sustainable smart machine or just like any other building depending on non-renewable resources and consuming them inefficiently. Passive design strategies are the ones which works towards cutting down energy consumed on active systems and through planning techniques it makes sure the use of natural resources as much as possible from use of natural light to cut down artificial light to direct sunlight for heating indoor air, so energy used to achieve indoor comfortable environment is as less as possible. In the following section of this chapter we will analyze few of these architectural planning tools and passive design techniques to maximize the efficiency of building with minimum resources possible.

4.4.1 Orientation of Building:

Orientation of building is referred as the positioning of building on site and generally referred to as solar orientation of building. Orientation of building is very important in determining the passive design efficiency of the building. (Gausam & Moore, 2018) A building designed facing south is preferable for sustainable design because of solar gain. For solar gain during winter day when sun is low we can get enough sunlight inside building and during this period UV intensity of rays is low and in summers when UV intensity is high sun's angle is high making it impossible for sunlight to enter directly inside the building that way south facing orientation of building is recommended but we need to be careful about the size of windows on this side. (Mazria, 1979) The most frequently used rooms during the day are oriented in the East and the North whereas the rooms that are used mostly during night should be placed on the South and the West side. (Fuller Moore, 1986)

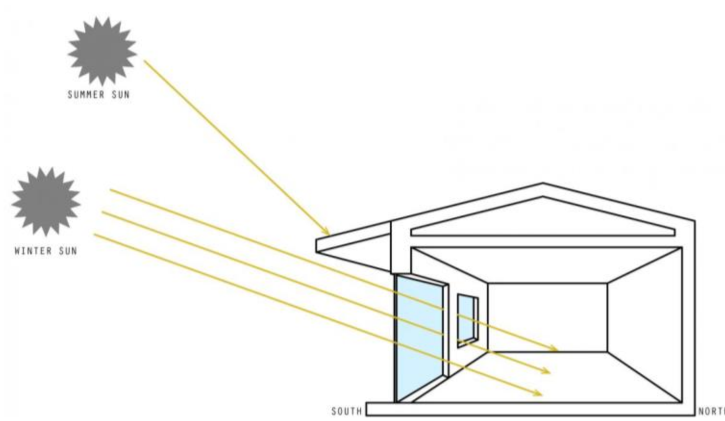


Figure 45: South Facade Interaction with Summer and Winter Sun (Green Passive Solar Magazine, 2018)

The important things to look around the site are if the building south side receive the unobstructed solar irradiance during daytime and what are distance to surrounding buildings, so we can measure their shadows to make sure no blockage of direct sunlight.

East and west side of buildings receives continuous uniform and strong solar irradiance though out the year at lower angle during morning hours on east side and during evening hours on west side and openings on those sides should be carefully designed. (Mazria, 1979)

Deciding orientation of building is part of ***"Passive Design"*** which serves the purpose of sustainability by cutting down the energy consumed on heating because of solar gain through openings in south façade and placing day and night spaces of houses and other commercial buildings on sides according to position of sun.

4.4.2 Envelop of Building:

For building there is special interface that decides the level of sustainability, between inside and outside, that is envelop of building. It consists of foundation, walls, roof, windows, doors and floors. Building envelop plays an important role in deciding the level of energy efficiency as part of "Passive Design" System depending on the orientation, the materials, type of insulation, size and number of openings. (Bolin, 2018)

The reaction of components of envelop with outside environment is important and to create the energy efficient system and comfortable indoor temperature we need to control that reaction according to the needs of occupants. The important question to ask in how to control that reaction.

For example, as south side has much more sun exposure, it is always recommended to use heavy materials like full concrete or high-volume brick walls to have the mass stack effect which reduces the heat gain in summer or heat loss in winters. If that's not possible high-grade glazed windows (double or triple glazing with argon gas is installed to reduce the effect and these techniques are evolving each day to increase the performance with minimum cost and decent appearance. There are many types of insulations that engineers use to control the effect of environment on building according to our needs.

Green roofs, shading devices for windows, glazed glass, insulated walls etc., all are different ways to minimize the environmental effect and use it for benefit of buildings to save energy. Perfect selection of materials in accordance with each side of building, environmental conditions and sun movement plays an important part for interaction of building with outside environment.

4.4.2.1 Envelop Insulation:

For better performance of structure in terms of energy efficiency and to create thermal comfortable temperature, insulations are becoming integral part of construction industry and there are many types of insulation available which are to be used at different places for different targeted goals. In the following section we will discuss few of these insulations and their usage.

a) Spray Foam Wall Insulation:

Spray foam wall insulation is ideal of existing structures specially houses as it can sprayed onto walls and later can be covered with plaster. It is sprayed on walls with small hose with container. It expands after being sprayed making is perfect for cracked walls. (Constellation, 2018)on Its U-value depends upon the thickness for example 150mm foam has 0.11 W/m^2 and 175mm foam has 0.16 W/km^2 U-value. Lower the U-value better the performance of material is. (Cooper Insulations, 2018)

Figure 46: Spray Foam Insulation (Corporation C. , 2010)

b) Fiberglass Insulation:

Fiberglass insulation is composed of extremely fine glass fiber with reinforced plastic and this insulation is available in form of blanket or loose fill. Fiberglass in excellent insulator and it does so by trapping air packets inside. (Retrofoam of Michigan, 2018) It is relatively inexpensive and can be used in floors, roofs and walls. It has cancerous binding material and it compresses easily which leads to high U-value. (Constellation, 2018) U-value of 1 inch fiber glass insulation is 0.45W/km^2 . (Beach, 2018)

c) Rockwool Insulation:

It is more solid than fiberglass insulation. It is composed of molten mineral and rock materials like slag and ceramics. One of its very important property for which its being used is its high fire and heat resistance. It is very sustainable material almost 90 % of material is pre-consumed material. (Huber, 2018) One disadvantage of this type of insulation is that it can retain moisture. U- Value of rockwool insulation is 0.33W/km^2 with 1-inch thickness, making it slightly better than fiberglass insulation. (Beach, 2018)

d) Rigid Foam Insulation:

Rigid foam insulation or commonly known as board insulation is composed of polystyrene, polyisocyanurate (polyiso), and polyurethane. It can be used to insulate almost any part of house. Mostly its used in cavity walls or for concrete blocks insulation.

It is almost two times more effective than any other material with the same thickness. (Norton, 2018) It has fire and moisture resistant properties. It has U-value of 0.2W/km^2 with 1-inch thickness. (Building with Chemistry, 2018)

4.4.2.2 Green Roofs

Green roof can be described as sustainable initiative in modern day, but green roofs has origins dating back to hanging gardens of Babylon. Green roofs provide series of environmental, social and economic benefits. Green roofs can be further categorized into two, first is intensive and second is extensive. Intensive green roof includes small trees, plants and shrubs with 30cm max root depth and add considerable amount of load of structure and extensive green roofs usually consist of green blanket of grass and this is installed in areas where green roof is not accessible except for maintenance. Extensive roofs are specially designed keeping in mind the environmental benefits. (Detrich B. Allen, 2007) Green is more than just plants on roof. There are many layers of different material chosen and placed carefully with special order to achieve sustainable benefits.

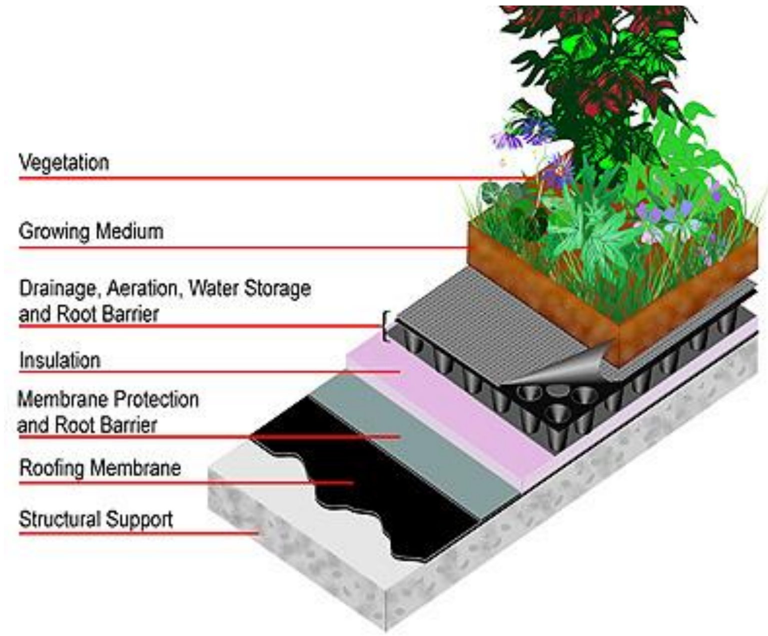


Figure 47: Typical Green Roof Construction Layers (Detrich B. Allen, 2007)

Above picture shows the layers of green roofs and there are many possible arrangements but important part to discuss here is how such initiatives benefits the buildings. Green roofs are gaining popularity over conventional roofs because of followings advantages.

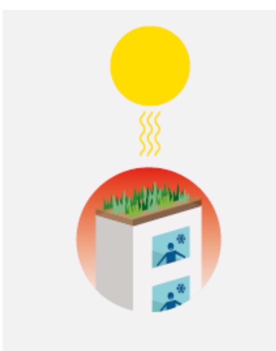
a) Stormwater Management:

Stormwater management emerges as one of the differentiating factors between conventional and green roofs as it can retain 75% of rainwater and rest slowly becomes run-off water. It is a good choice in areas with long cold and snowy seasons. Green roof retains water up to its maximum limit and rest it percolates but while green roof layer is saturated all the sediments and particles gets trapped in the soil layer leaving water cleaner and this way water used for plants is less consumed from non-renewable sources as green roofs can be watered from rain so often. (MacDonagh, 2018, pp. 4-6)

b) Air Quality

High rise buildings often create problems of heat island by reducing wind speed and pollutants can be trapped in the air for longer period and that creates air pollution specially CO_2 particles. Green roofs in such areas where there are no or less trees and green spaces are available on ground, can benefit in reducing this type of pollution. (MacDonagh, 2018, pp. 25-30) Plants and trees absorb CO_2 from traffic directly cleaning the air and through photosynthesis not only green roofs help in absorbing CO_2 but they create oxygen in process. (Carpenter, 2014)

c) Thermal Comfort:



One of major benefit of green roof is its capacity to absorb energy and create thermal comfort indoor environment thus saving amount of energy spent by active systems to create optimum indoor temperature and humidity. Heat island effect is one of major drawbacks of conventional roof specially in cities where roofs absorb a lot heat from sun and then radiate it while green roof will not only radiate zero energy but also absorb a significant amount of heat and transfer very less to indoor from roof. (Detrich B. Allen, 2007, pp. 5-10)

According to one study done in Ottawa, they have compared the heat gain and energy spend to moderate the indoor temperature between a conventional roof and green roof. The average daily energy demand for space conditioning due to the heat flow through the conventional roof was 6.0-7.5 kWh/day (20 500 – 25 600 BTU/day). However, due to the green roof decreases the heat flow and the average daily energy demand was less than 1.5 kWh/day (5 100 BTU/day) which is a ***“75 % reduction”.*** (Baskaran, 2018)

d) Urban Food Production & Garden spaces:

All the progressive cities have one thing other than strong economy in common and that is livability of city and the quality of life city offers and that can be measured by the open and green spaces city has. Green spaces are not just recreational space but also a mean to create viable and better environment. One more potential these spaces present is that we can grow vegetables and other crops and produce enough food which can contribute not only to environment but also to the economy. It also gives adequate green spaces with in congested and high dense cities without disrupting existing structures(Carpenter, 2014).

4.4.3 Façade Openings

Façade openings or windows are the charging points in passive design systems and what important is, how to control them and use them in our favor. Environmental conditions are not same everywhere and not same during the whole year so, it’s the design of windows is very critical for architects. From orientation of windows to the size and from shading devices to type of glazing used for windows, all defined the performance of windows.

4.4.3.1 Window Glazing:

Single glazed windows have only one glass pane between indoor and outdoor making it inefficient to control indoor environment because there is not enough insulation. Double glazed windows have two panes of glass with air-gap or insulation gas in between. Glass thickness varies from 3mm to 10mm and air or any other gases used between two panes provides enough insulation needed. If environmental conditions require we can used triple glazed windows. (Next Generation Glass, 2018) Double or triple glazing works better because there is trapped dry air or gas in between glass panes and through the process of convection heat exchange is reduced.

Double glazed window has U-value of 1.4W/m^2.k and its typical composition is 6mm glass panels on sides with 16mm air in between and if we put ***"Argon"*** in between rather than air we can get U-value of 1.1W/m^2.k. (Saint Gobain, 2018) So we can always improve window performance through different means. In the following section we will look at different glazing techniques available.

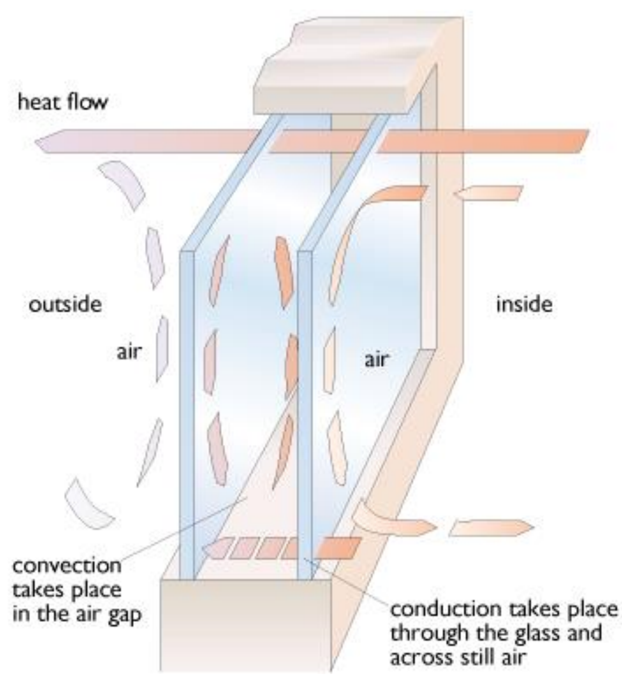


Figure 48: Convection and Conduction Mechanism through Double Glazed Window (Open Edu., 2018)

a) Glass and tints:

Typical clear glass is transparent, and it has no significant resistant again heat gain or loss, but this can be improved by introducing tints in the glass when it is in molten state. It is an absorbent material and available in glass and plastic glazing. Because of its absorbing properties some amount of incident heat can be absorbed and rest can be transferred to interior space. Absorption depends on tint and thickness of glass.

b) Refractive Glass

Tinted glass can reduce a shading coefficient to about 0.65. With the help of other glazing technologies such as reflective surfaces and coatings, shading co-efficient and coolness factor can be increased because glazed shining surfaces refract some amount of direct sunlight decreasing direct sunlight in interior spaces. Pyrolytic (hard coat) is a single layer of metallic oxides applied while the glass is still in a semi-molten state and it produces the refractive layer on glass.

c) Plastic Glazing

Plastics glazing's were originally used for safety glass. They are less brittle and lighter in weight than glass, and they block essentially all UV radiation. There are many types of plastic glazing for example "***Acrylic glazing***" which has good light transmittance. The other examples include ***"Olycarbonate"*** and ***"Fiber plastic glass".*** (Brian M. Deal, 1998)

d) Vacuumed Glazing

In this system of glazing a vacuum is created between two panes of glass so there is no heat exchange through the process of convection. Conductive and convective heat flow created by the gas between the two glass panes are reduced by the vacuum. (W.J.Hee, 2014, p. 341)

4.4.3.2 Dimension of Windows:

Assessment of opening or window area is necessary during the design stage keeping in mind the energy efficiency of system. In sustainable design we want to use daylight as much as possible to cut down the energy consumption from non-renewable resources, so it is important to realize that bigger glass areas let larger amount of direct sunlight in and causes indoor air to heat. It could be good thing is winters and in cold areas but in summers specially in hot climate areas it could be a problem and in cold areas sun is not always out which can also cause problems so with respect to the size, decision should be made very precisely.

There are many investigations done to find the ideal window sizes which ensures the maximum efficiency of energy.

CBISE suggested minimum area of windows for view to minimize the energy consumption and that suggested limit is 30% max.

Maximum Depth of wall (Distance from window wall)	Minimum area of Window in wall (%)
<8m	20
8m – 11m	25
11m – 14m	30
>14m	35

Table 7: Maximum Area of Window in Wall w.r.t Walls Depth (Eneder Ghisi, 2004)

An experiment to find the compatibility ratios between window sizes required for view and for energy efficiency in the city of Florianopolis. Following graph shows the energy consumption against window areas by computer simulation program DOE-2.

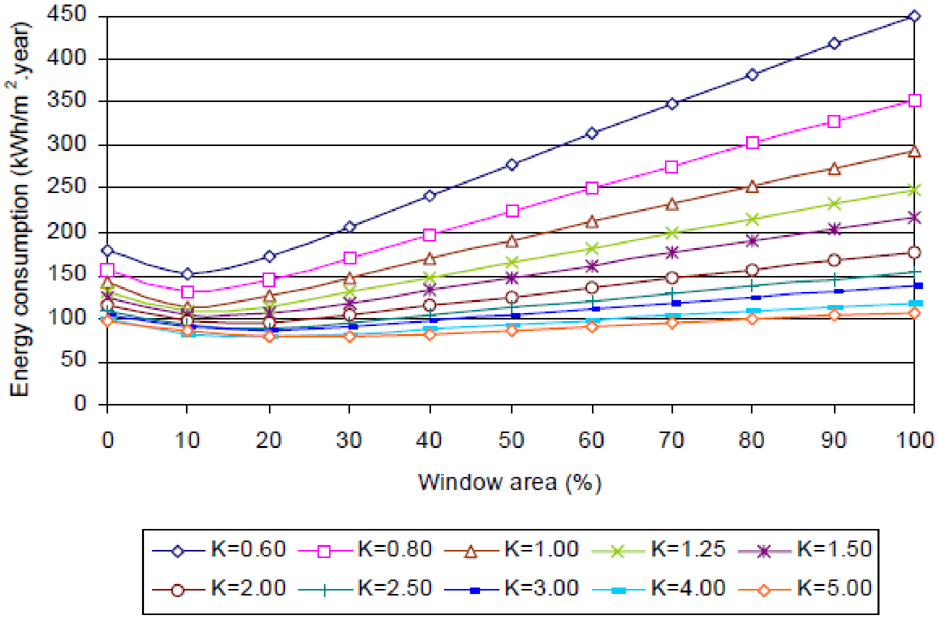


Figure 49: Relationship between Energy Consumption of Space and Its Opening Area (Eneder Ghisi, 2004)

K = WD/[(W+D)/H] and room ratios of 1:1, 1:1.5, 1:2, 2:1, 1.5:1, were used.

K	2:1				1.5:1				1:1				1:1.5				1:2			
	N	E	S	W	N	E	S	W	N	E	S	W	N	E	S	W	N	E	S	W
0.60	11	15	18	10	11	15	20	10	16	19	21	12	20	25	25	15	25	26	31	19
0.80	11	15	19	11	12	16	21	11	17	19	22	12	21	26	26	16	27	27	33	19
1.00	12	16	20	11	13	17	22	11	18	20	24	13	22	27	28	17	28	29	36	20
1.25	13	17	20	12	14	18	23	12	19	21	25	14	24	28	30	17	29	31	38	21
1.50	13	18	21	12	15	19	24	13	20	22	27	15	25	29	32	18	31	32	41	21
2.00	15	20	23	14	17	20	26	15	21	24	30	16	27	31	36	20	34	36	47	23
2.50	16	21	25	15	19	22	28	16	23	26	33	18	30	34	40	22	37	40	53	25
3.00	18	23	26	16	22	24	30	18	25	28	36	19	32	36	44	23	40	43	58	26
4.00	21	27	30	19	26	28	35	21	29	32	43	22	37	41	52	27	45	50	69	29
5.00	24	30	33	22	30	31	39	24	33	36	49	25	42	46	59	30	51	58	81	33

Table 8: Ideal Window Sizes w.r.t Room Ratio (K) (Eneder Ghisi, 2004)

It is evident from table that many ideal window areas are smaller than the minimum window glazed areas. Ideal window area (IWA) depends on many factors including efficiency of lighting and heating system, window glazing typology and envelop materials. By the experiment we can learn that ideal window size is not an exact size, but we can calculate optimum window area by considering location, orientation, façade design, glazing typology, envelop material, shading devices and efficiency of lighting, heating and cooling systems. (Eneder Ghisi, 2004)

4.4.3.3 Shading Devices:

Sun shading devices inhibit solar radiation (i.e. block, allow) into the building and they are used internally or externally. They can also be made between internal and external spaces. They can be fixed or mechanically operated (dynamic façade) operable according to the needs of occupants and sun movement. Shading devices can also be natural elements like tall trees and plants.

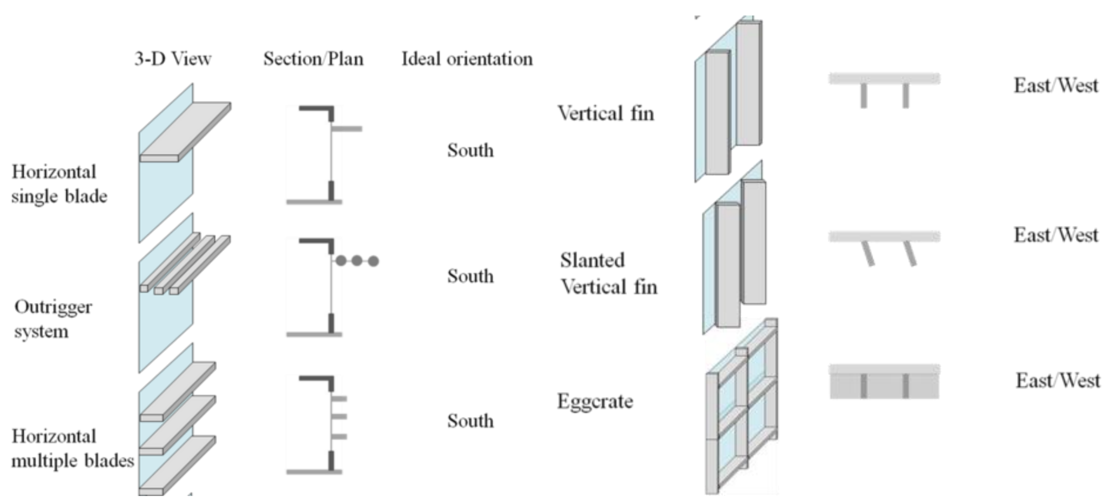


Figure 50: Different Typologies of Shading for Windows w.r.t to Orientation (Bem Book, 2018)

There are mainly two types of shading devices first is simple internal shadings like drapes, curtains, louvers blinds, blackout blinds etc. These shading devices are used almost everywhere the second type which is external is more important and it has further three categories, horizontal, vertical and egg crate. (Sealey, 1979, pp. 45-50)

a) Design of Shading Device:

1. Understand the sun path.
2. Select the typology of shading device.
3. Calculate the design dimensions.

Third step is the most important step and in the following section we will discuss how to decide the shading device dimensions. We must calculate the "***horizontal shadow angle"*** for vertical shading devices and ***"vertical shadow angle"*** for horizontal shading device. ***HSA*** is the angle between normal of pane and azimuth of sun. ***VSA*** is angle between ground line and altitude of sun.

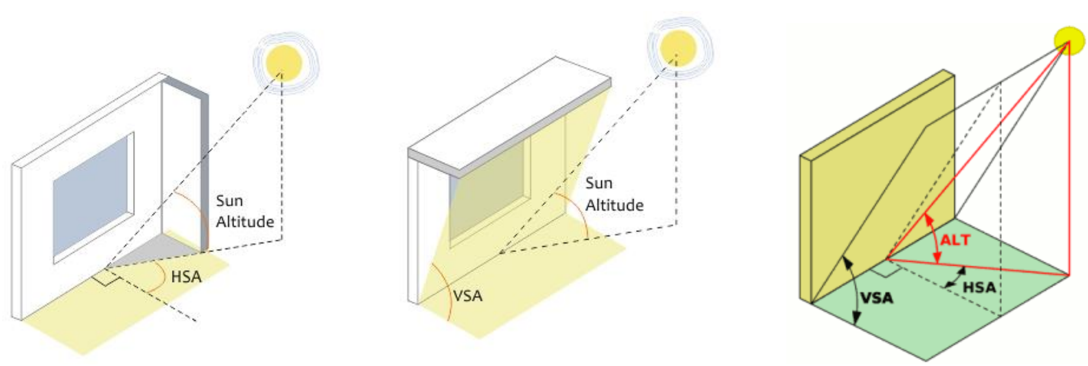


Figure 51: Shading Devices Lengths and Respective VSA, VHA (Saifelnasr, 2015)

tan (VSA) = tan (altitude) / Cos (HSA)…………… (a)

tan (HSA) = tan (altitude) / Cos (VSA)………….. (b)

Depth = Height / tan (VSA)…………………………. (c)

Width = Depth / tan (HAS)…………………………… (d)

Height (H) is being referred to the distance between shade and sill then depth and width for each side of window can be calculated by above formulas. (Saifelnasr, 2015)

4.4.4 Centric Planning:

Centric planning or in other words we can say grand entrance, focal courtyard, sheltered space with semi-public nature. Most often it becomes the core of design and whole planning revolves around the centric open element. These Centric courtyards, with or without conventional roof or opening have following effects on building sustainability. (Zhou, 2011)

- Natural lighting through central courtyard makes it possible for light to access all areas of buildings and save energy consumed by lighting.
- Pre-heating of indoor air though sunlight accessible by atrium is possible saving huge amount of energy on heating in winters.
- Facilitates the circulation of air and hot air from inside goes out of building through open spaces of atrium in the roof keeping indoor temperature low.

Figure 52: Air Circulation through Central Atrium (Ratcliff Architects, 2018)

With proper use of techniques, planning and materials all mentioned points are efficiently achievable. Efficient heating and ventilation through the building can be possible through appropriate volumetric design of atrium. The shape and orientation of atrium plays important part for proper airflow through the building and proper solar heat gain as passive measures. (Vassilev, 2015)

4.4 Water efficiency in buildings:

Water conservation is basic principle of sustainable development because after energy water is one of major source which needs our attention in term of sustainable and efficient use. It can be achieved by using efficient and smart system and by using alternative sources (recycling and reusing). There are many methods and technologies through which we can minimize the use of water in buildings. In the following section of chapter, we will discuss those methods.

4.4.1 Rainwater Harvesting:

In simple terms collection of rainwater falling on earth surface is called rainwater harvesting. (Sheth, 2017)Rainwater is efficient source of water specially in rainy areas. Most of rain water goes to waste as run off but this water can be used for many purposes in the building.

- In the green landscape areas of buildings, it can be used to water plants and grass.
- Rainwater can be collected and stored to be used in cooling or heating systems of building.
- Rainwater can also be used and reused in bathrooms for flushing.
- With the proper recycling techniques, rainwater can be able

Rain water harvesting consist of three stages collection, distribution and storage. Collection area is almost all area of building (specifically roof area) and some of hard area on ground. Distribution system consists of pipe lines from catchment areas to storage area. The diameter of pipes depends upon rain intensity and catchment area. (Oindrila Das, 2015)

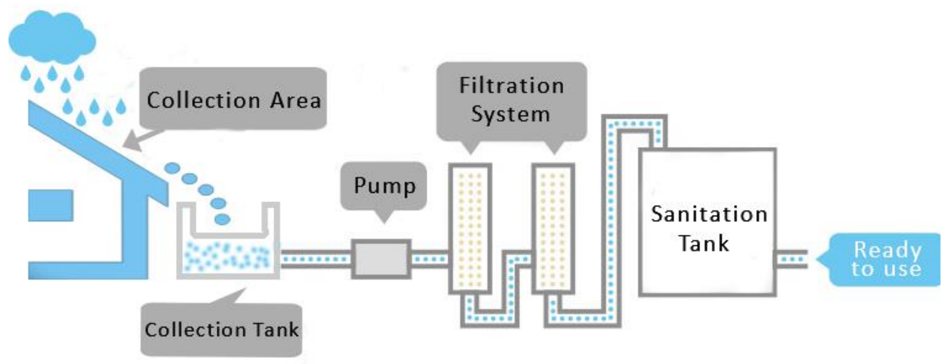


Figure 53: Rainwater Collection System (Clean Water, 2018)

4.4.2 Water Efficient System:

In houses and in commercial buildings there are two main points where mainly water is used, kitchen and bathrooms and if these two are equipped with efficient and smart appliances, the water usage can be minimized. According to a study almost 50% of household water is consumed by shower and toilet flushes and if we control water consumption of WC and shower we can save up to 30% of that water.

Normally 4 to 5 liters of water is used per flush but with the used "***Vacuumed flushed toilets"*** this amount can be reduced to 1-1.5 liters. Vacuumed toiled used air pressure to flush the waste. (Sheth, 2017)

"Dual flush toilets" have flush tanks with two flush buttons which gives users a choice for short flush when needed and other button is for normal flush. Shot flush can save up to 2-2.5 liters per flush. (Weber, 2018)

"Low flow fixtures" are essential part of any sustainable systems. Almost more than 50% of water goes unused when tap is open full and continuously running. These fixtures reduce the flow of water, ultimately cutting down water consumption.

Now days more efficient dishwashers and washing machines are available in market which use 40% less water and saves 30% energy. By using such appliances, we can achieve the level of water efficiency we need from consumer market. (Oindrila Das, 2015)

4.4.3 Water Recycling:

Water recycling has great potential in domestic as well as commercial industry. About 70% of water used is grey water. Grey water is used water from showers, hand basins, dishwashers, kitchen sinks, laundry machines and car washing. According to an estimate an average household produce 140liters/day grey water and it can be recycled and reused for different purposes in the house.

- Recycled water can be used to flush the toilets.
- It can be used for irrigation of landscape areas and green roofs.
- After proper treatment grey water from commercial areas can be used in cooling towers.

Grey water recycling unit removes chemical elements of detergents, soaps etc. from it and food particles, oil and grease as well. The dual piping system should be installed which can separate the recycled water from potable water. Blackwater from WC is required high quality filtration, disinfection and activated carbon treatment which can be used for flushing toilets and irrigation as well. (Oindrila Das, 2015)

4.5 Conclusion:

Keeping in mind all the challenges we are facing and designing our buildings to tackle those challenges is the way forward. A lot of work in this regard has been done and a lot is to be done. With the advancement in technology we should adapt new solutions at our disposal. Sustainable and green buildings are the future, so from the preliminary phase of developments we should decide how new building won't be a burden on system, rather it will be helpful in making future a better place and be the guideline for future projects. There are many buildings which adopt these techniques and working efficiently, so all we need is to learn from their example and work towards better future.

Chapter 5 Sustainable Buildings | Case Studies

5.1 Introduction:

In the previous chapters we discuss about the sustainable developments on urban scale and how through the adoption of different techniques and long-term planning strategies sustainable goals can be achieved. Human beings spend 80 to 90 % of their lives indoor so in order to achieve sustainability and eco-friendly cities, buildings play the crucial role in order to do so and there are slightly different approaches to achieve sustainable goals for example there are smart buildings which use active system as well as passive systems in order to achieve sustainability but smart buildings use active systems in a most efficient way possible and other advanced available technological solution to produce and efficiently use resources for operational life cycle of building. The other concept is green buildings which uses nature as tool for eco-friendly environment with minimum carbon footprint in construction and in operational phase. Self-sufficient houses are also a reality which means living off the grid with all means available independently. In this chapter we will try to analyze few of these physical examples and learn from different experiences, their construction techniques, their life cycle performance and more importantly their working principles.

We studied and analyzed many buildings before selecting the following three examples as case studies the first building which is Genzyme Centre in Boston is very good working example of smart building using a combination of active and passive systems. Earthship houses are off the grid living concept which deals with extreme challenges in this regard and last example is Rene Cazenove apartment building is simple but smart in its design and strategical approaches.

5.1 – Genzyme Centre Boston, USA

Genzyme center is one of few buildings in USA which has earned LEED platinum certification. Genzyme Center is located at 500 Kendall Street in Cambridge, Massachusetts. The building is 12 story for Genzyme corporation and international biotechnology company. More than 900 employee works in the building.

5.1.1 Facts and Figures:

Building type	Commercial Office
Construction	New (2001 - 2003)
Area	32,000 sqm
No. of stories	12
Rating	LEED's Platinum (52 Points)
Architect	Behnisch, & Partner, Inc.

Table 9: Facts and Figures (Genzyme Center) (Toffel, 2010)

5.1.2 Design Objectives:

- The designers of building focused on five LEED's five main objectives of green buildings.
  a) Water efficiency.
  b) Energy efficiency.
  c) Sustainable development.
  d) Sustainable materials.
  e) Indoor environmental quality.
- Building is expected to have 42% lower energy cost.
- Renewable energy resources for active systems.

- 32% less water usage in comparison to other conventional buildings.
- Almost (90%) work places with natural light.
- Zero or minimum waste production.

5.1.3 Strategies to achieve objectives:

Sustainable Materials: Most of the products used in construction are organic or made from recycled materials and are low or free volatile compounds. 23 % of materials used had recycled content in them for example steel, aluminum, dry gypsum walls and ceilings. Locally produced materials have low carbon footprints which were used there. For structural integrity of building, concrete slab and columns were used but filigree concrete slab was used for its environmental benefits. It is two-inch pre-stressed pre-cast concrete with polystyrene inside partially where less strength is needed which reduces the amount of carbon foot print, weight of slab decreasing the number of columns to support the slab. Slab has a thermal mass which helps to reduce the heat gain. Green roof is also part of strategy which reduces more heat gain from roof and reduces CO2 emission. Urea urea-formaldehyde-free wood composites were used to avoid many health-related risks. Wood with wheat chips was used which is by-product and recyclable. Low or VOC free materials were used (Dara Olmstead, 2018)

Natural light: 90 percent of work places have natural light to reduce the amount of energy consumption on lighting. 46 percent of envelop is double glazed glass which allows natural light to come in. Four techniques have been used to manage. First is “U-shaped perimeter blinds that reflects the light on to the metallic ceiling to increase lighting and reduce glare. The blinds automatically tilt according to sun direction and close at night. The other thing they introduced was Heliostat on the roof to reflect the light through atrium to increase the natural light in buildings. Seven Heliostat track sun movement and the atrium can also be closed when sun is too strong and direct sunlight is to be avoided.

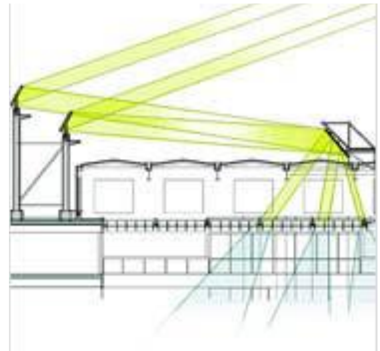
 

Figure 54: Roof Mounted Prism to Reflect Light in Interior Spaces (Toffel, 2010)

The distribution of light is further enhanced using more than 700 prisms arranged in way to reflect light into the building and light wall of atrium with reflective surface. Wall is composed of aluminum panels which allows light to pass through. (Toffel, 2010) Sensors are installed to make sure lights are off when employee leave the room and it also turn to “soft-off” mode when day lighting is enough. (Dara Olmstead, 2018)

Heating and Cooling: Building has heating and cooling system operating on low-grade waste steam system for heating and cooling instead of electricity which reduces the Co2 emission and building is cooled by stack effect through atrium. The hot air goes up through the atrium and cools down the building.

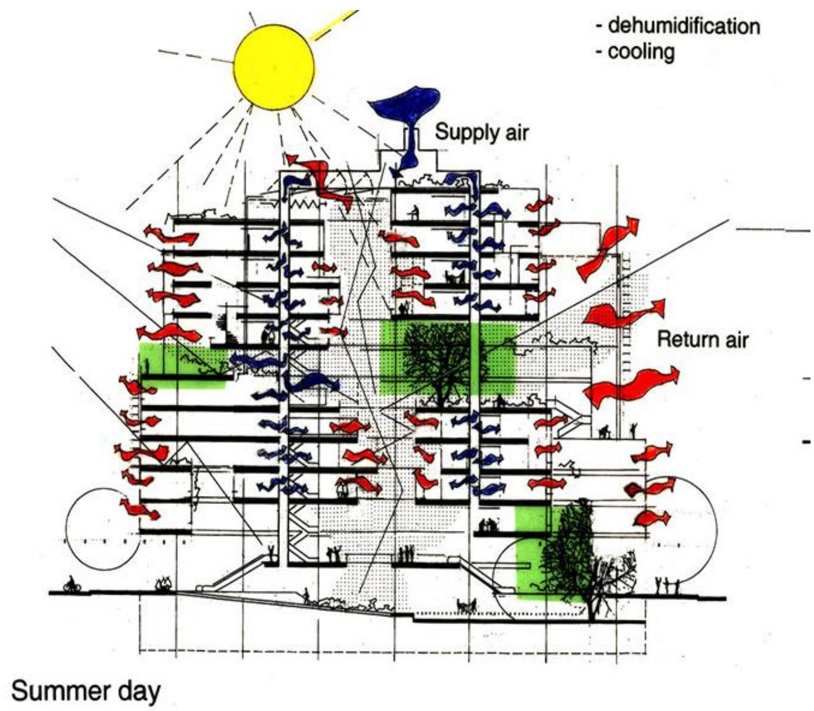


Figure 55: Air Circulation through Building Atrium and Facade for Summer Day and Day Lighting (Partners, 2018)

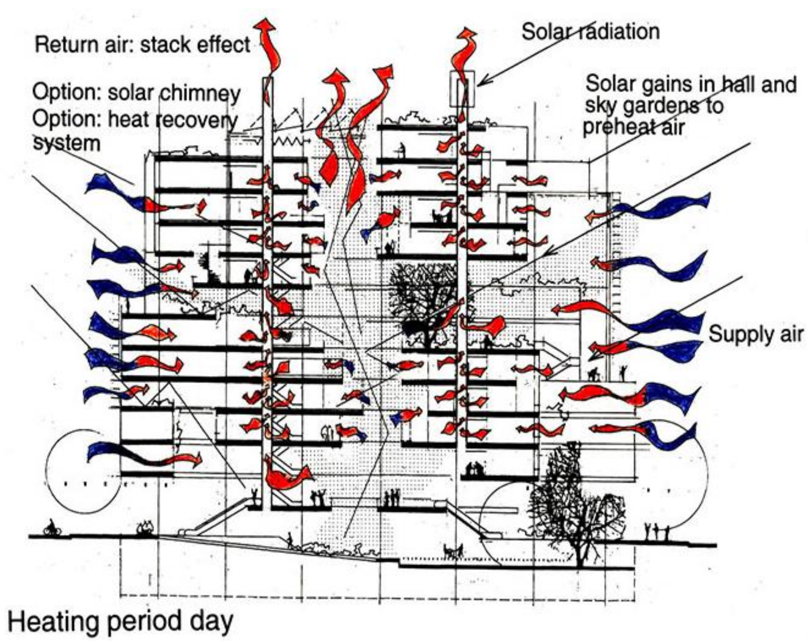


Figure 56: Passive Heating Approach for Building in Winter's Day (Partners, 2018)

Offices receives their supply air from buffer zones (solar radiation already pre-heats the air in buffer zones) and through façade-integrated flabs. During times with moderate air temperature window ventilation is possible and if more heat is needed it is provided by duct systems. (Partners, 2018).

Logia is double glazed glass which covers 32 % of façade (four feet long to provide better insulation) and its provides tempered space using solar heat radiation and ventilation flaps. (Corporation G. , 2018)

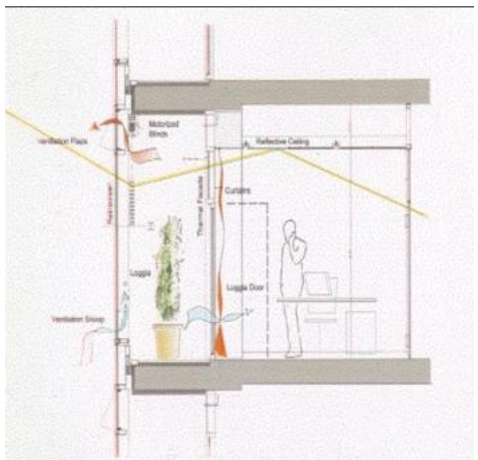


Figure 57: Double Glazed Window Configuration (Loggia) (Partners, 2018)

Integrated planning of open and closed spaces, atrium, intermittent gardens are breathing spaces for building and helps in ventilation of buildings. Roof gardens also reduce heat gain from roof.

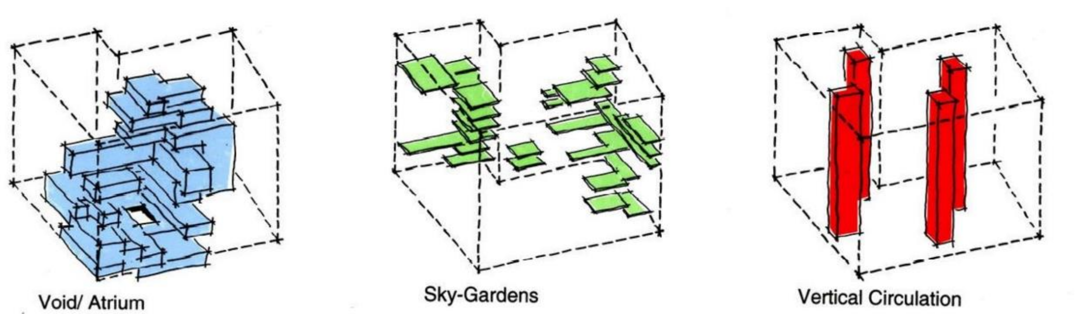


Figure 58: Conceptual Space Configuration of Open & Green Area (Partners, 2018)

Renewable Energy Sources: All the energy consumed in Genzyme Centre is from renewable resources and building has 1650 ft^2 of solar panels which produces 24,00 to 26,400kwh yearly and its beak output is 20kW. All other energy is purchases from outside. (Dara Olmstead, 2018)

Water efficiency: Water efficiency is achieved by vacuumed urinals and duel flushed toilets (There were no duel flush toilets at that time in USA, so they imported it from Australia). Sensor based taps to reduce the usage and low flow taps are used to increase efficient usage. Rain water harvesting on rooftop and being used in cooling tower also reduces the demand of water. This building saves 500,000 gallons of water per year (Commercial Real Estate Development Association, 2018)

Building Management System: A complex, specifically designed management system of 5000 controlled points manages the efficient use of energy in terms of lighting, heating and cooling and other miscellaneous uses. System automatically shuts off the HVAC system if window is open and reduces the air circulation when room is not occupied. It also monitors the availability of light available in the room and readjust the lighting. These smart systems are important part of sustainable development and energy saving methodology. (Dara Olmstead, 2018)

5.1.4 Lesson Learned:

Building energy management systems is one of the most important and integral part of smart sustainable systems with such high-tech buildings. Relying not only on high-tech smart solutions but also integrating green passive approaches to minimize the demand of energy. Storm water harvesting, and other water efficient techniques should be integral part of planning. Depending on the typology od building and use of space, designers should decide which is he critical issue and needs more attention in terms of sustainable solution like in this projects architects have given critical importance to the use of day lighting.

5.1.5 Conclusion:

Behnisch, & Partner, Inc won the competition because they offered a solution to problem and rather than expanding their experimental horizon they focused on the most pressing issues and everything came together in place from there. They have done a lot work for bring passive lighting solution as this is a working office ad people need lighting in each corner of building. Unconventional choice of materials with installations and central courtyard they bring natural light without compromising the thermal comfort of indoor spaces. Smart systems install monitor each movement of occupants and select the most efficient yet comfortable solution. Indoor open spaces and garden balconies provides ventilation and pre heated air when needed which is very smart solution to many problems. This is a good example of perfect combination of planning and technology.

5.2 Earthship Houses, Brighton UK:

Self-sufficient house design based on the idea of off-grid sustainable living. The idea was conceived by Mike Reynolds and few of such houses were built in Tao, New Mexico. In Brighton England, such type of houses is being built. Earthship are modular in design and a lot of variation can be done using the base idea. (Andrew Miller, 2015) These houses use natural systems to provide all utilities need for household. (Rockwood, 2014)

5.2.1 Facts and Figures:

Building type	Residential
Construction	2005
Area	125 sqm
No. of stories	1
No. of Rooms	5
Architect	Mike Reynolds

Table 10: Facts and Figures (Earthship Houses) (Rockwood, 2014)

5.2.2 Design Objectives:

Mike Reynolds have been working on this concept from 1970 and the design objectives are like any other sustainable green building, low carbon, self-sufficient, off the grid sustainable and ecological friendly buildings. These houses use natural means for all needed utilities for living. (Rockwood, 2014)

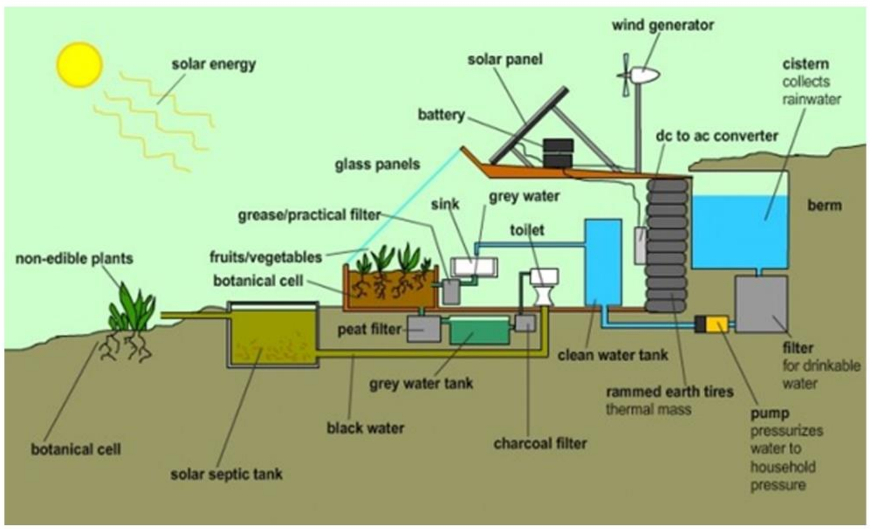


Figure 59: Earthship Housing Working Mechanism (Rockwood, 2014)

5.2.3 Strategies to Achieve Design Objectives:

Energy Efficiency:

Earthship like any other houses have electrical appliances and lighting system and they run of renewable resources which includes Photovoltaic cell, solar thermal system, wind turbine. PV panels of 18 x 62W Uni-solar electric panels with a peak output of 1116W, 900W Whisper wind turbine and 2 x 2m^2 solar thermal panels. The combined power generation is 20kW capacity. (Heun, 2007) Earthship houses are solar passive buildings. These buildings use the concept of thermal mass gain at back wall of house and glass front with 22^o angle at the front which allows the maximum heat gain in winter when sun is lower and reflect the light when sun is at highest position in summers. Thick walls used as battery for heat storage. (Eco Open Houses, 2018) (Tea Spasojevic-Santic, 2016)

Water Efficiency: Earthship has no main connection for water supply and the concept is that water is harvested for natural resources, recycled and reused for four times in the system. First rainwater is collected and treated to a safe limit for drinking and in washrooms. Then grey water from sinks and bathtubs will be used to water plants. Grey water in flushing the toilets and in the last phase black water and sewage feeds the plants retreating it through soil and making it harmless again. Area of roof and annual yearly rainfall can collect 50 thousand litters of water and this is same amount one person uses average per year. Dual flush toilets have been used to minimize the water usage. (Andrew Miller, 2015)

Greywater recycling is being done by ***"Nylon Stocking Clamp"*** at the end of pipe to filter the grease and other particles from sink and shower. The *"Botanical Planter"* are designed to recycle the water though natural process of transpiration, evaporation, oxygenation reducing the level of bacteria and removal of other particles. 2.33m2 of planter is needed for each plumbing fixture. There are two greywater planters with the area of 12.75m2. The planters are made up of layers of up to 450mm of 20mm pea shingle, 75mm sand and 150mm of topsoil to maximize the efficient treatment of greywater. (Eco Open Houses, 2018)

Reclaimed Materials: Almost all the material used in the Earthship houses are recycled, reclaimed materials from wood to tyres, cans, bottles and rammed earth. Tyres are filled with rammed earth and places at the back end of house to act as shear wall and to create the thermal mass effect its depth is 1.5m and then there is layer of plaster. Rockwool insulation (600mm) in the ceiling. (Tea Spasojevic-Santic, 2016)

Type	Description	U-value
Floor living	100mm concrete	3.355
Floor, Greenhouse	25mm sand, 25mmflagstone	3.904
Glazing (external, internal)	Double glaze, 4mm clear with 16mm air	2.715
Roof	0.4mm steel, 200mm Polyisocyanurate, 25mm softwood	0.110
External Wall	1600mm earth, 25mm adobe render	0.613
Internal wall	50mm concrete	3.382

Table 11: Construction Element and Respective U-values(Howard, 2018)

Food growth: One of very important and conventionally different from all other projects of this kind is indoor gardens for food production. Greywater is being used to grow vegetables. It in the veranda area facing south and it use heat gain to grow vegetables efficiently. (Bindu agarwal, 2017)

Figure 60: Indoor Vegetation with Direct Sunlight (Bindu agarwal, 2017)

5.2.4 Lessons Learned:

Sustainable reclaimed recycle materials play an important part in decreasing the CO_2 emission not only in early phase but also later in operational phase. Unconventional construction material can be used and achieved the same and even better if deal efficiently, results. Off the grid living is possible with care analysis of resources and efficient usage. Selection of recycling techniques is important with respect to objectives. Passive systems of buildings are only way forward. Locally available abundant materials should be used. Whole system and collection of technological intervention should work as a system supporting each other.

5.2.5 Conclusion:

From conceptual to experimental phase, the Earthship houses are very close to becoming a reality. Few of such house have been built in Brighton, UK and are in analytical phase to assess the performance. It's a good one step which choses a lot of practical and few radical steps to achieve its targeted goals. Some critics suggest that these targets might be too ambitious but in my opinion with right strategical approach, awareness and willingness of ownership these houses could be a norm.

5.3 Rene Cazenove Apartments, California USA:

Rene Cazenove is the one of very few sustainable residential projects in san Francisco transformative Transbay Redevelopment area. This is permanent home to formerly chronically homeless residents, many who have physical and mental disabilities. Apartment building based on the concept of mini-living and provides its residents social educational and medical facilities. It is located at 25 Essex Street San Francisco, California.

Figure 61Rene Cazenove Apartments, California USA (Community Housing Partnership, 2018)

5.3.1 Fact and Figures:

Building type	Residential
Construction	2013
Area	6942 sqm
No. of stories	7
Architect	Leddy Maytum Stacy Architects
LEED Rating	High Gold

Table 12: Facts and Figures (Rene Cazenove Apartments) (Morancy, 2018)

5.3.2 Design Objectives:

The main objective behind the design was to combine the social, environmental and financial stability. Design team focused to bring all challenges and their solution to table addressing three main key sustainable goals. Long term efficient and cost-effective use of energy and water are top on the list. Social integration to create healthy environment for disabled people. (Architectmagazine, 2018)

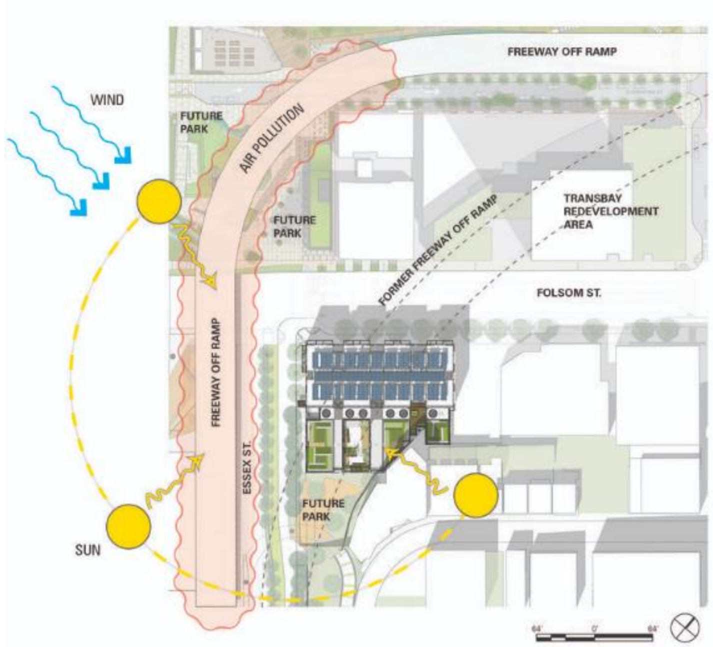


Figure 62: Site Map and Sun Orientation (Morancy, 2018)

5.3.3 Strategies to achieve Design Objectives:

Energy Efficiency and Cost reduction Measurement: Reducing energy cost in the installation phase and long-term operational phase, was critical goal for designers because of low income residents and non-profit owner. Cooling inside the building is provided by the natural ventilation, ceiling fans and operable windows to allow desired ventilation rather than air conditioning which reduces the cost of cooling. Solar hot panels running along the solar canopy are used to provide hot water. Low ampere high efficiency lighting is used inside the building and these lights are recommended to use during night. During day maximum light is gain through direct sunlight. The rooftop solar panels produce significant amount of energy (net EUI of 23.9 kBtu/sf/yr) in addition to the solar hot water panels Along with the other energy efficiency strategies.

Figure 63: Working Mechanism of Building regarding Water, Light and Air Circulation (Morancy, 2018)

Water Efficiency: Storm water retention tank is located at underground beneath the courtyard which manages the surge of storm water. Low flow fixtures with dripping irrigation allows the efficient use of water. All toilets are attached to municipality recycled, reclaimed water. Through these methods total of 25 to 25% less water is used then conventional buildings. (Cohen, 2018)

Air and Lighting: 96% of building areas have access to day lighting. The orientation of building and big windows helps with this purpose. On ground floor the lighting is accessible through central patio. Fresh air is provided continuously to all habitable spaces from the building roof where it is filtered. San Francisco's moderate temperature allows the use of ceiling fans combined with passive techniques of ventilation allowing 68% of building areas to be naturally ventilated. (Ecobuildingpulse, 2018) In the picture below blue color shows the natural ventilation and yellow color shows the natural light.

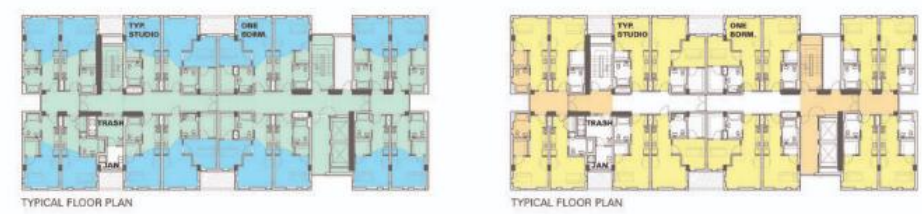


Figure 64: Access Diagram for Natural and Artificial lighting and Air Circulation (Morancy, 2018)

Materials: Material selection was not only based on sustainable selection of materials but also the need of residents. Low emitting materials and finishes were essential for the formerly homeless residents, many with health disabilities. Most of wood used was without formaldehyde. resilient flooring, ground concrete flooring, resin wall panels, and special hardware, Exterior materials were selected for longevity such as the integrally colored fiber-cement cladding which is used as rainscreen. (Cohen, 2018) Construction waste was handled carefully and 84% was diverted from landfills. (Morancy, 2018)

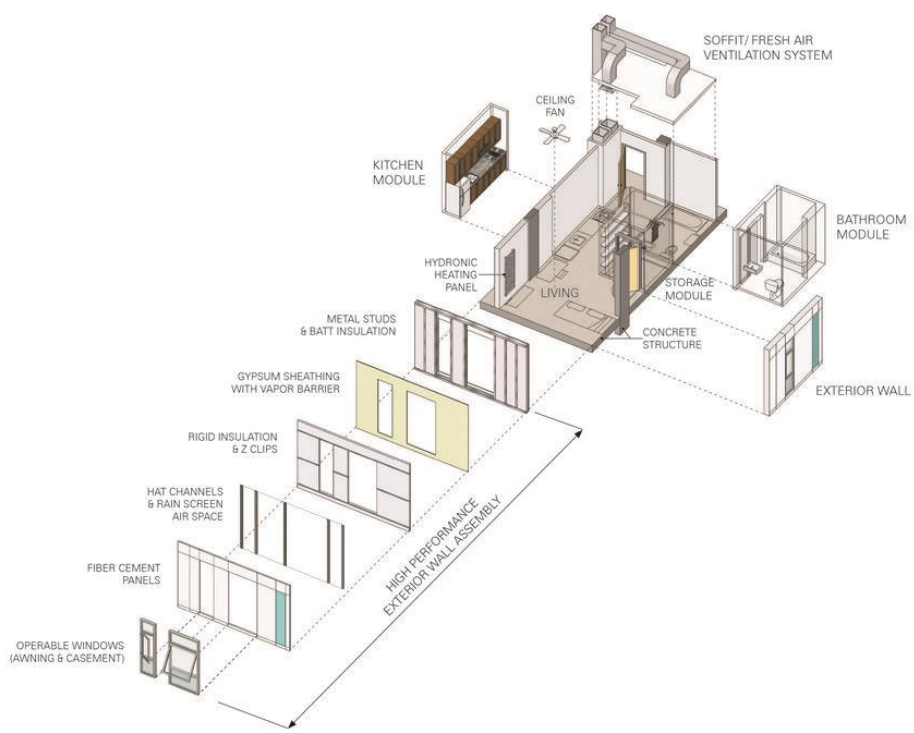


Figure 65:Construction/Material Details of a Housing Unit (Morancy, 2018)

Above image shows the layers of construction and typology of materials chosen to achieve desired sustainability level.

5.3.4 Lessons Learned:

Designing a building for targeted user should always be top on the list regardless of sustainable goals. Community involvement and social integration can be ensured though design of building. Selection of suitable technologies like in this project because of moderate climatic conditions no air conditioning is provided but they used low energy consumer fans and natural ventilation. Sustainable energy resources (PV panels) should always be on top of list. Use of day light through planning and material selection should be maximized without compromising the indoor thermal comfortable temperature.

5.3.5 Conclusion:

This is the example of mixture of simple technological solutions and planning approach. Smart choices in planning create less room of active system and thus creating sustainable environment for example the well-lit areas of building and operable windows to provide ventilation when needed. Residents of building well the core of the design and integration of community in building with integrated planning proves that. Avoiding unnecessary installation systems with more energy consumption was one of the most important choice made by architects and rather using passive system in combination of less energy consuming active systems. In my opinion this is the perfect example of how small smart choices can lead to sustainable performance of building.

5.4 The Edge Office Building Amsterdam, Netherlands:

"The Edge" often referred as the world greenest and smartest building is situated in Amsterdam. The office building has fifteen stories. The building has achieved the highest ever rating by BREEAM of 98.4 %. Smart cutting-edge technologies have led developers to achieve this status. From thousands of sensors to track motion, temperature, lighting and humidity to mobile app for building users are integral part of planning.

Figure 66: The Edge Office Building Amsterdam (Stutz, 2018)

5.4.1 Facts and Figures:

Building type	Office
Construction	2012-2014
Area	39,910 sqm
No. of stories	15
Architect	PLP Architecture Ltd (London) / OZ Architect
LEED Rating	Platinum (98.4%)

Table 13: Facts and Figures (Edge office) (Aftab Jalia, 2017)

5.4.2 Design Objectives:

"The ambition of the project was two-fold: to consolidate Deloitte's employees, previously spread around multiple buildings throughout the city, within a single environment; and to create a 'smart building', intended as a catalyst for Deloitte's transition into the digital age" (PLP Architects, 2018). Clients and architects of the project had clear sustainable goals to achieve in terms of energy efficiency. Use of active systems as efficient as possible with the help of smartest technology available should be integral part of design. All source of energy should be Renewable sources for each energy usage in building. (BREEAM, 2018)

5.4.3 Strategies to Achieve Design Objectives:

Energy Efficiency has been achieved by two renewable resources used for all the energy uses in building. One is "*solar energy*", for that solar panels has been installed on the roof and on the south façade of building which was only 1920sq.m but to meet the energy demand of building 2280sq.m of Solar panel in total were needed so other PV panel were installed in surrounding buildings. (Business, 2018) Other form of energy which they use for heating in winters is geothermal heating which is achieved by a aquifer bored into ground 130m below the earth zero level. (Aftab Jalia, 2017, p. 9)

Lighting and Ventilation is the most important feature that has been handled by the three companies together Philips, Mapiq and Schneider Electric. They have made custom LED lights panels powered by low power ethernet cable which acts as internet connected data hub with 2800 sensors. (Business, 2018)

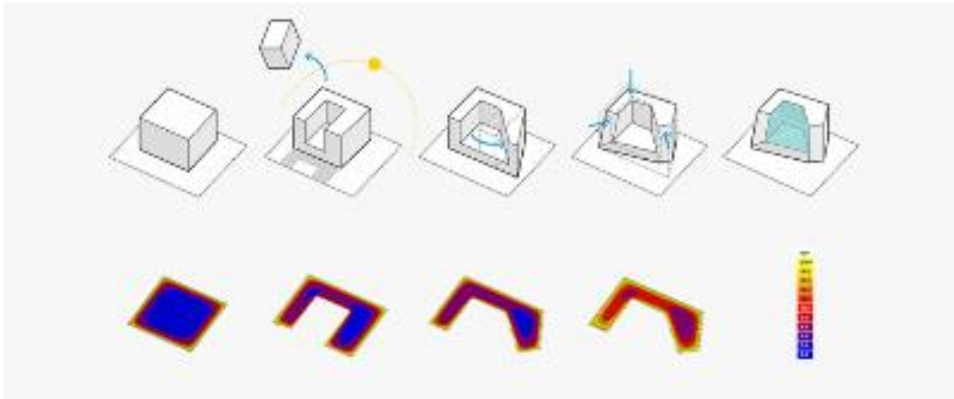


Figure 67: Heat Distribution Analysis According to Building Geometry (PLP Architects, 2018)

The big atrium in the middle with glass roof and walls provide enough and abundant lighting and air circulation to the offices which opens inside the building and all other spaces facing outside also get natural light and circulating fresh air with operable windows. Above image by PLP Architects shows how introducing atrium into space has affected the indoor temperature because of sun movement and air circulation. (PLP Architects, 2018) Ventilation system push the circulating air from room to the atrium for there its then pushed to rooftop through atrium opening.

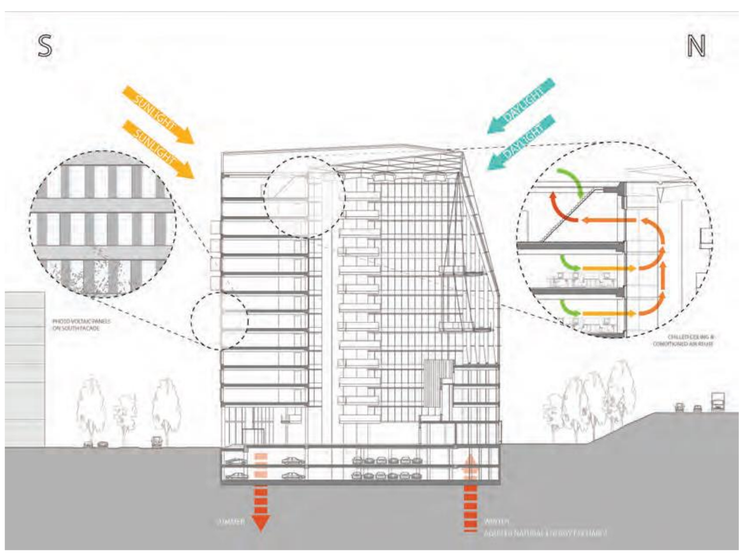


Figure 68: Sun Interaction with Building Envelop and Air Circulation Mechanism (PLP Architects, 2018)

Smart systems are the cardinal part of Edge building. 2800 sensors to collect data to optimize the use of energy and mobile apps for efficient and correct use of all facilities is key to achieve its sustainable goals. There are many car charging points which operates on solar energy. Mobile app connected lights and operating systems in offices helps occupants to use the lights and other systems more efficiently. Custom security robots and automated recognizing parking gates are few of smart interventions in Edge office. (Business, 2018)

Sustainable Materials and most importantly suitable materials for the right place is important and architects have delivered the task as needed. South side of building has thick concrete and brick wall to provide mass effect for heating. Double glazed glass on north east and west façade provides natural lighting and necessary ventilation. (Aftab Jalia, 2017) (Garofalo, 2018)

Water efficiency is achieved by rainwater harvesting and recycling the water for ecological garden irrigation and toilet flushing**.** (Garofalo, 2018)

5.4.4 Lessons Learned:

Taking user need and client wishes into consideration at the start of design and engineering. Assemble multifunctional and motivated teams from different background and specialized in specific task to achieve the level of efficient design. Involvement of product designers and suppliers to integrate better in design and in achieving the targeted results for products like in this case Philip was attached with the project and they design the interconnected smart lighting system. Smart systems at the tip of finger provides easy accessibility for occupants to control the indoor space.

5.4.5 Conclusion:

With clear vision and direction from the primary design phases of projects, the designers and engineers combined efforts delivered the targeted goals. The project was huge success because the products Specially lighting systems used in buildings are specifically design and installed according to the needs of this project. Innovative architectural solutions like circulation of worker with no designated work station was interesting points which helps to raise the space to workers ratio. The approach of design was not only to achieve sustainability according to the same old rules but through recognition of specific key issues and their solution which in my opinion serves the purpose of sustainability well like this was office building so indoor comfortable temperature, ventilation and light natural or artificial was necessary so the planners decided to make these things center of their design and everything fall in place.

Chapter 6 The City of Pisa | Analysis

6.1 Why Pisa?

In September 2015, the General Assembly of the United Nations issued the 2030 Agenda for Sustainable Development, with 17 objectives called Sustainable Development Goals, and which will have to be achieved by all countries who have signed the agreement by 2030. Moreover, according to National Energy Strategy plan-2020 (**Strategia Energetica Nazionale – SEN) there** has been a decisive plan to achieve sustainable goals set by EU Commission. In 2016 Ministry of Environment launched a new campaign of green and sustainable finance. Director-General for Sustainable Development, Francesco La Camera said that, it was clear that “a deep economic, social and environmental transformation” was needed to deliver both the Sustainable Development Goals and the Paris Agreement on climate change. (Deloitte, 2015)

Delrio law to define the boundaries of metropolitan areas and there are 14 of them which absorb 8,000 towns in them. Each metropolitan city has President of area (Mayor of city) and local council which will see to the administration of area. While this has been regarded as a historic change and aims to stop urban problem. It elevates the authority of cities with in political framework but at the same time fourteen metropolitan cities will become center of investment, infrastructure and strategical innovation hubs while leaving other small cities like Pisa behind. Because Florence is going to be the metropolitan region and its boundary will include Pisa so for cities like Pisa their role will not be that significant in terms of policy making. (D'ANTONIO, 2014) and there are already no strict laws in Tuscany region for sustainable development.

Figure 69: Italian Sustainable Guidelines Scheme According to Regions (Epp, 2015)

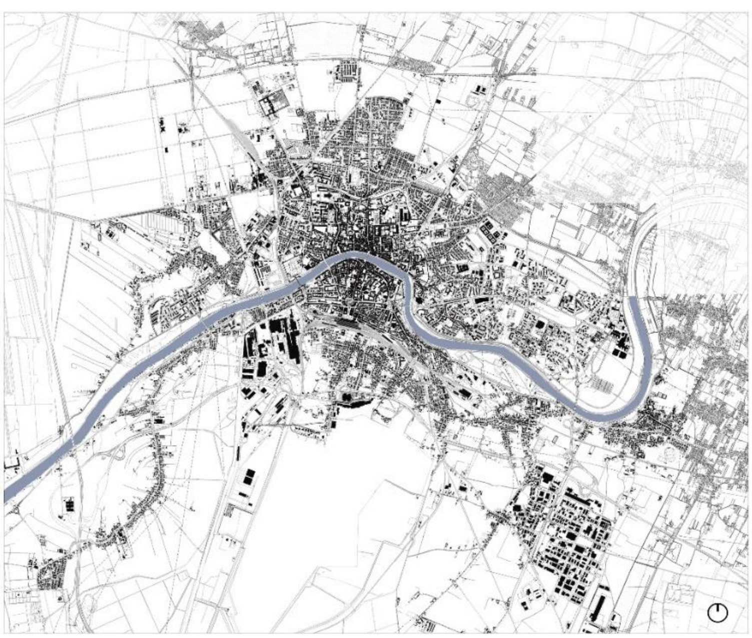
Another reason to choose Pisa city is that it's a coastal city and Italy has such a huge coastal area with high potential of renewable sources. The north part of region has relatively cold environment and south part has hot humid. The central part has cool winters and relatively humid and hot (25 to 33^{O}C in summers) so to develop a strategy for country like Italy we choose the city in central region so that it can be adaptable in any part of country.

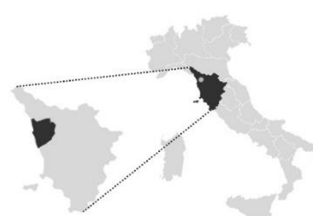
6.2 The city of Pisa

Pisa is the city in the central western part of Tuscany's region. Tuscany is the region in central Italy. Pisa city is on the western coast of Italy 80km west of city of Florence. The River Arno divides the metropolitan city into two halves. The city of Pisa is famous for its leaning tower, but it has more than 20 other magnificent historic churches.

The population of city is around 90,000. The city of Pisa covers 185km2 area. Pisa has remarkable group of buildings, Piazza del Duomo located at the northwestern end of the medieval walled city. This piazza contains the cathedral (Duomo) the baptistery and or Leaning Tower of Pisa and cemetery.

The city of Pisa is also famous for its renowned university which was founded in 14th century. It is one of countries top art and architectural university. Pisa is important railway junction in central Italy. Industries like glass, textiles, pharmaceuticals and light engineering goods are vital part of Pisa's Economy.





6.2.1 Historical Background:

Pisa, historically known as Pisae was under control of Roman Army as naval base and Pisa has survived the collapse of Roman Empire. During 11th century city flourished because of nearby coastal area and fertile Tuscany land with many agricultural products. Pisa's importance was due to its expansion towards the banks of Arno River.

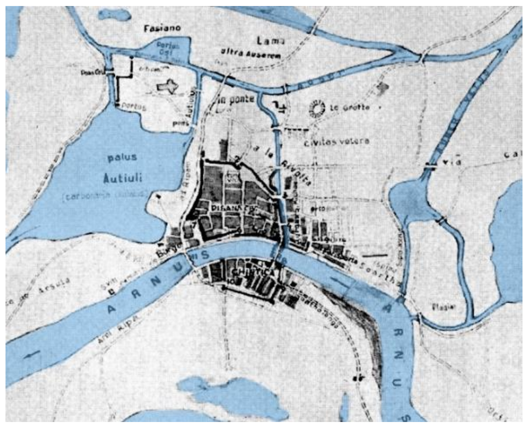


Figure 70: 11th Century Pisa City (Vintage Maps, 2018)

The construction of boundary wall in late 12th century joined three different villages of Pisa and made into wholesome town. Other than leaning tower of Pisa there are more than 20 churches which was built during 11th and 12th century. In 13th Century city of Pisa was supported in many areas of trade and cultural exchange by German Emperor.

Figure 71: 17th Century Pisa City (Vintage Maps, 2018)

City of Pisa lost the battle against Florence and Genoa in 1324 but after that city became the trade hub for woolen Products and became the main port in the Tuscany region.

The university of Pisa was founded in 14th century. The had strategic position because of Sea coast and Arno river. In 1495 when French army's invaded Italy Pisa managed to keep its impendence but again in 1509 Florence conquered Pisa.

In the 16th century renaissance of Pisa city began by Cosimo-I of the medici house. Agriculture, economic and legal facilities helped to populate the city. Along the bank of river, they build residences. In world war two the city of Pisa suffered many damages to its infrastructure and historical landmarks. In 19th century the new system of railways was built for the city of Pisa to develop the better connection for trade.

6.3 Infrastructure of Pisa City

6.3.1 Road and Train Network Tuscany Region:

6.3.2 Facts and Figures:

Galilio Glalio International Airport

27 airlines to more than 50 cities in Europe, Russia, Middle East with upto 4 Million Pessengers per year.

Galilio Glalio International Airport

Two train stations with Regional train lines to Genoa,Rome, Livorno and Florance.
Fast train Connection with Florance Line.
!5 Million Pessenger each year by Pisa Trains System.

Pisa Bus Station

There are 2 bus services operating connecting cities like Milan, Rome, Naples and international Bus Conne-ctions like (Munich) Germany and (Innsbruck) Austria.

Fact and Figures

City Area | 185km^2

Population of City | 90,000 inhabitants (2015)

Population of Metrpolitan Area | 200,000 inhabitants (2017)

Population Density of City | 488.4 inhabitants/km2 (2017)

Female Population | 52.4% ; Male Population | 47.6%

Population by Age Group:

0 - 17 years	13.7%
18 - 64 years	60.2%
65+ years	26.1%

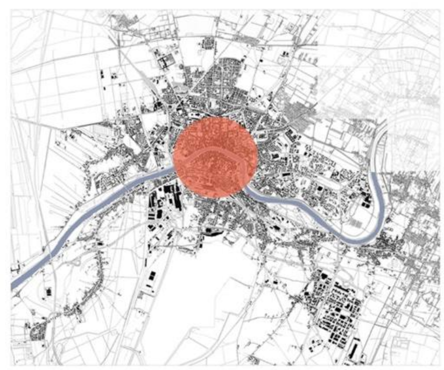
Nationality:

Italians	86.5%
Foreigners	13.5%

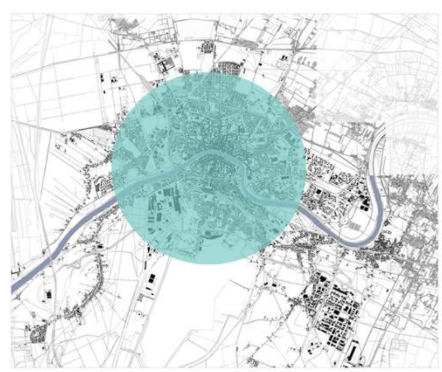
Vehicular Data:

City Vehicles	60,000
Outside Vehicles Entering City	90,000
Bike Path	40km

City Centre | Diameter of 1.5km



Urban Area | Diameter of 3km

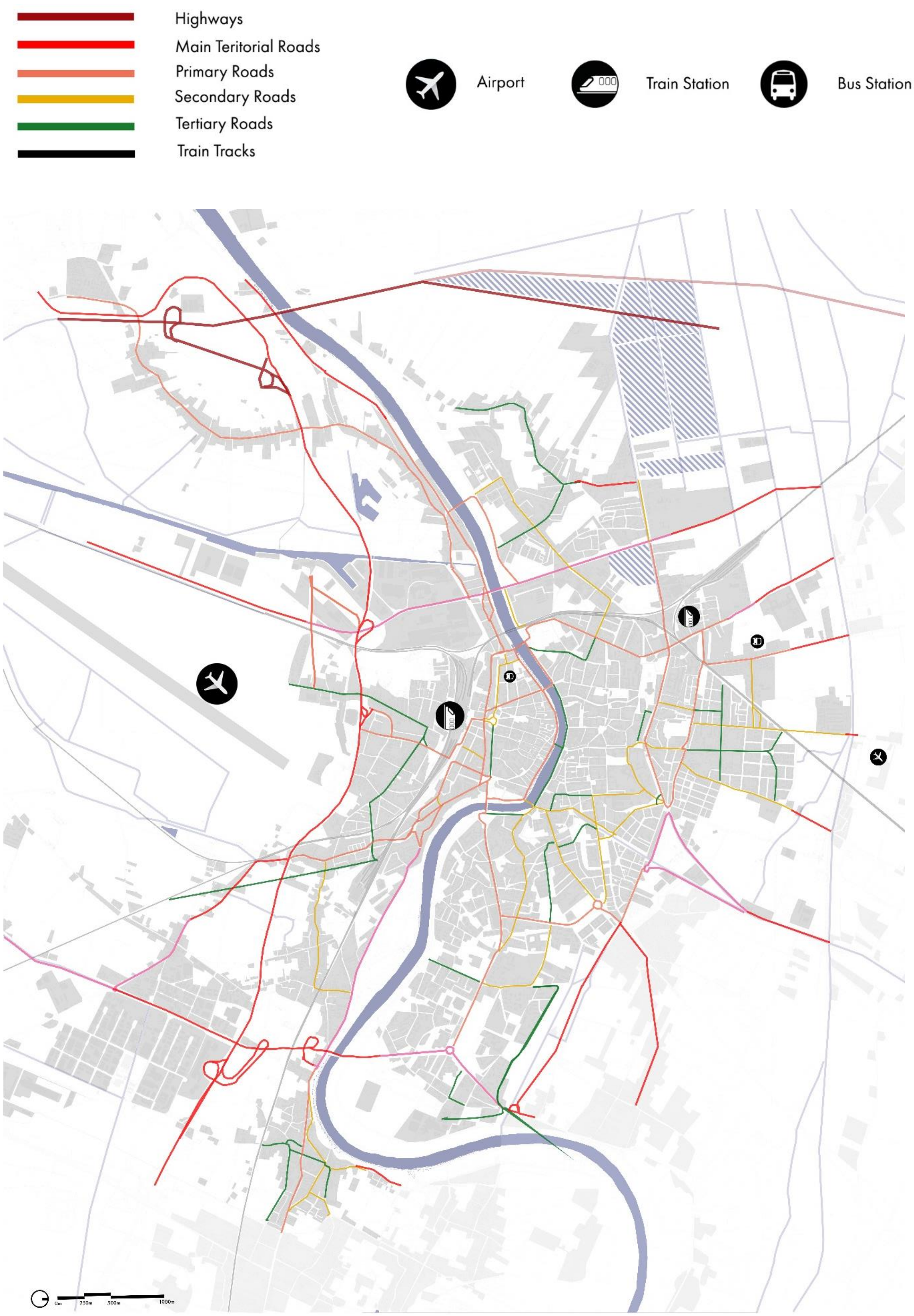


6.3.3 Pisa City Transport infrastructure & Focal Points:

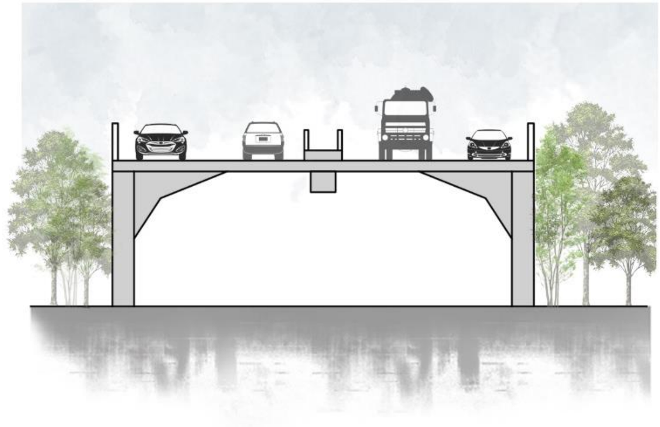
City Transport system is one of the most important features of its infrastructure. Connection to other regions of and major trade hubs of country is important for city economic growth. The city of Pisa has important location in that regard. The International airport and Trains station in city forms cardinal network of connection with Italian cities as well as other cities in European countries. Trains transporting 15 million passenger each year and 4 million passenger travels through Airport.

National highway "*A12*" passed through the western part of city as well southern side connecting it to Milan, Genoa, Rome and Naples. Trains also provide three main connection to cities like Genoa, Florence, Rome and La Spazia the direct connection and to all other cities an indirect connection.

Car ownership is one of major problem in the Tuscany regions and city of Pisa owns 60,000 cars and overall 90,000 cars enter city for work and other purposes. The city of Pisa has 40km long cycle track. Pedestrian only parts are mostly near city Centre.


Highways
Main Teritorial Roads
Primary Roads
Secondary Roads
Tertiary Roads
Train Tracks
Airport
Train Station
Bus Station

Site Images:	Typical Sections



Highway | 26m wide

Main Territorial Roads | 20m wide

Primary Roads | 12-14m wide

Secondary Roads | 8-10m wide

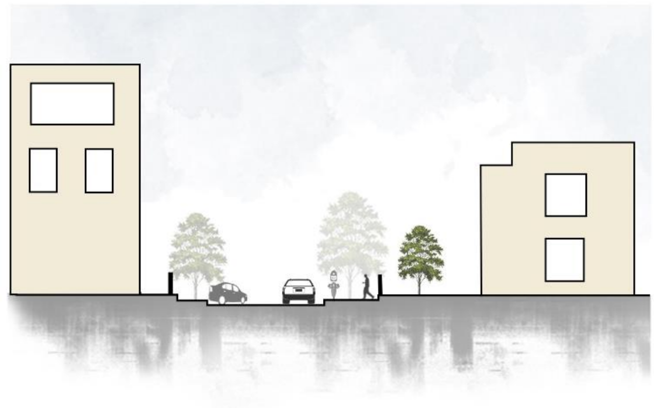
Site Images:

Tertiary Roads | 4-6m wide

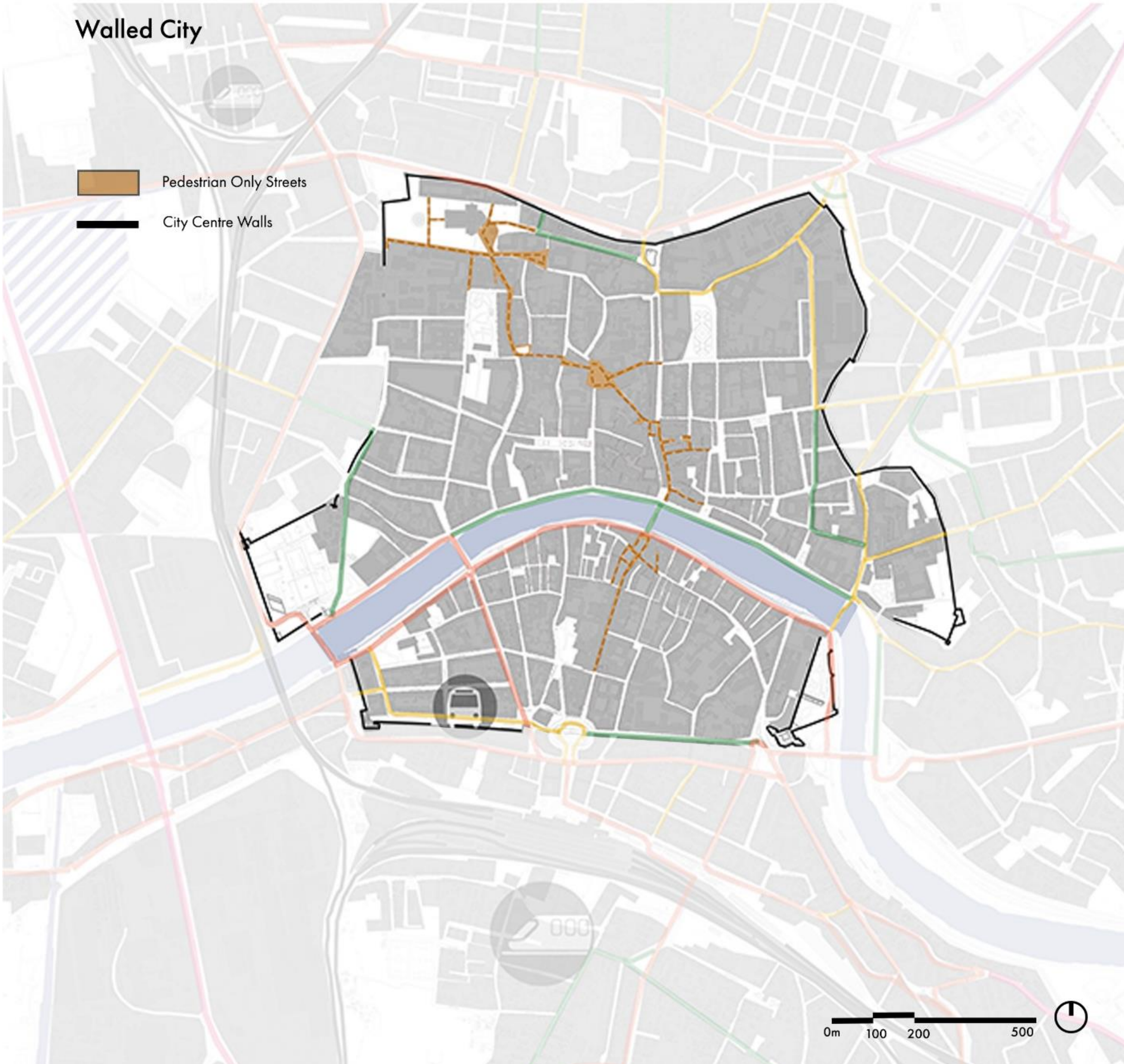
Walled City Road | 4-5m wide

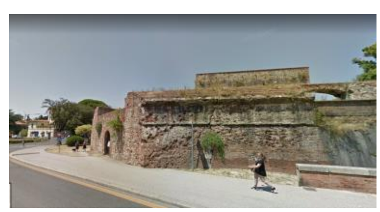
Walled City Street | 5-7m wide

Typical Sections:

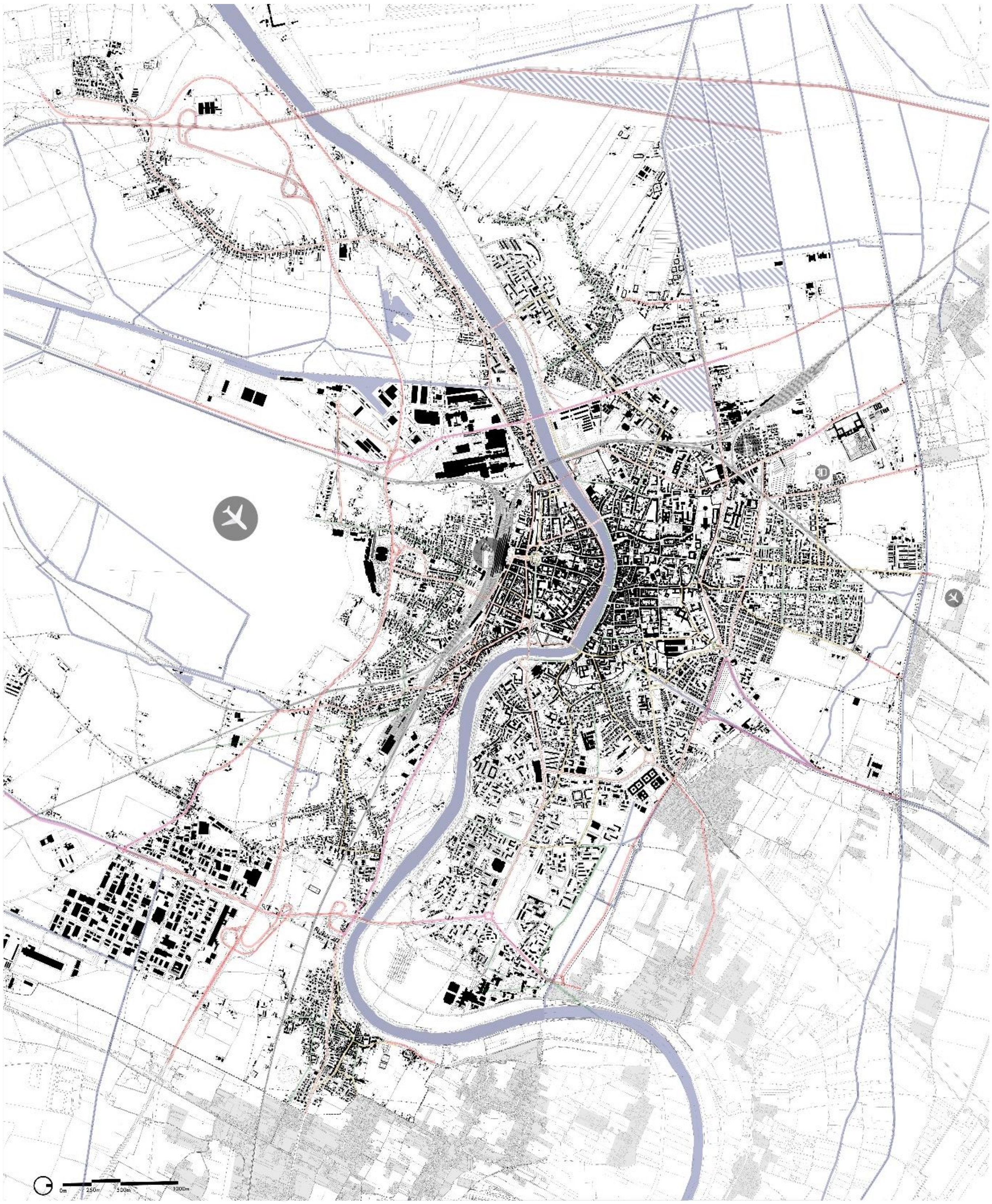


6.3.4 Walled City & Pedestrian Streets:

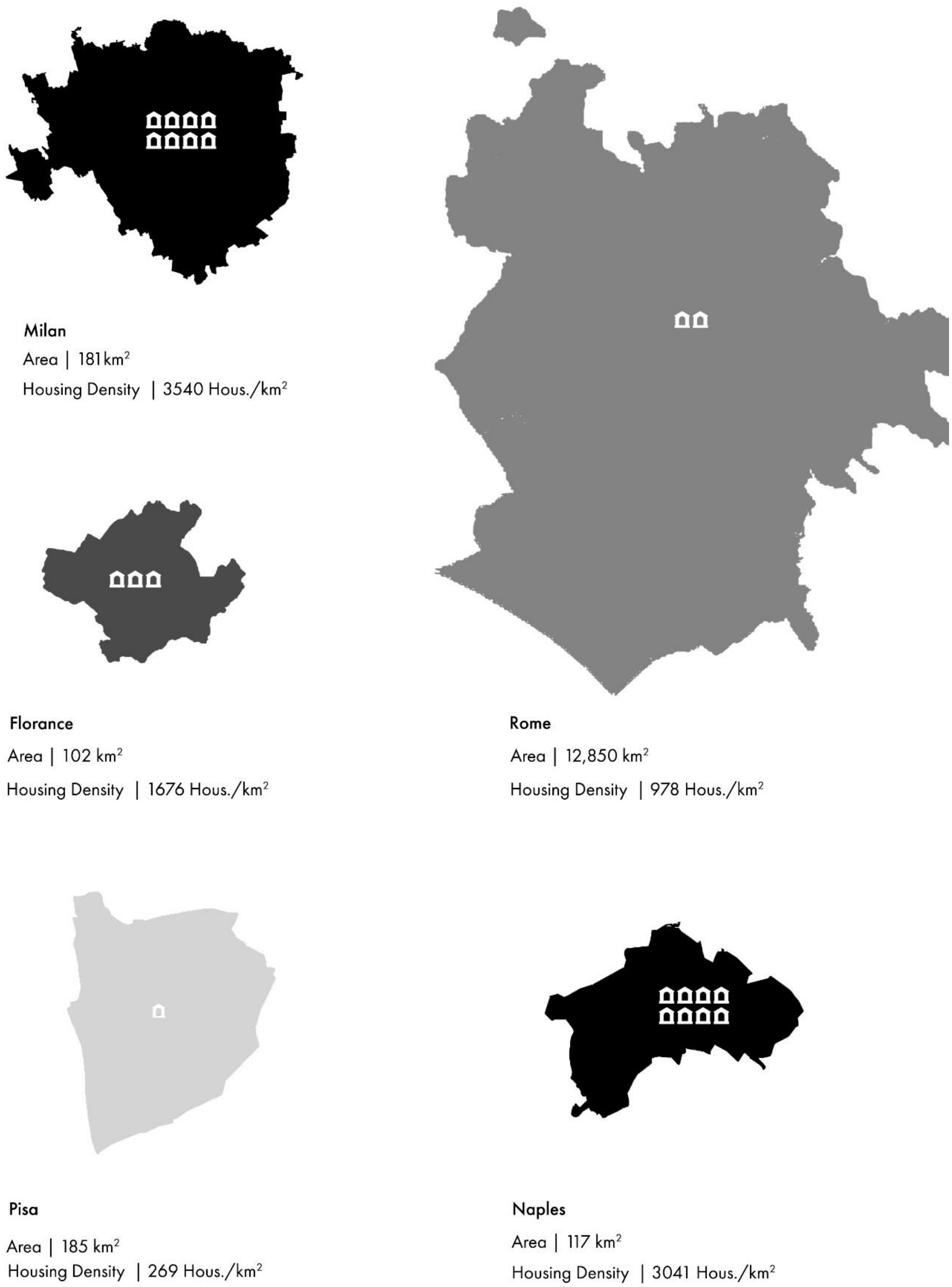




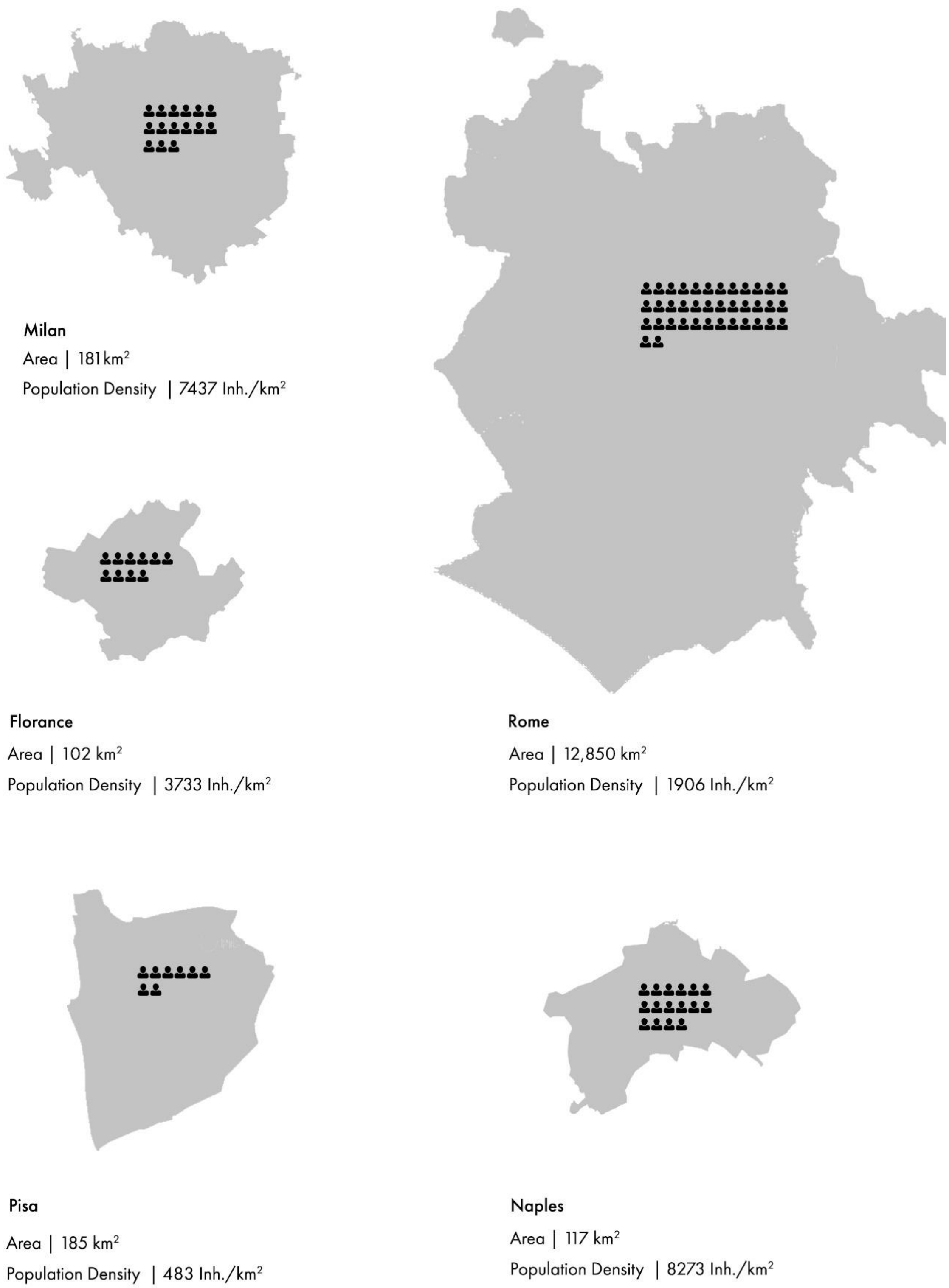
6.3.4 Open and Built Spaces



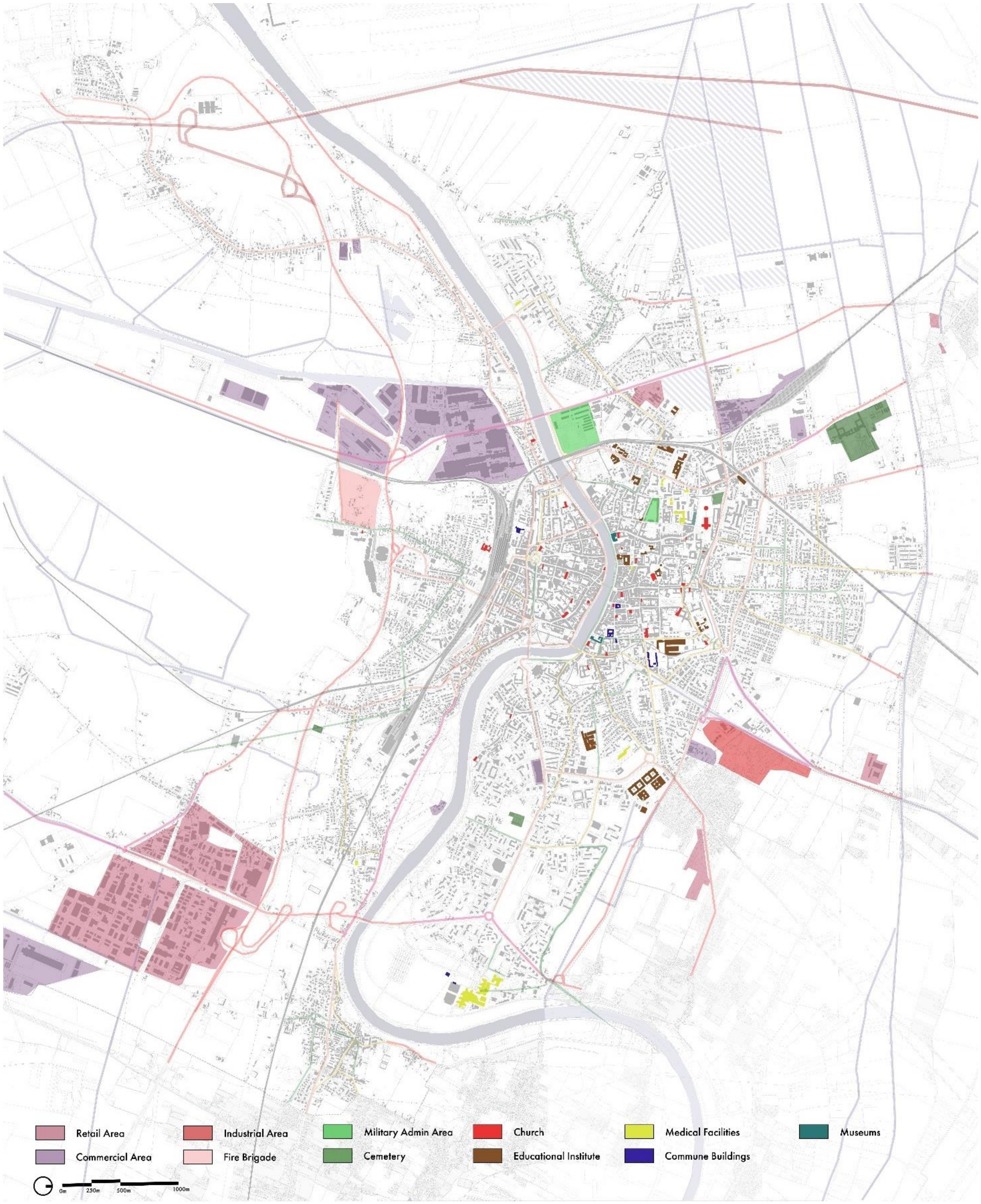
6.3.5 Housing Density:

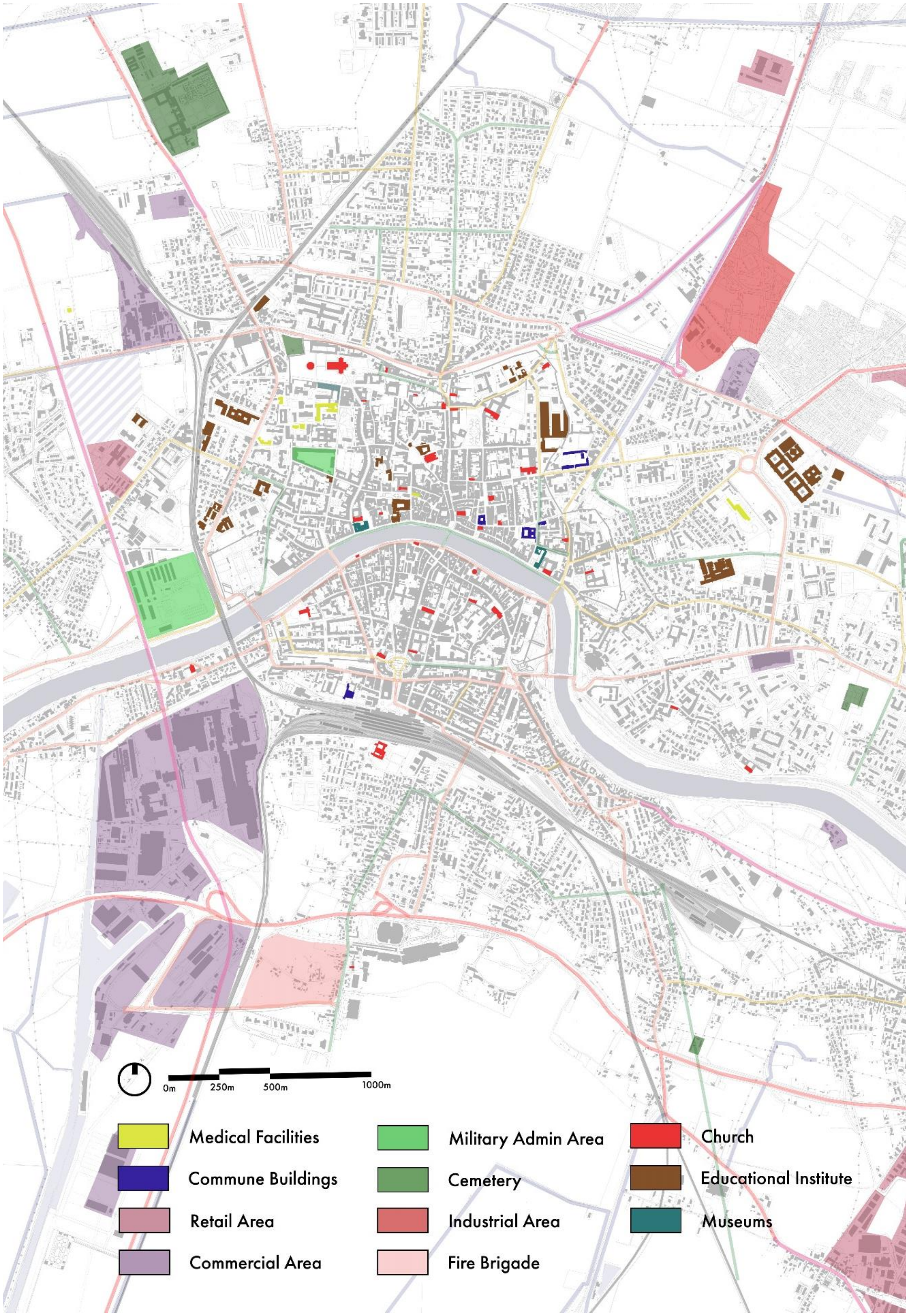


6.3.6 City Scale Comparison:

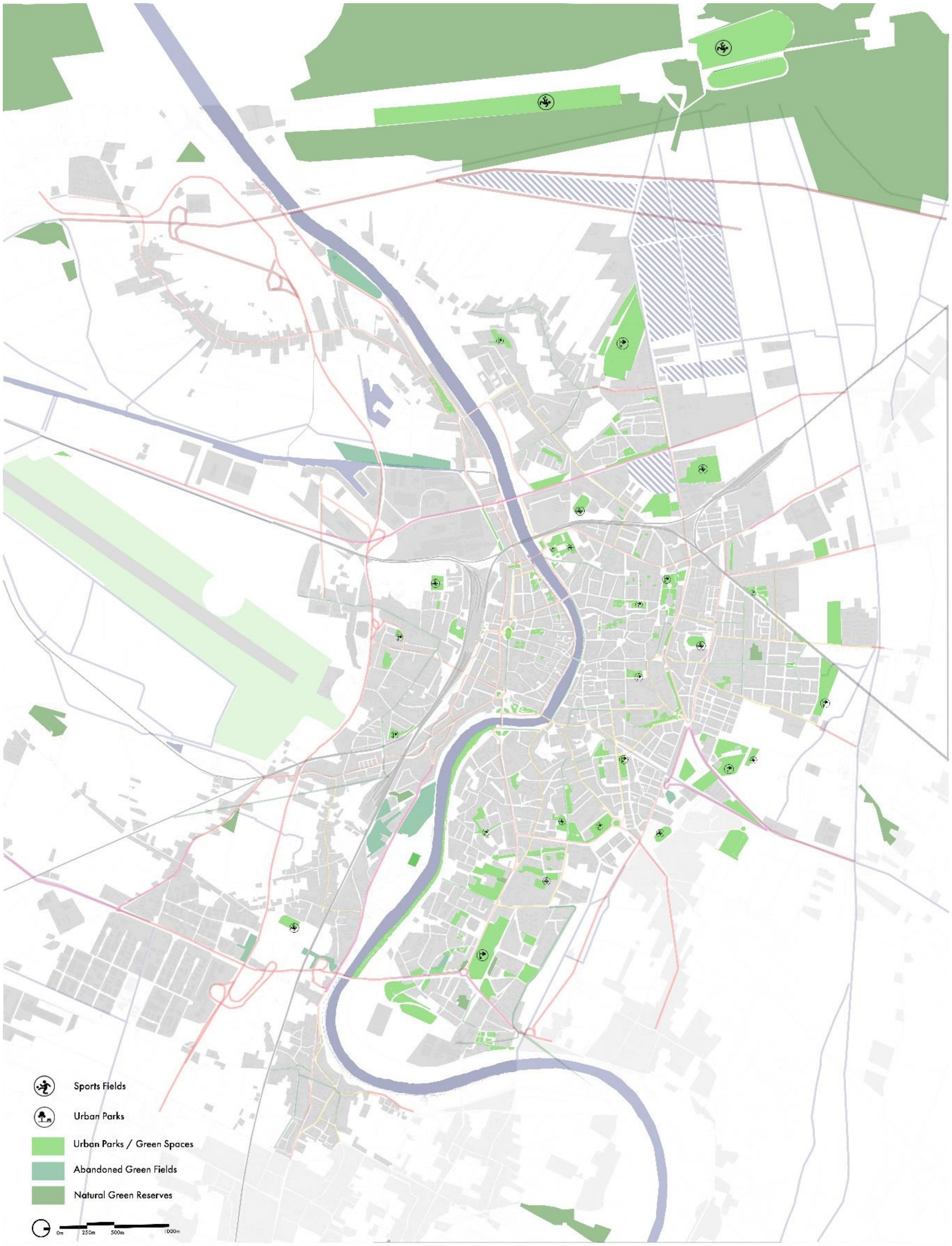


6.3.7 Functional Division of Pisa:

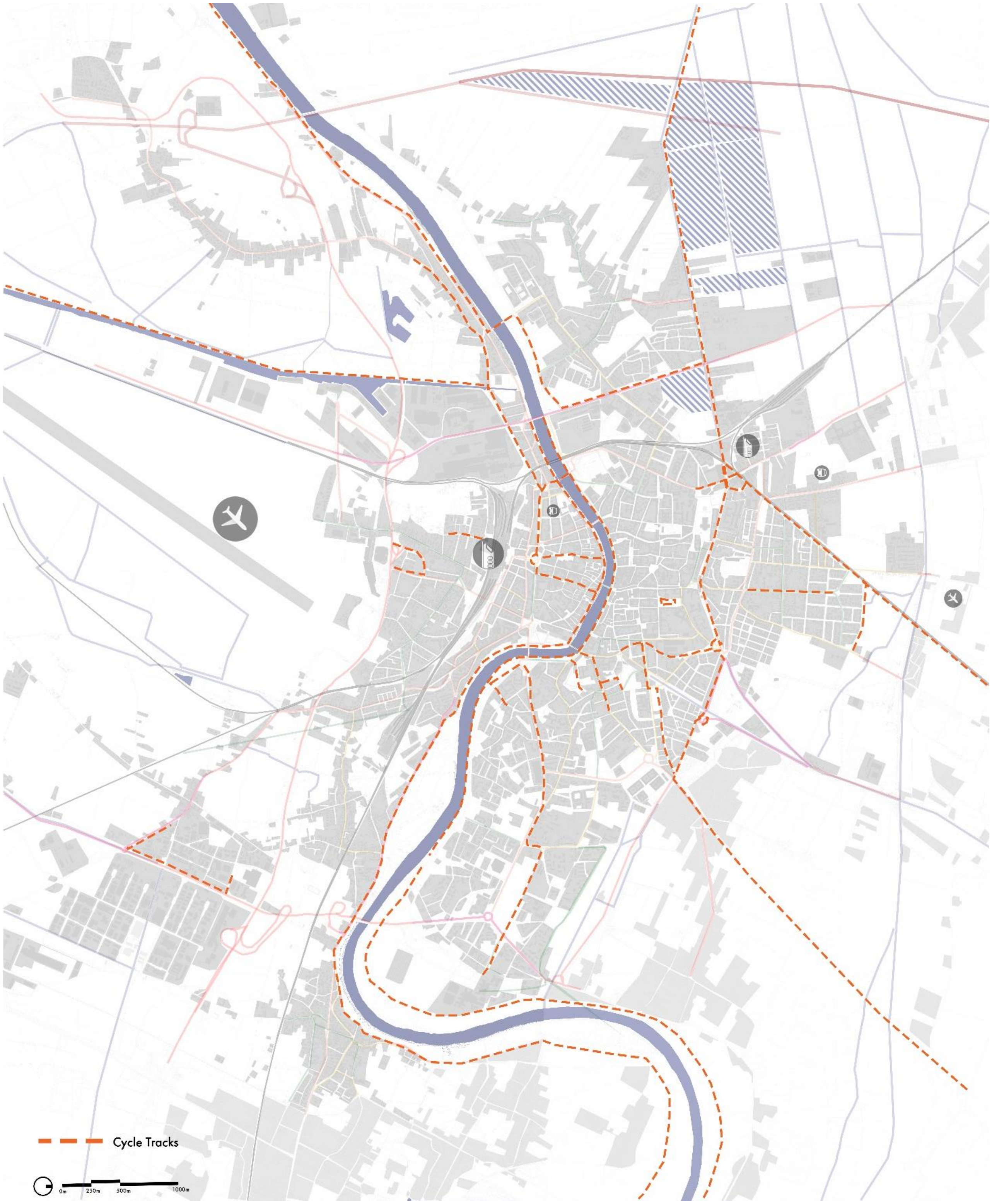



0m
250m
500m
1000m
Medical Facilities
Commune Buildings
Retail Area
Commercial Area
Military Admin Area
Cemetery
Industrial Area
Fire Brigade
Church
Educational Institute
Museums

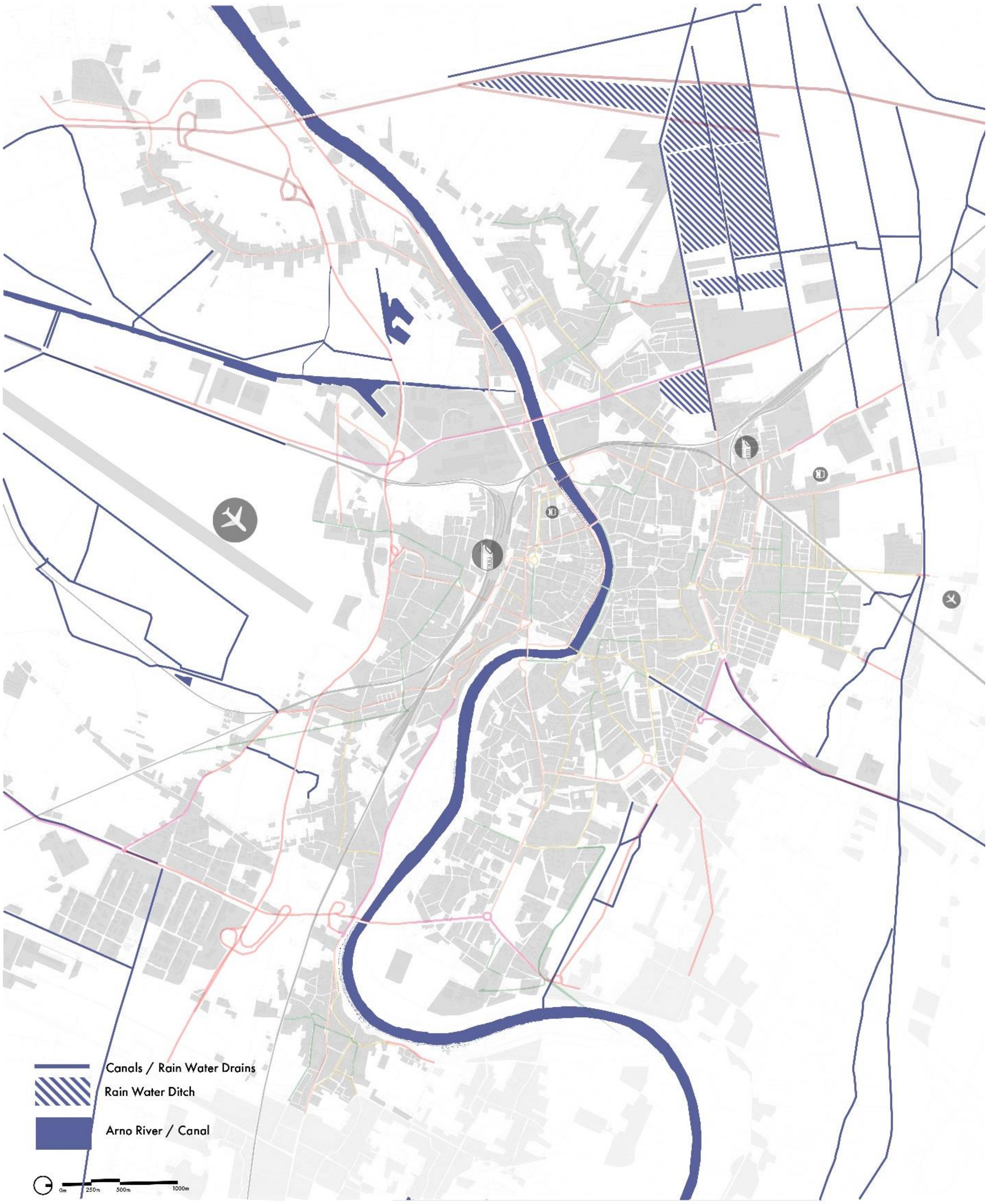
6.3.8 Green System:



6.3.9 Cycle Tracks:



6.3.10 Irrigation System:



6.4 Climate Conditions:

Pisa is located near the coast, so it experiences the Mediterranean humid subtropical climate. City enjoys all seasons, but it has comparatively mild winters and hot summers. Temperature is at its lowest in the months of December to February with the average of 4ºC to 6ºC. it can go as low as 0^{O}C. The hottest months of summers are July and august with high humidity (60% to 70%) and average temperature up to 30ºC. April and October have highest precipitation average with 9cm average and month of July has minimum with the 2cm average.

In winters wind direction is from east and in summers they come from western sea Coast. In spring the wind comes from south-western part which is Tyrrhenian Sea. That's why Pisa has cool winters with average temperatures above freezing point and humid summers.

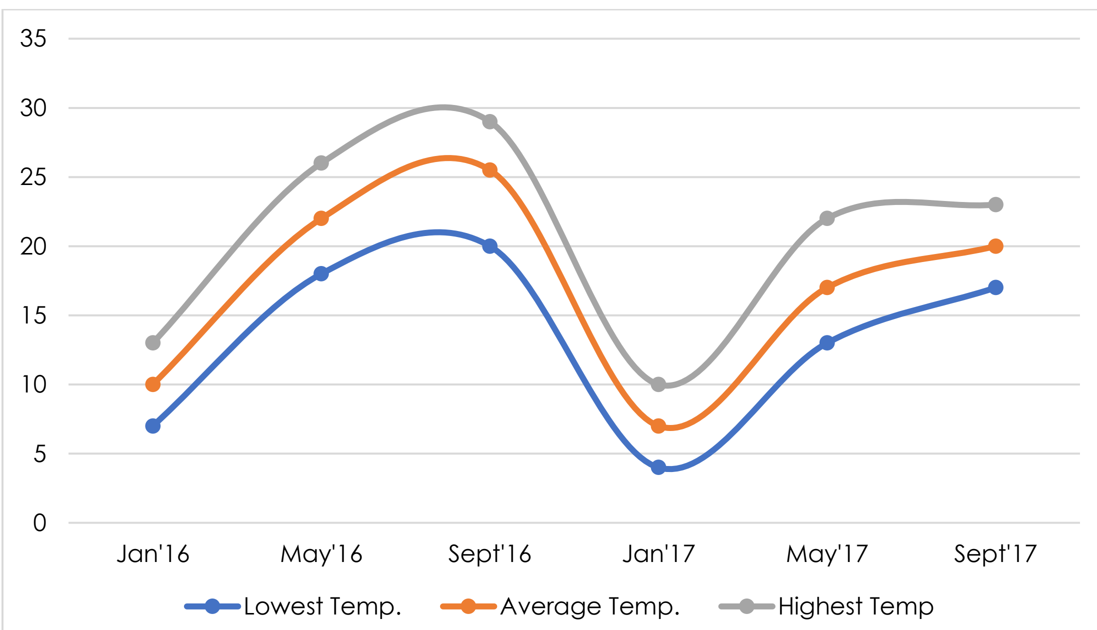


Figure 72: Maximum and Minimum Temperature (ºC) (World Weather Data Online, 2018)

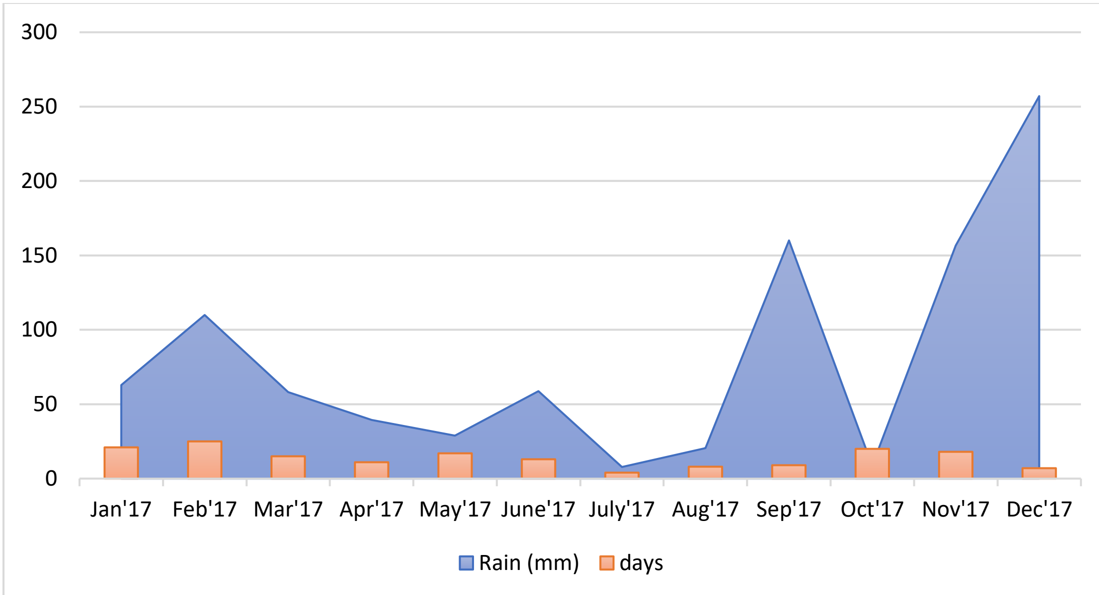


Figure 73: Average Rain/month (mm) (World Weather Data Online, 2018)

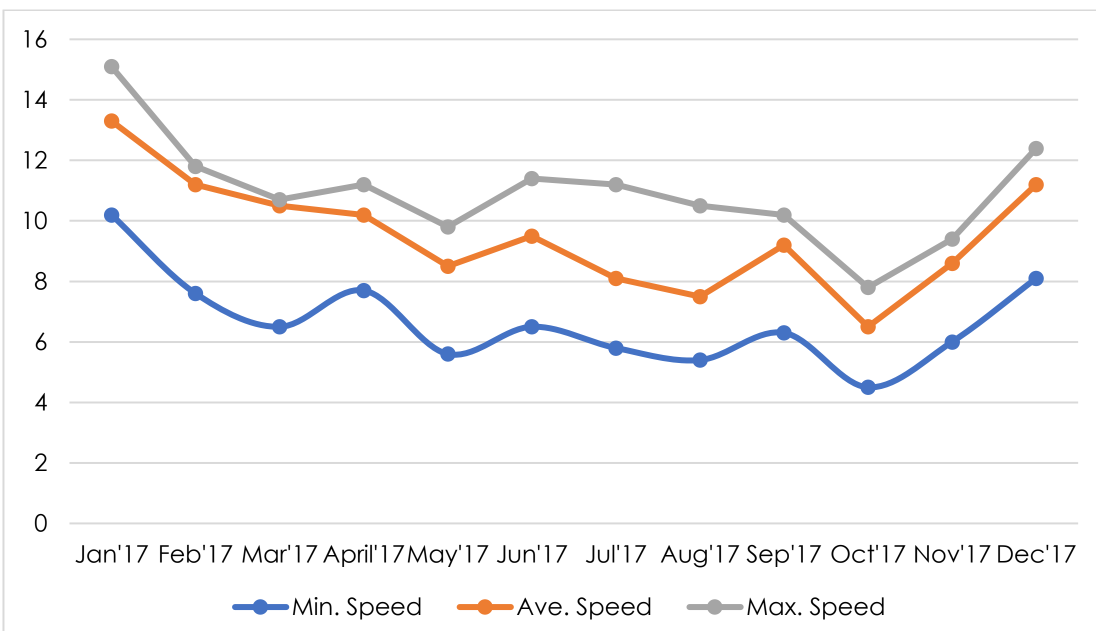


Figure 74: Wind Speed (mph) (World Weather Data Online, 2018)

Wind Speed varies around the year, but we can see that average wind speed mostly above 8 mph and it goes as high as 15mph. The wind speed is not high enough for large wind farm but for small level intervention this speed is good and small system would work well.

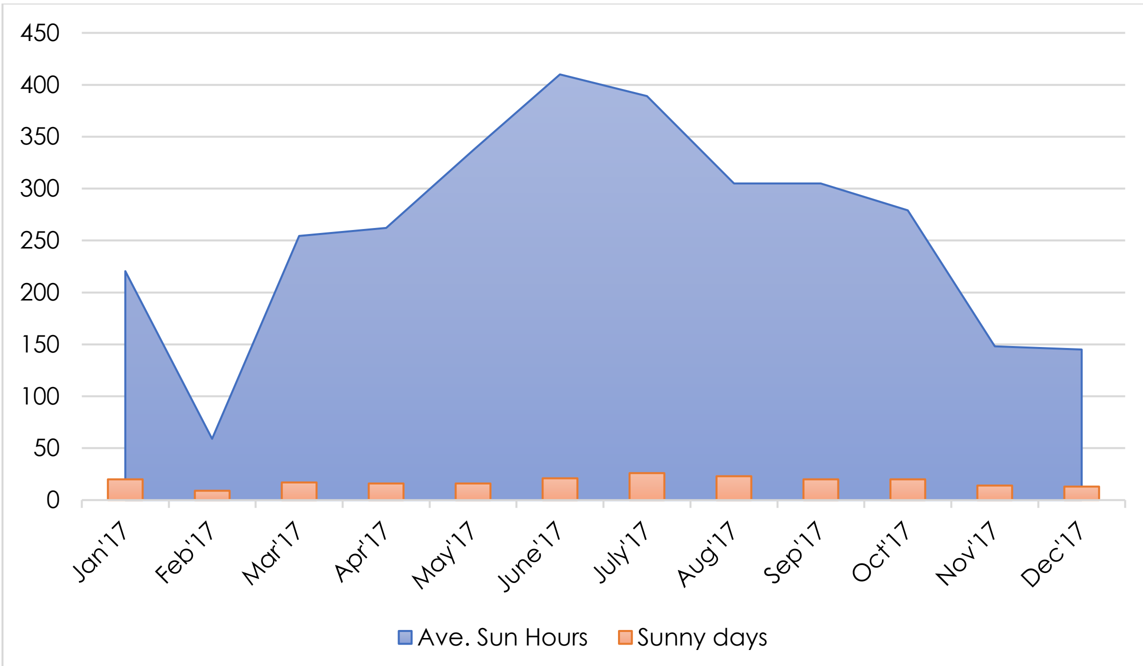


Figure 75: Average Sun Hours and Sunny Days (World Weather Data Online, 2018)

Analyzing the weather data of Pisa from 2017 it is very clear that City of Pisa receives the enough amount of sunlight for adequate number of days. From April to October the average of 350 hours per month and 24 to 27 sunny days a month would give enough solar irradiance for efficient Solar power system.

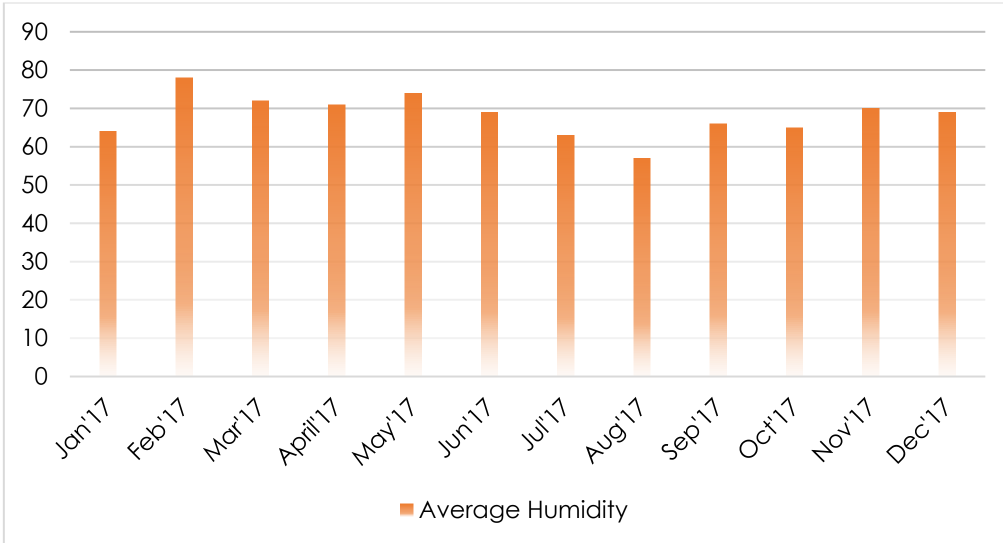


Figure 76: Average Humidity (%) (World Weather Data Online, 2018)

6.5 Data Audit:

6.5.1 Waste Production:

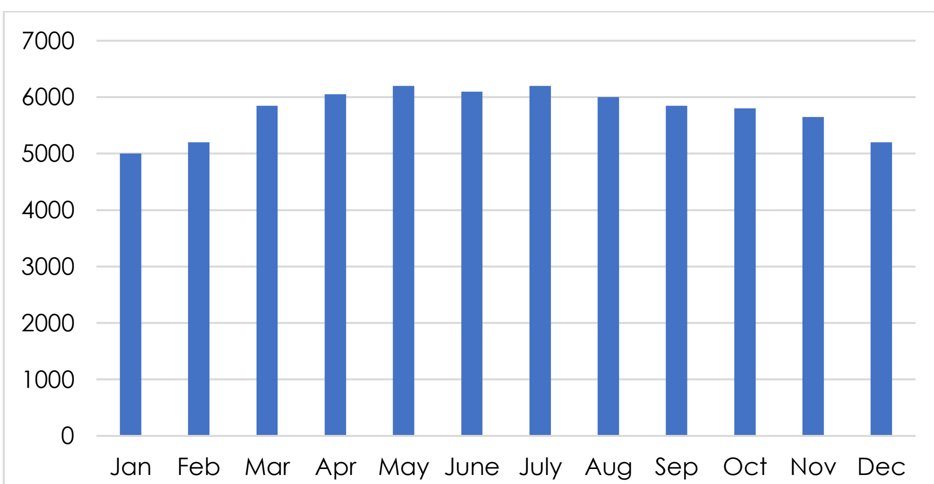
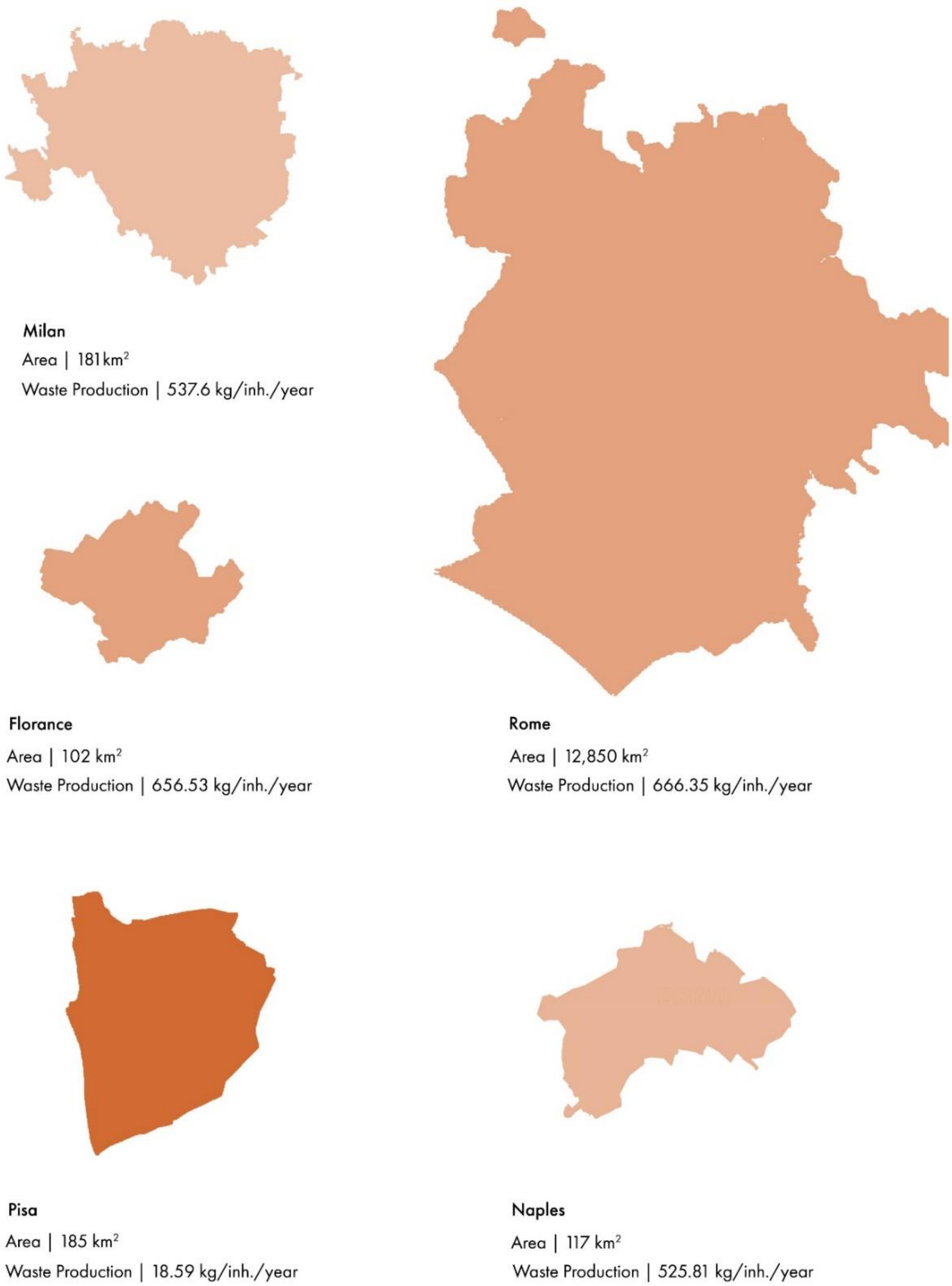


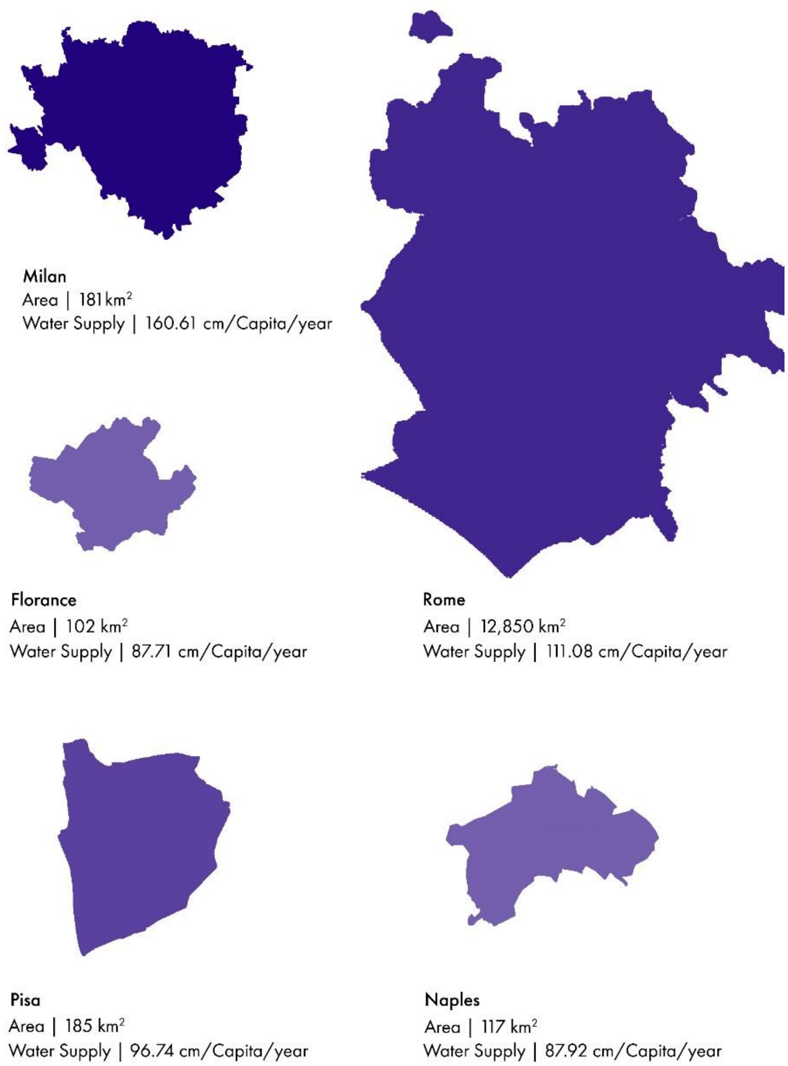
Figure 77: Waste Collection by Commune (tons) (Commune Di Pisa, 2018)

Collection of indifferentiable waste was 30,396 tons and differential waste was 38,998 tons making it total of 69,394 tons for year 2016.



6.5.2 Water Consumption:

Surface Water quality and tap water is good for drinking purposes, but it has some traces of chlorine and small strains of local E. coli. The water of river Arno is poor. BACTERIOLOGICAL QUALITY INDEX (IQB) Suggest that the quality of water is mediocre. Quantitative state of underground water is with moderate condition of disequilibrium, and city of Pisa suggests the smart and sustainable use of water use of water. *1259789 mc /annum* was total amount of water supplied by municipality in the year 2008. Water supply of major cities of Italy per capita is as follows (Commune Di Pisa, 2018).



6.5.3 Pollution Index:

Indicator	Index	Category
Air Pollution	45	Moderate
Drinking Water Pollution & inaccessibility	37.50	Low
Dirty and untidy	68.7	High
Noise Pollution	50	Moderate
Water Pollution	37.50	Low
Green and Park system in city	56.25	Moderate
Dissatisfaction with Garbage Disposal	50	Moderate

Table 14: Pisa City's Pollution Index (Numbeo, 2018)

Pollution Index for world health organization is 52.02 which moderate.

6.5.4 Transportation Index:

Index	Value	Category
Traffic Index	68.68	High
Time Index	16.7	Moderate
Inefficiency Index	33.90	High
CO_2 Emission Index	1,330	High

Table 15: Pisa City's Transportation Index (Numbeo, 2018)

Due to traffic there is 319.20kg of CO_2 per year per person and to tackle this amount of CO_2 produced we need minimum 15 trees per person to produce enough amount of oxygen to tackle that amount of CO_2 because one tree absorbs 21kg of CO_2 per year.

6.5.5 Quality of Life Index:

Index	Value	Category
Safety Index	59.09	Moderate
Health Care Index	76	Very High
Climate Index	59.8	Very High
Cost of Living Index	89.8	Moderate
Property Price to Income Ratio	9.82	Moderate
Pollution Index	52.02	Moderate
Purchasing Power Index	76.15	Moderate

Table 16:Pisa City's Quality of Life Index (Numbeo, 2018)

Quality of Life index of 161.71 which falls in moderate to high quality of life. For Milan it is 128.43, for Rome it is 111.61 and Naples it is 88.04 (Numbeo, 2018)

6.6 Energy Consumption:

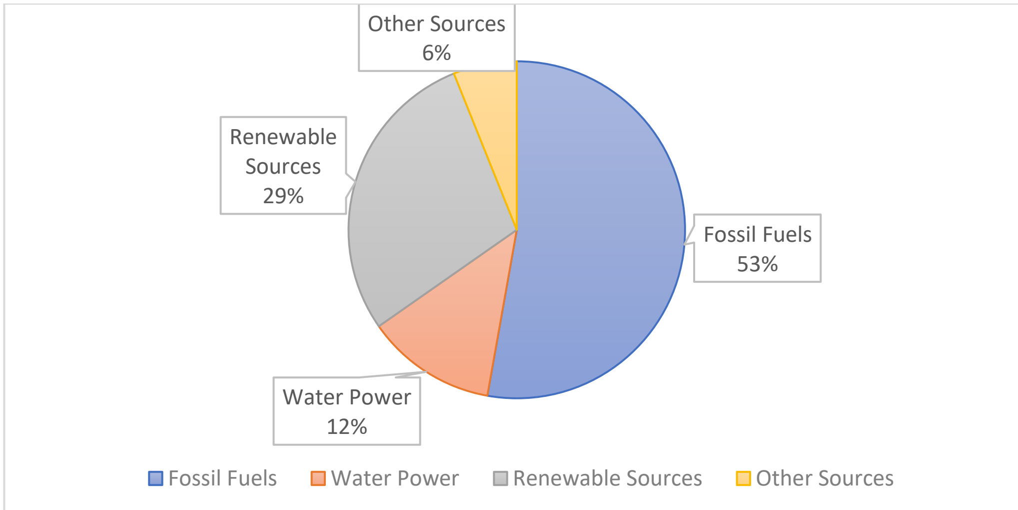


Figure 78: Energy Resources in Italy (Giulia Iorio, 2015)

Average energy Consumption per capita per year for Italy is 4,692 kwh. The average family of 4 to 5 people consume 1500 kwh per month in Italy. Italy produces energy not only from fossil fuels but also from other sources.

Italy produces 91% of its required energy and other 9% is acquired from other countries in Europe. The Carbon emissions according to 2014 survey is 5.29t per capita and it was t its lowest value in 2014. In 2004 it was recorded the highest in last decade. In the following section we will see the dispersion of renewable energy resources in each region of country. (Giulia Iorio, 2015)

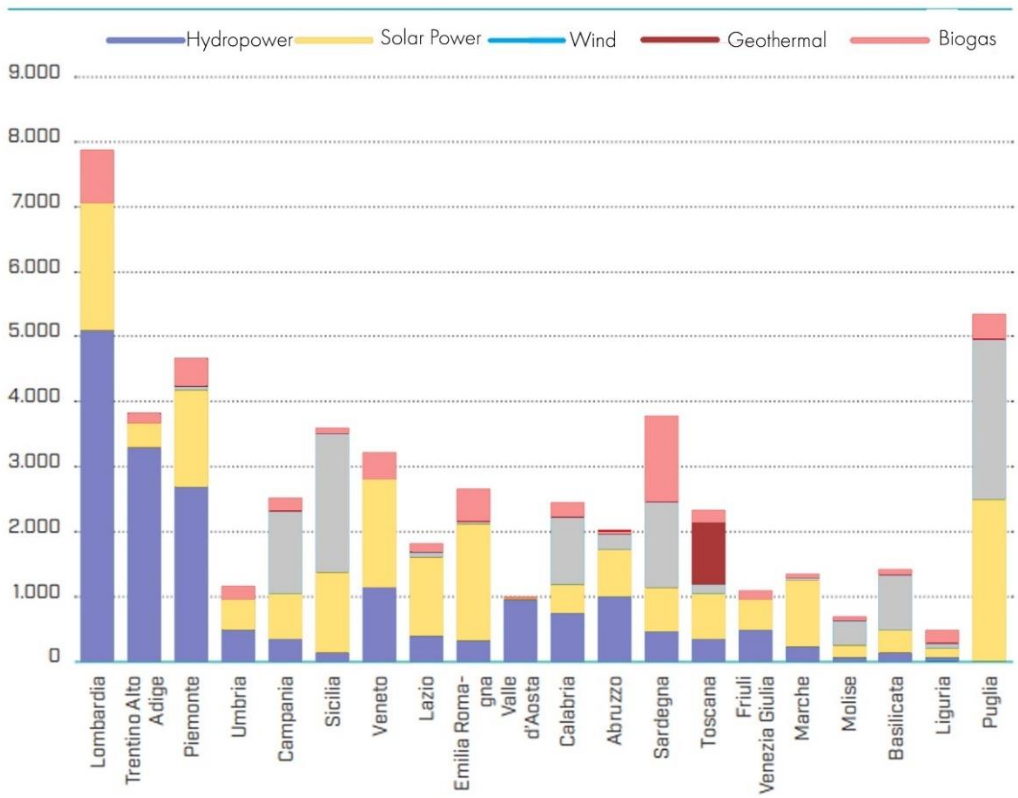


Figure 79: Distribution of Production of Renewable Energy (MW) Resources for Italian Regions (Giulia Iorio, 2015)

Interesting point to note is here that Tuscany is the only region which has Geothermal power sources but in comparison to other regions in solar and hydropower capacity, it is low. Italian building and residential sector consume 37.1 % of total energy followed by 33.3 % transport and 21.6 industry.

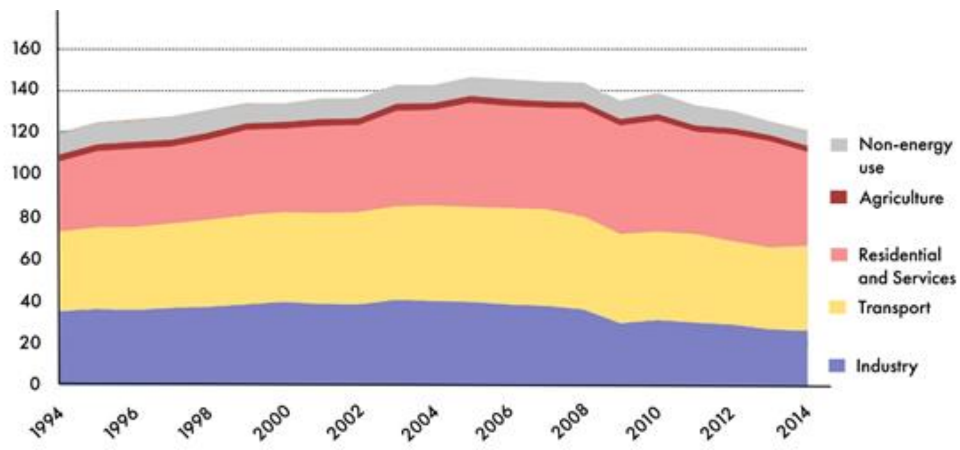


Figure 80: Energy Use by Sector in Italy (Mtoe) (Giulia Iorio, 2015)

The average consumption of electricity per capita for Italy per year is 4800 to 5000kWh. The population of Pisa is 90,000 which makes it 441,000mWh for the city of Pisa per year and 36,570 MWh (36,570,000KWh, one unit is equal to 1kWh) per month is needed. The price for 1kWh electricity is 0. 146.The total price of electricity per year according to these calculations is 5,339,220 Euros paid by the city of Pisa per month. Average value of per capita consumption is not only for domestic usage, but It also includes commercial, transportation and industrial sectors consumption. Only domestic average consumption is around 3000 to 3700kWh per capita.

6.6.1 Energy Demand Supply and Distribution:

"Terna Rete Italia" is the leading grid operator in Italy which is responsible for electricity transmission in Italy. Italy has eight main regions for this purpose. The city of Pisa comes in the Florence region. According to 2015 statistics all regions produce less amount of energy than they consume except Naples, Palermo and Cagliari. Italy imports energy from France, Switzerland, Austria and Slovenia. Different Regions also interchange different amount of energy. All the energy shown in the next diagram is in GWh.

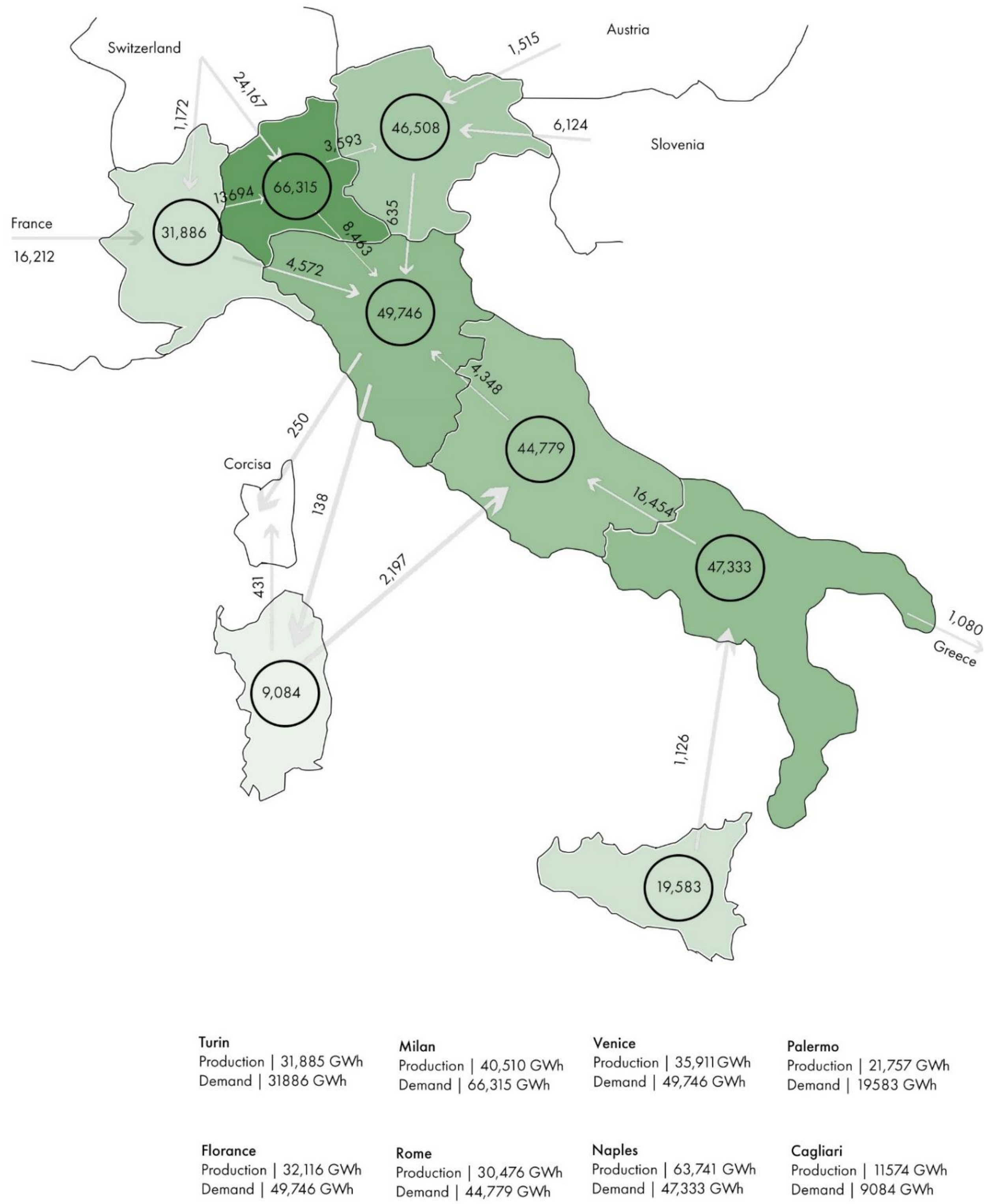


Figure 81: Italian Electricity Demand and Supply Distribution system (Provisional Data on Operation of Italian Power System, 2015)

6.6.2 Future Energy Policies

According to European Energy Market reform, there has been targets set to achieve before 2020 and National Energy Strategy (**Strategia Energetica Nazionale - SEN**) adopted in March 2008 has defined four objectives to improve the sustainability of Italian Energy Sector including Reduction of energy cost, reduction of foreign dependency from 89% to 67% and boosting investment up to 180 billion in green energy sector.

20-20-20 EU Energy Efficiency Targets for Italy are,

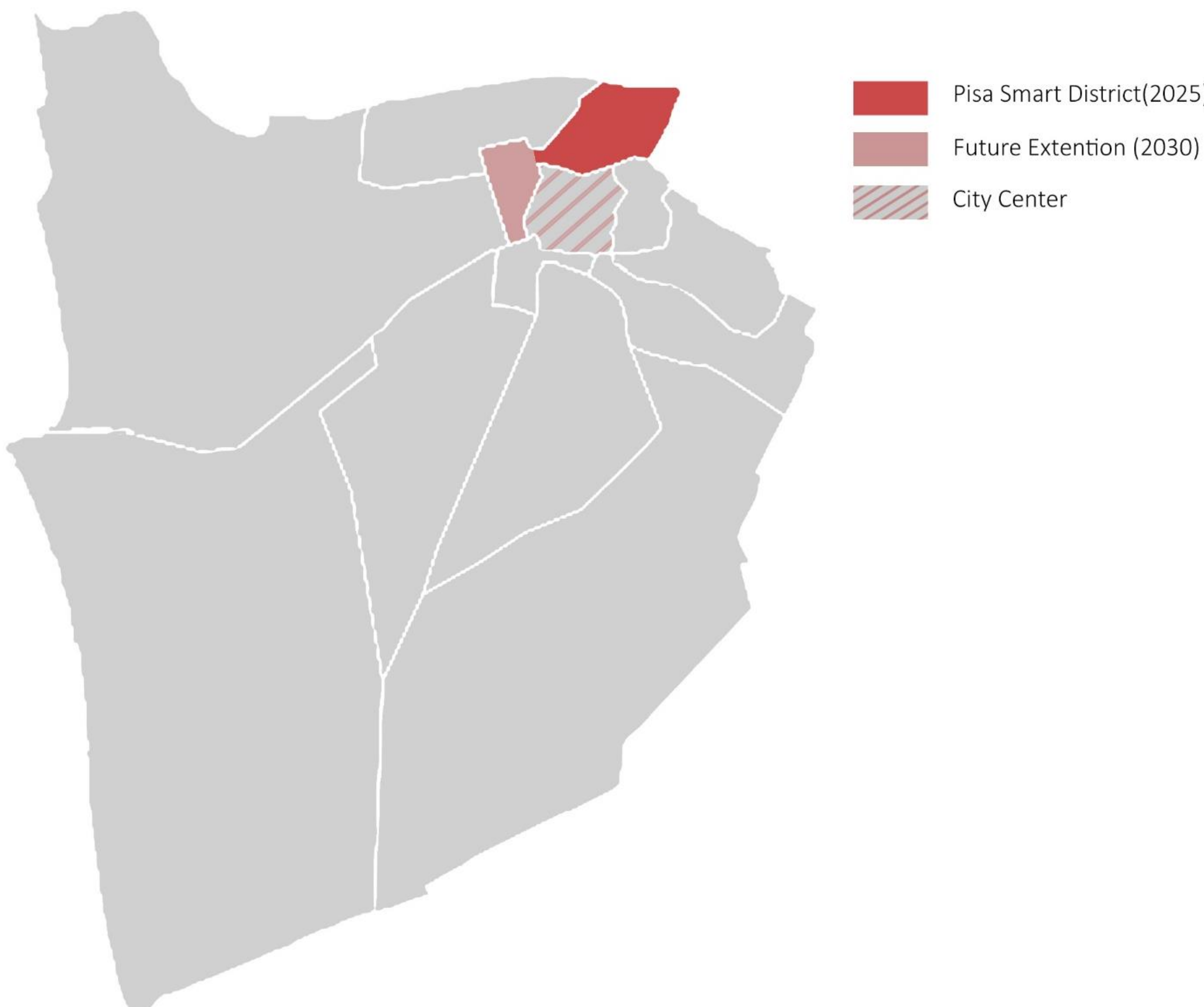
- Reduction of greenhouse gas emission by 18% till 2020 compared to 2005.
- 15.5Mtoe of energy savings in annual energy consumption from 2011 to 2020.
- Achieving the share of 17% from renewable sources in final consumption.

Italy had already achieved 68% of its renewable targets between 2008 to 2012 and by the year 2020 it will surpass the set targets. (Agency, 2016)

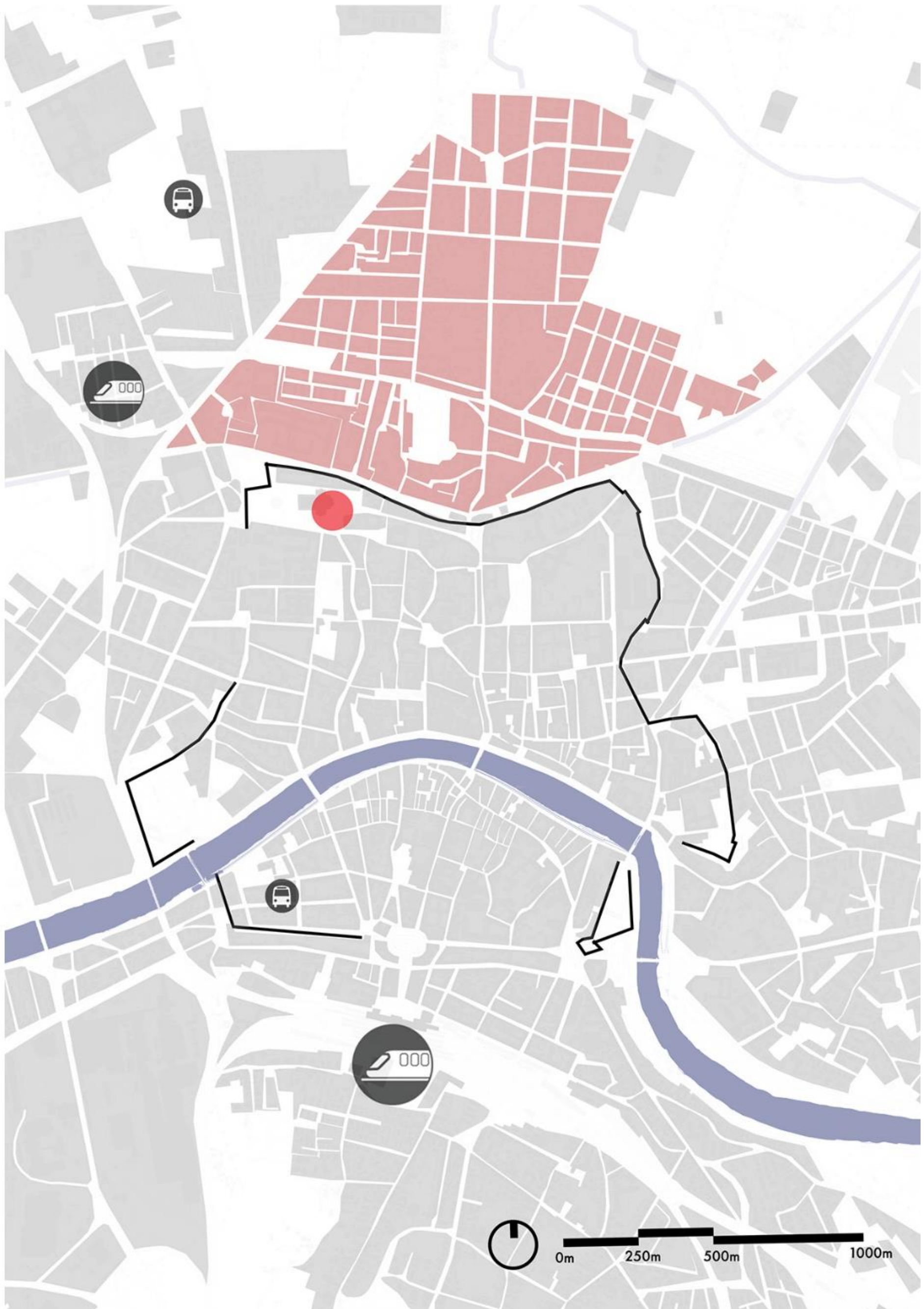
Chapter 7 | A Sustainable District (2025)

7.1 Site Introduction

The area of Porta Nuova / Porta Lucca is located upper northern part of city and has been selected for redevelopment project as New smart district. The mostly buildings in this area has been constructed during first two decades after 1950. In this area, only few residential buildings were construction during first decade of 20th century.



The site has been selected because of its proximity to city center. From the far edge of smart district to city center the distance is 1.8km and to the Centrale station is proximately 2.5km on foot and 4km by bus. One other train station is right next to the area. The Redevelopment is part of proposed plan for Pisa Smart city 2025 and the other part is extension of this area as part of 2030 smart city plan.



7.2 Existing Conditions:

7.2.1 Building Energy Ratings:

Building energy classes or building energy ratings **(BER)** are given to buildings according to their energy performance (How efficiently they consume energy) and their emission of CO_2. It is like energy label of household appliances. From A+ to G is the rating given to the building. Almost 75% percent building in this area are G-class building and rest are F-class and E-class with exception of three D-class, one B-class, two A-class and three A+ class buildings.

7.2.2 Functional Distribution:

Most of the function in the Port Lucca area are situated in the south part of area near walled city center. They are at almost 20 to 30-minute walking round trip distance from far edge of area. and whole trip to the area where bar, restaurants and banks are available.

7.2.3 Green Areas:

In Porta Lucca area, there is only one big public park on western side of area near Porta Nuova area. There is one golf course and there are few very small parks. Most of part has residential buildings and few blocks has their own green areas with trees. Trees are almost around every road. Number of trees in the area range from “***4500 to 5000”***. In the center of area there are two densely vegetated gardens.

7.2.4 Road Classification:

The main primary road passes through the area connecting it to Municipality of *"Lucca"* through *"San Giuliano Terme".* The other secondary roads connect the area to suburban areas of "*Gatano, Tre-Ponti Vecchiano, Nodica"* etc on one side and in city they connect it to Centrale train station and airport. They also provide access to city center.

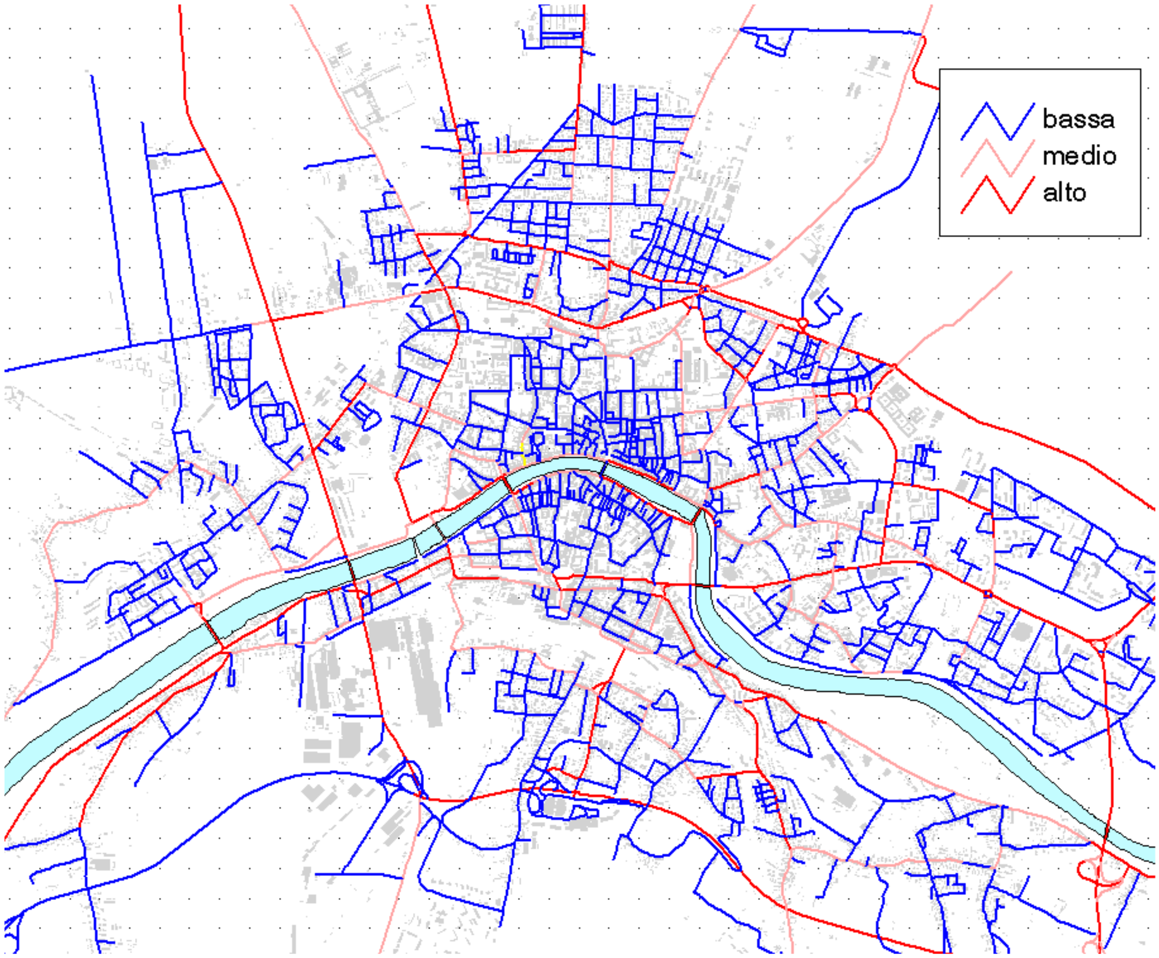


Figure 82: Traffic Density Through Different Roads of Pisa (Ciacchini, 2011)

Here is a description of the city according to the traffic density, where the blue lines correspond to low traffic (less than 50 vehicles/h) and the red ones to the high traffic (from 170 up to more than 2000 v/h). (Ciacchini, 2011)

7.3 Design Recommendations:

Design recommendations are based upon the previous research data and analysis of case studies. In this section we will develop the set of guidelines and a sample toolkit on urban level as well as for buildings. Environmental problems, water crisis, waste management, renewable energy resources and efficient energy management and CO_2 production will be among major issues to be handled. We will analyze how design recommendation will influence our goals of self-sufficiency and sustainability.

7.3.1 Urban Mobility Strategy:

There are approximately more than 10,000 cars in the area and due to travel to work, school and shopping, an average person produces almost 319 kg of CO_2. The following graph shows the percentage of means of transportation.

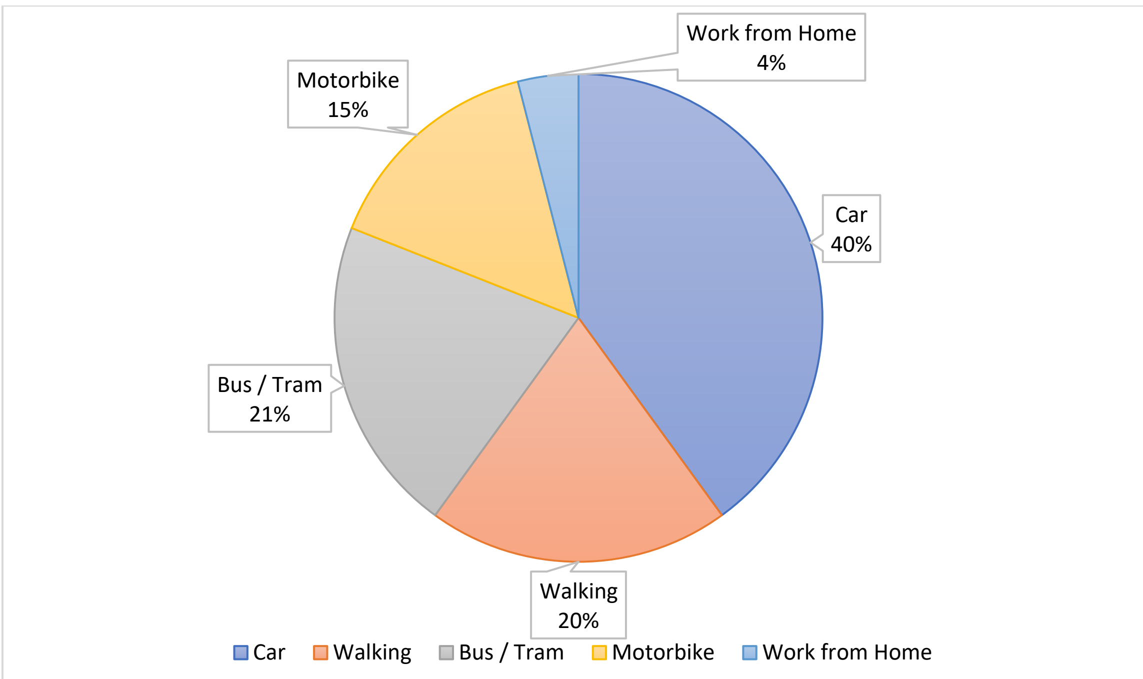
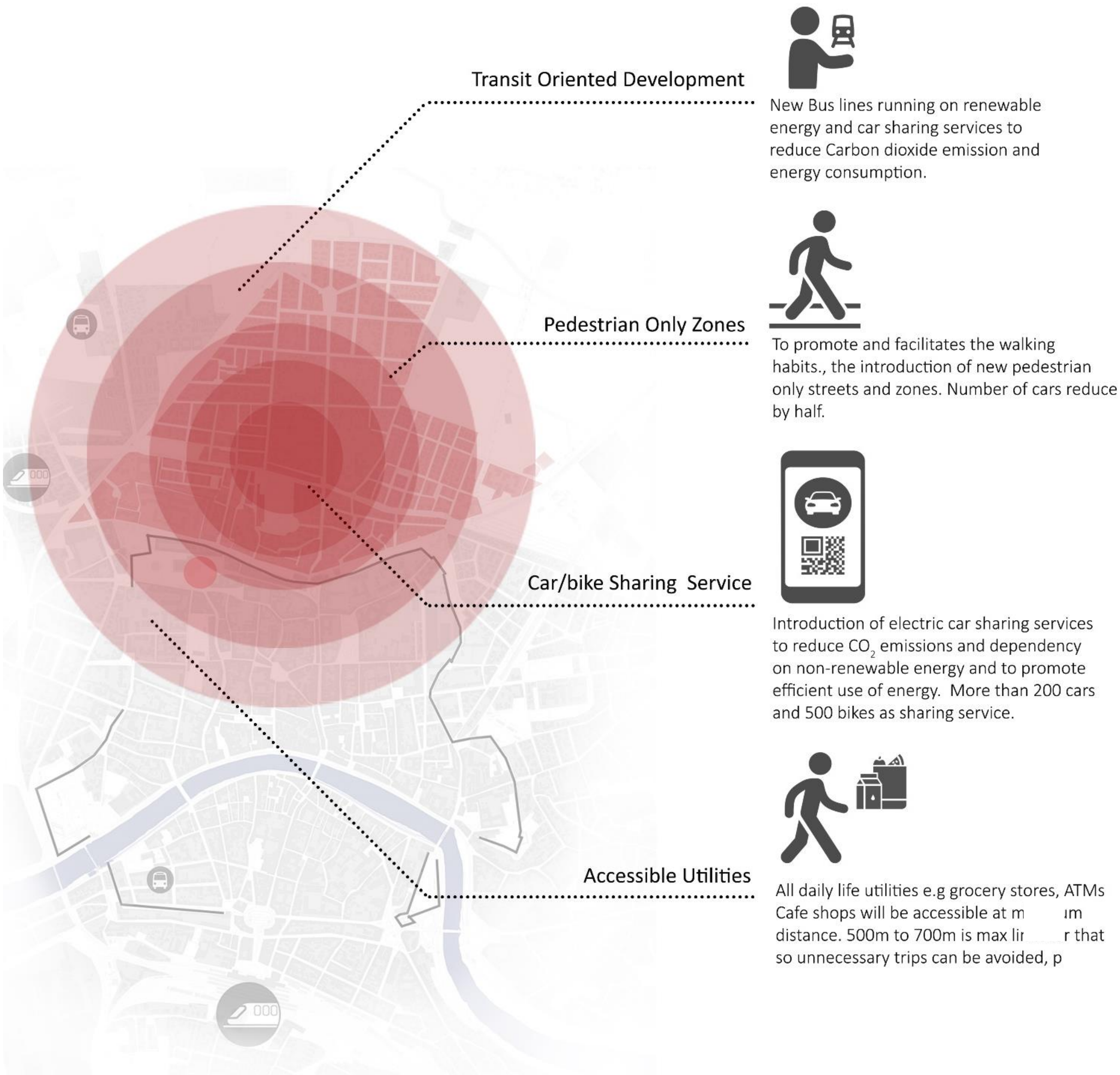


Figure 83: Means of Transportation (Numbeo, 2018)

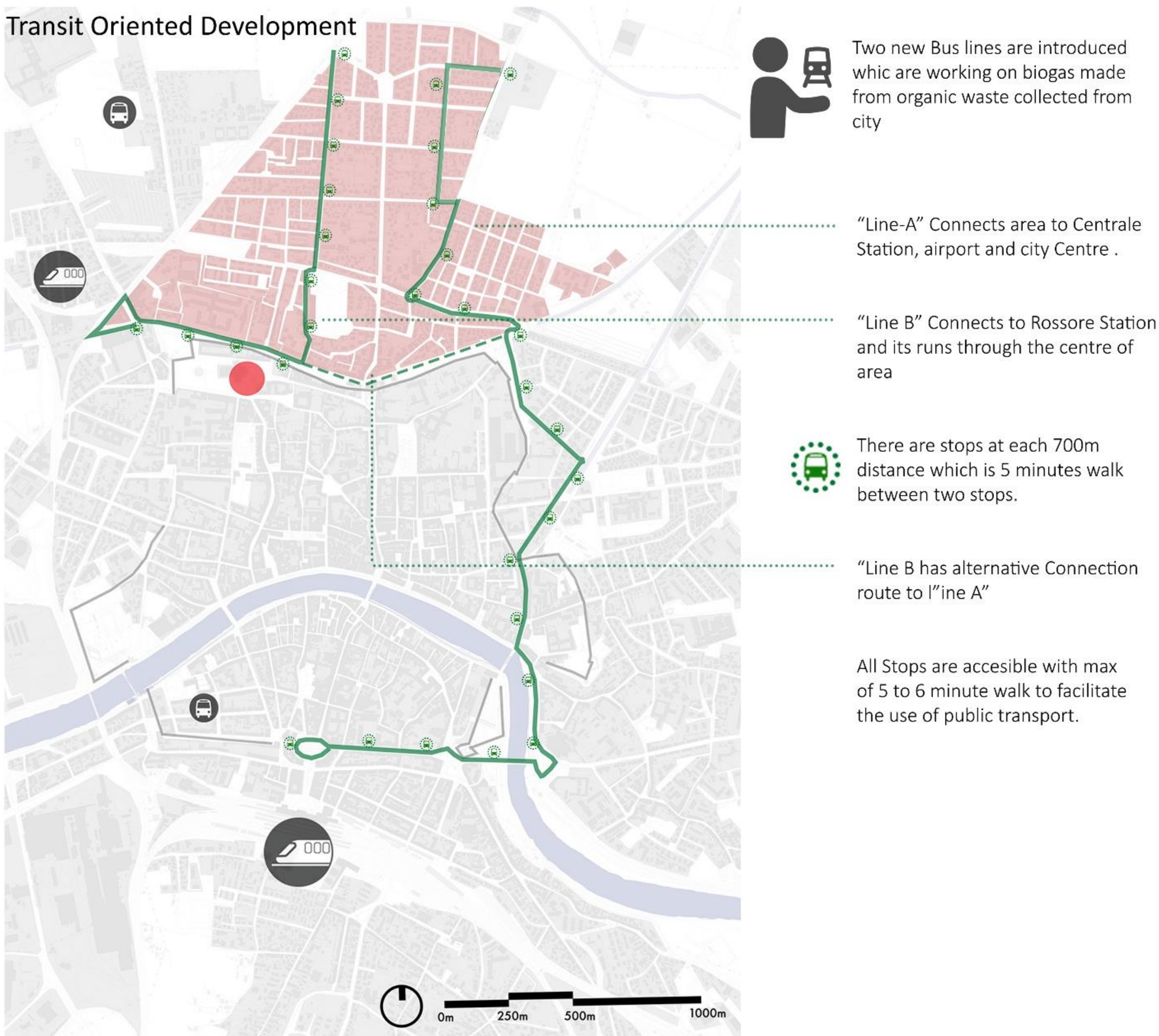
Only 20% trips to school, work and shopping are made by walking and 80% trips are made using cars, motorbikes and public transportation which runs on non-renewable energy resources.

7.3.1.1 Objectives:

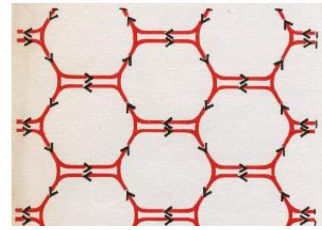


7.3.1.2 Design Guidelines:

Transit oriented development has been core of design in order to reduce number of cars in the area and to cut down CO_2 production. Cars are major source of fuel consumption and Co_2 production in the city. There are almost 12,000 cars in area and target is to reduce this number to 6,000 through *restrictive car entrance in certain areas*, *car sharing services*, accessible *services in 500m range* and *facilitated transit-oriented development*.

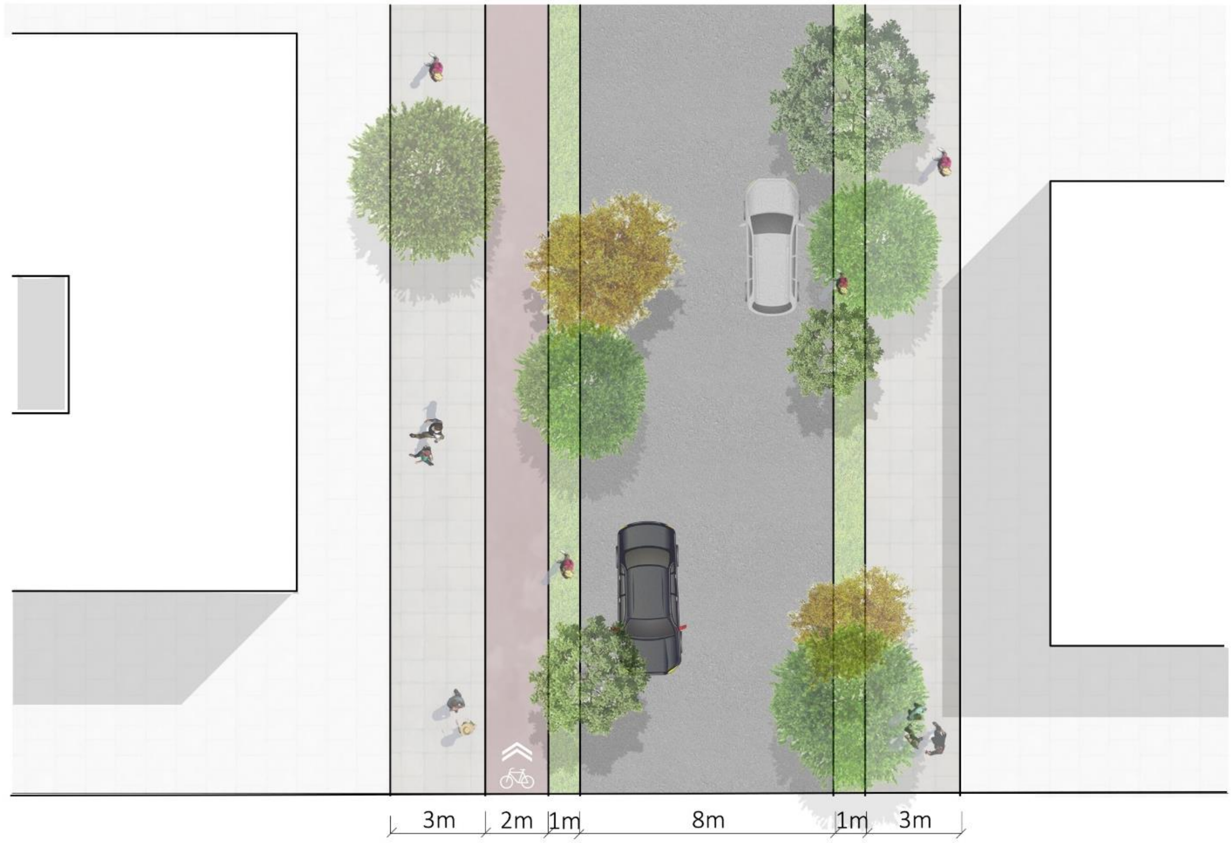


Number of cars will be reduced by introducing the concept of "***Colin Buchanan's honeycomb traffic plan"***. This way cars will go around the block and pedestrian friendly streets will become center of city life.



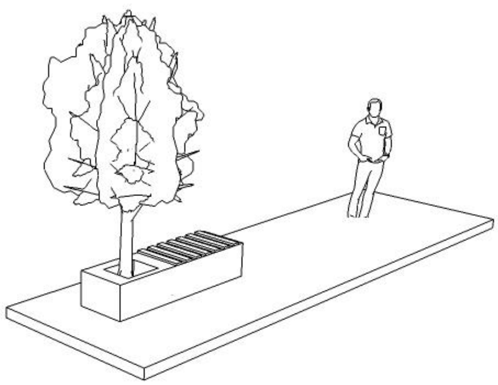
Typical Pedestrian Only Street

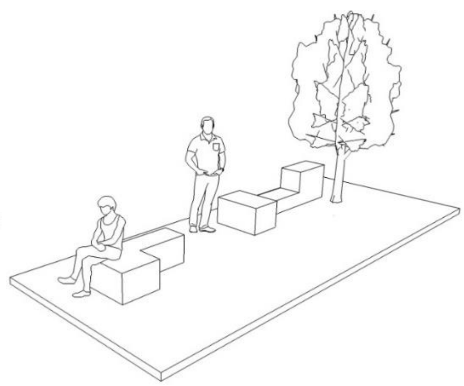
Car Accessible Roads"

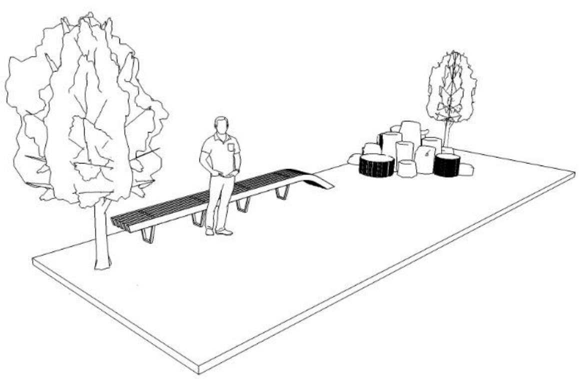


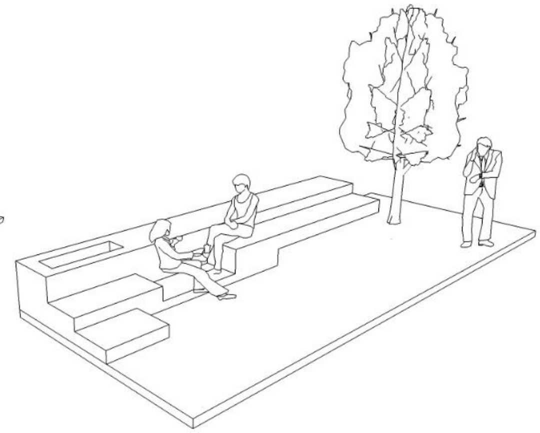
The purpose of creating pedestrian only streets is to create lively city life where interaction between people is essential and residents can enjoy city life sitting on sidewalks, walking along the way.

Pedestrian only streets have provision of car entrance for emergency e.g. in case of medical emergency or fire hazards. Car Barriers are operable and can be opened when needed.



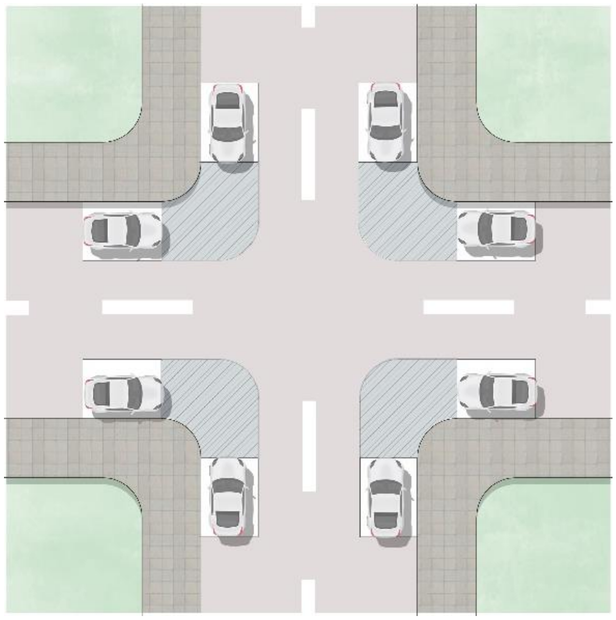


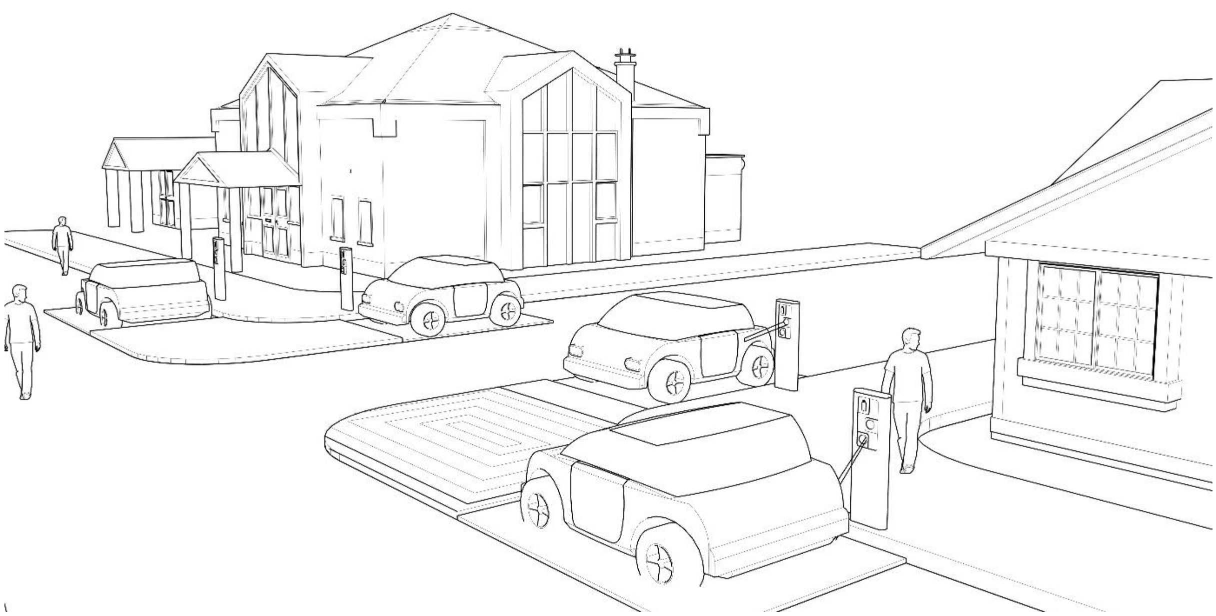




In first phase 200 cars have been place around the city and more than 800 people will benefit from this service and 500 bikes will also help us to cut down Co_2 production and gas consumption. If first phase is successful, then in next phase (2030), one hundred more cars in Porta Lucca will be introduced. ***Commune di Pisa*** has recommended that first only 10 stop with 80 to 100 cars should be installed and according to demand and change in behavior of residents we can further increase the numbers, because such initiatives takes time for residents to get familiar with and adapt new ways.

On each selected point there are two cars at each corner total of 8 at each point given the demand by residents, and the 20m^2 space at corner is floor mounted solar panel producing 1.2 kWh electricity to recharge the cars.

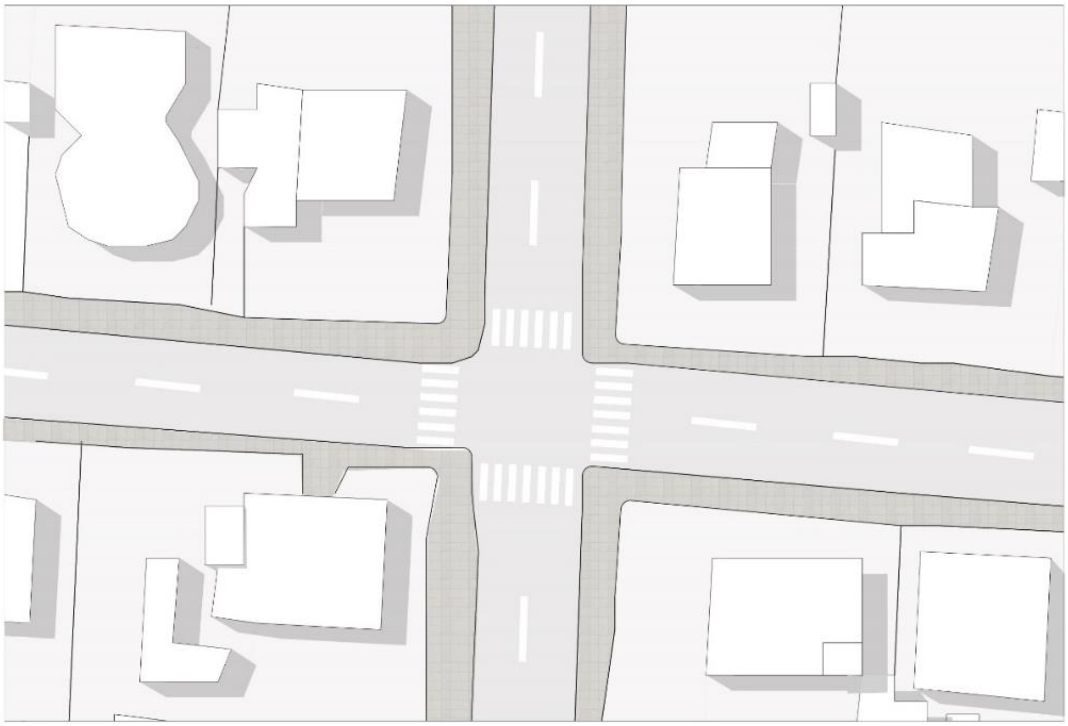




To avoid unnecessary fuel consumption for cars and motor bikes, the planning of town should be in a way that all daily life necessities should be in walking distance. School, clinic, grocery stores, coffee shops and small fast food places are few of them and if we integrate them in a way that they are accessible for everybody it will reduce daily trips to city center and commercial hub by 60 to 70%. And block sizes should be small, not more than 100m, so it’s easy to get around in foot.

In Porta Lucca all these utilities are in the northern part near city center and people have to take cars and buses to reach there.

Existing Conditions at potential four sites are almost same and one of them has been chosen to show the conceptual redesign example which can be replicable at any of these sites.



In **Conceptual New Urban Plan** square have been designed as lively space in city fabric to sit and enjoy urban life with shopping activity around. The surrounding residential buildings can be converted into commercial ones.

Its conceptual approach towards creating decentralized retail area in urban fabric which is a big problem in Pisa city. This conceptual approach can be replicated anywhere in town with the will of people as it will turn their residential properties into commercial bringing more revenue each year. Adopting this approach can be beneficial for owners raising property value but it also has some limitations.

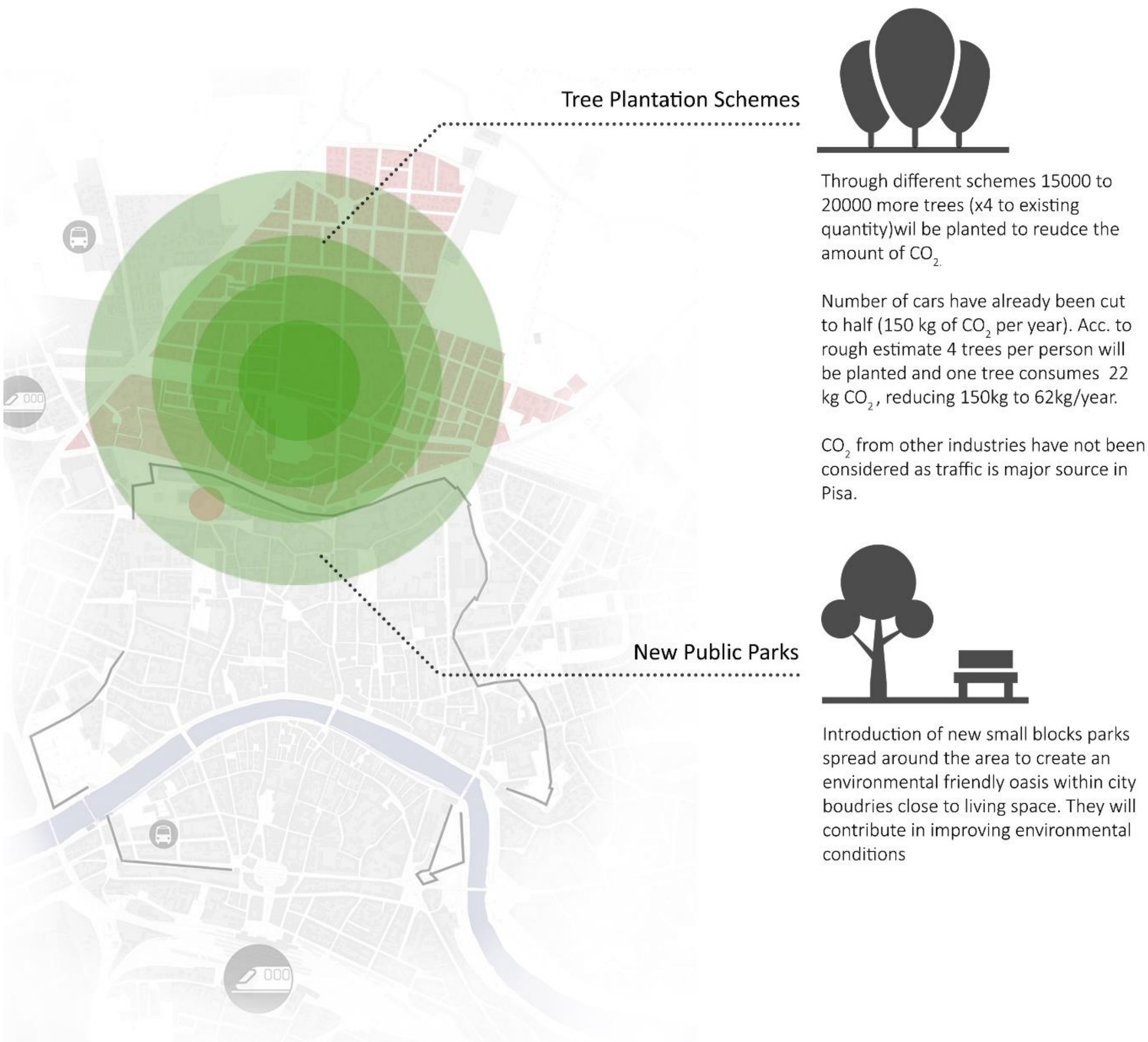
Limitations

- To Form new retail areas, residential buildings must be converted into commercial buildings and willingness of property owners can be a problem.
- Cash flows for development of new piazza's could be problem for Commune di Pisa.
- At road-cross where new urban squares have been proposed, there is not enough spaces for such intervention and to create more space city might need to acquire private land.
- A radical approach has been adopted in following replicable example of new urban square where we propose to destroy one building and acquire land from one of surrounding building's private area. This kind of solution comes with limitation of owner's agreement and commune acquiring such land.
- Nevertheless, this conceptual approach can be adopted in potential places marked in *"accessible utility map"* with modifications according to site conditions.

7.3.2 Environmental Strategy:

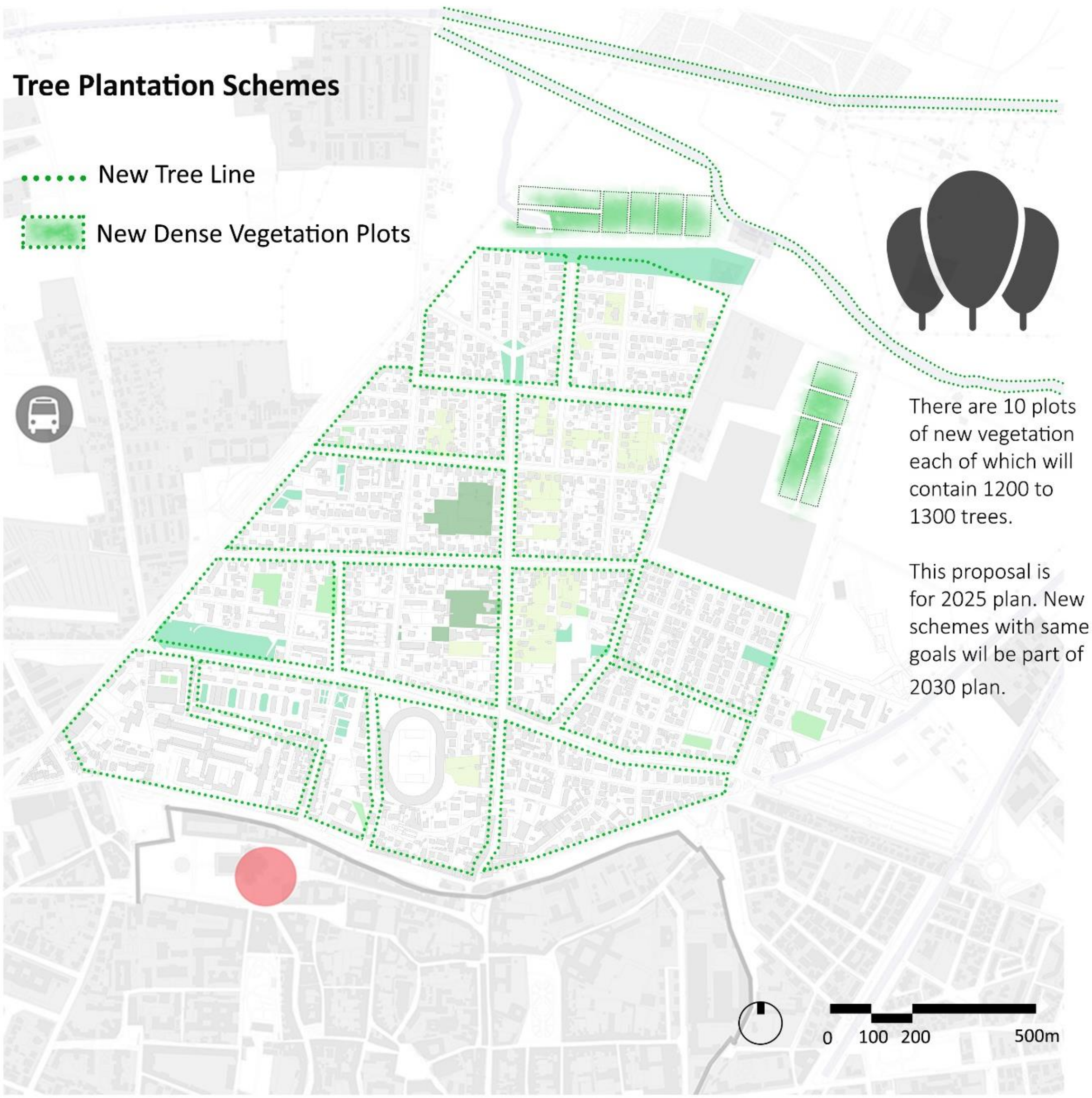
According to our analysis air pollution has index of 45 which is moderate, and the index of dirt and untidiness is high, and it has index value of 68.7 and CO_2 emission is very high. One person is responsible for 320 kg of CO_2 per year and it needs 16 trees to consume that amount of CO_2. (Numbeo, 2018)

7.3.2.1 Objectives:



7.3.2.2 Design Guidelines:

On one Acre (1 acre = 4046 m^2) we can plant approximately 700 trees with the division of ***6m^2 per tree.*** According to our proposal we need total of ***80,000 m^2***. We propose ***8,000m^2*** of 10 plots on the upper southern and eastern side of area. there are two plot sizes, ***80mx100m*** and ***40mx200m***. Plot size has been kept small so its easy to water and maintain them.



4.7% of total area was green including parks, golf course, private gardens and miscellaneous greens. In our proposal we have added 25,700m^2 and green area have increased from 4.7% to 6.4%. Decentralized small block parks are also part of scheme as ***"jane Jacob's"*** describes this concept in her book ***"Life and Death of Great American Cities"***

16m^2 open space is available per person and 8m^2 per person is available as green space.

7.3.3 Biogas Buses:

Proper and efficient waste management is necessary for sustainable and clean environment and healthy city life. In all Italian cities like Pisa there is sorting system of waste. Organic, paper & plastic, metal & glass and indifferent waste are four types which are collect. Organic waste is the unhealthiest form of waste which creates smell and is home to germs and bacteria, but this organic waste has one huge benefit and this we can turn this waste into biogas through the process of anaerobic digestions. Metal, glass and paper can be collected and sent for recycling.

- Biogas Buses will be introduced as ***"Line A"*** and ***"Line B"*** which will run on biogas or electricity from digestion process of organic waste and feces.

Figure 84:Operational Double Decker Biogas Bus in U.K.

- Approximately 5500 tons of organic waste is produced per year in the Porta Lucca area and it can be converted into biogas.
- If waste material contains 70% of biomass and the dry organics amount to 60% of the biomass. Thus, the total mass of dry organic material ($C_6F_{10}O_4$), is equivalent to 420 kg/tone of waste material. The molar mass of ($C_6F_{10}O_4$), is 146 g/mole. In other words, the expected yield of methane is 8.32 k.mol per ton of waste

material. In terms of mass, 133,5 kg or 0.1335 ton of methane per ton of solid waste is anticipated. (Mohamad Y. Mustafaa, 2015)

- 0.1335 x 5500 = 735 tons per year, producing ***62 tons*** of biogas (CH_4) per month.
- 0.55kg is equal to 1m^3 of Methane gas. So, in one tone there 2000m^3 of biogas.
- According to three Swedish examples studied the average cost of 6.5Euros to 8.5euro per 1000ft^3= 28.3m^3, ***0.2 to 0.5 euro per m^3***. (K Krich, 2005, pp. 8-10)
- Biogas bus mileage is ***2km/1m^3*** costing average of 0.25 euros per km (production and operational cost). So, in 1 tone, 4000km of distance can be travelled.
- Bus lines 20 mints span between two consecutive buses making 6 trips for both line in one hour. Operational timing is from 6:00am to 2:00am (18 hours a day).
- "Line A" has approximately ***8.4km*** trip and Line B has ***3km*** trip total distance in one day by two lines will be ***594km*** in one day total. Total cost in one day will be 150 to 200 euros.
- One tone of biogas is enough for ***65 day*** (2 months). In other words, this plan is feasible to adopt, and Porta Lucca has enough resources to run it safely once plant has been installed. Extra biogas can be used to power cars and other bus systems in city.
- It decreases CO_2 by 80 to 85% which serves our goal of sustainability and carbon free area. In production process, with CH_4, some of CO_2 is also produced which can removed through following process.

7.3.4 Sustainable Building Strategy:

In our areas of study mostly buildings are F and G-class buildings and through different strategies we can try to improve the energy performance of these buildings. One other important thing to do in the buildings is water conservation. In the following section of the chapter we will discuss these methodologies.

7.3.4.1 Water Conservation Strategy:

To minimize water usage and wastage we can adopt following method.

"Dual flush toilets" have flush tanks with two flush buttons which gives users a choice for short flush when needed and other button is for normal flush. Shot flush can save up to 2-2.5 liters per flush. (Weber, 2018)

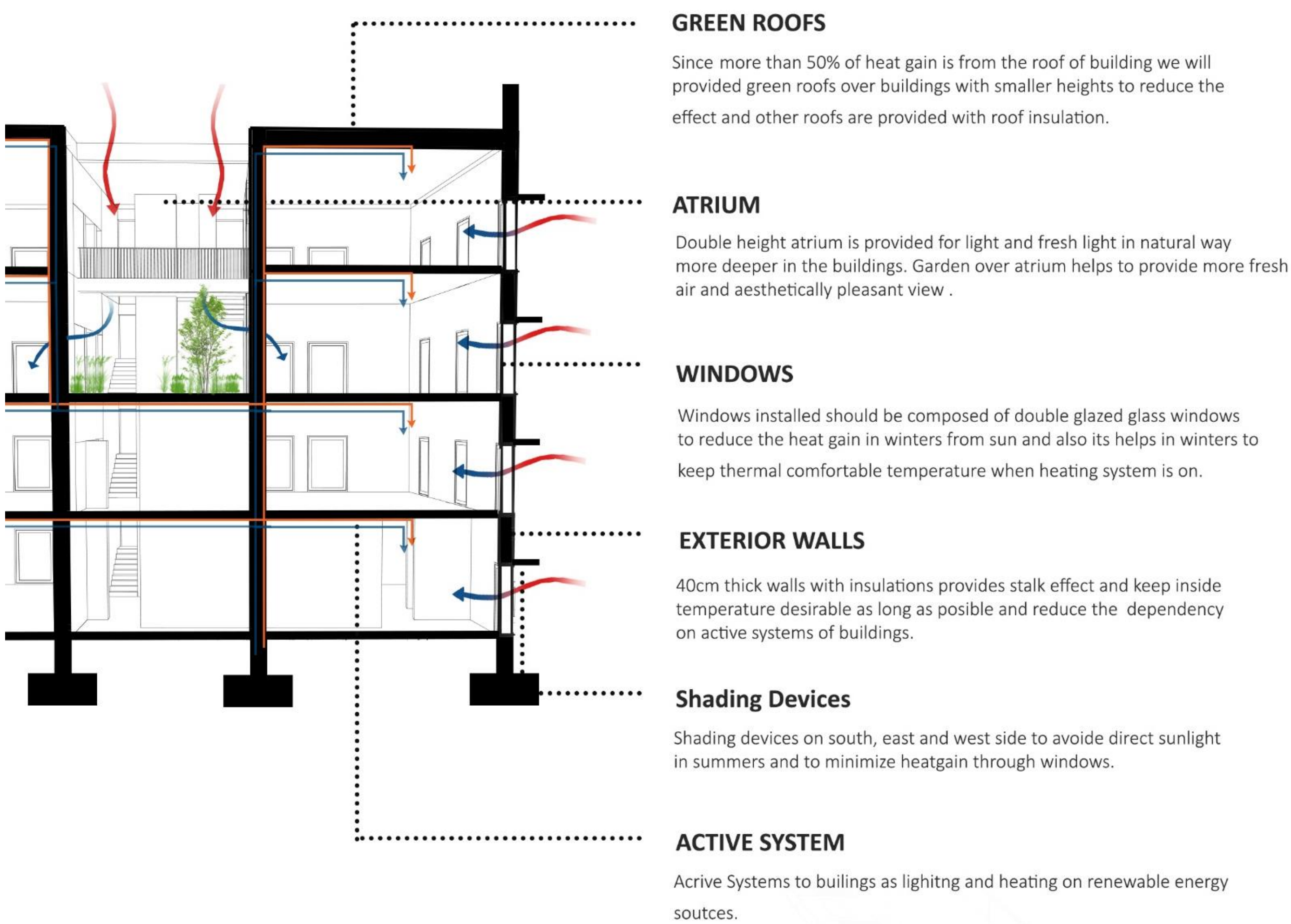
"Low flow fixtures" are essential part of any sustainable systems. Almost more than 50% of water goes unused when tap is open full and continuously running. These fixtures reduce the flow of water, ultimately cutting down water consumption.

Now days more efficient dishwashers and washing machines are available in market which use 40% less water and saves 30% energy. By using such appliances, we can achieve the level of water efficiency we need from consumer market. (Oindrila Das, 2015)

Normally 4 to 5 liters of water is used per flush but with the used "***Vacuumed flushed toilets"*** this amount can be reduced to 1-1.5 liters. Vacuumed toiled used air pressure to flush the waste. (Sheth, 2017)

7.3.4.2 Improving Building Energy Performance:

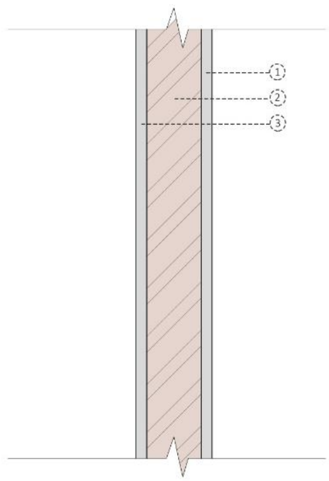
In Porta Lucca, on Existing Buildings we can try to modify few things to improve their energy performance. Building's Envelop is important in this regard and we need to modify it to improve energy performance. Windows and Roof will also be part of modification scheme.



a) Wall Design:

Existing walls were simple brick walls with plaster and paint. We have proposed addition in layers of walls on inside with Rockwool insulation and another layer of thin brick wall with air films in between to increase the R-value.

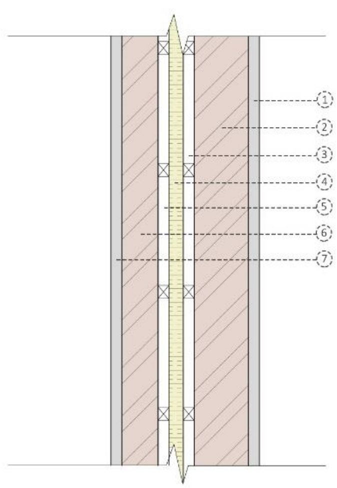
Existing Wall



1. 1.5cm Plaster with Paint (R-Value 0.01 km^2 / W)
2. 15cm Brick wall (R-Value 0.18 km^2 / W)
3. 3cm Plaster with Paint (R-Value 0.01 km^2 / W)

R-Value Total = 0.20km^2 / W)
U-Value Total = 5 W/ km^2)

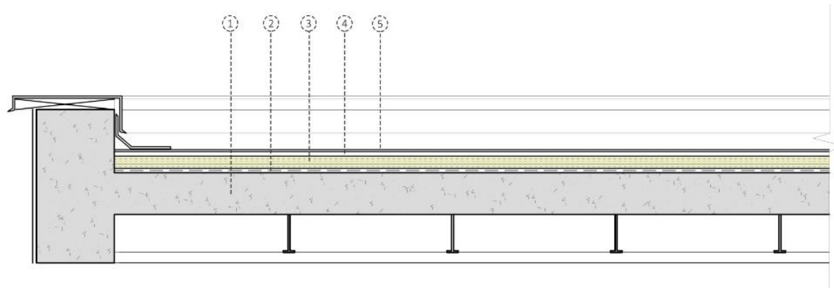
Modified Wall



1. 1.5cm Plaster with Paint (R-Value 0.01 km^2 / W)
2. 15cm Brick Layer (R-Value 0.18 km^2 / W)
3. 3cm Airfilm (R-Value 1 km^2 / W)
4. 4cm Rockwool Insulation (R-Value 3.8 km^2 / W)
5. 3cm Airfilm (R-Value 1 km^2 / W)
6. 10cm Brick Layer (R-Value 0.12 km^2 / W)
7. 1.5cm Plaster with Paint (R-Value 0.01 km^2 / W)

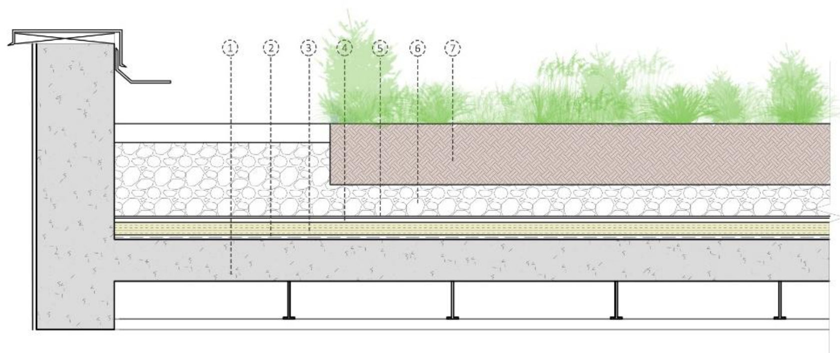
R-Value Total = 7.95km^2 / W)
U-Value Total = 0.125W/ km^2)

b) Roof Design



1. 20cm Concrete Slab (R-Value 1.2 km² / W)
2. 4cm Insulation (R-Value 3 km² / W)
3. Vapor Barrier (R-Value's Negligible)
4. Primer (R-Value's Negligible)
5. High Performance Underlay
Mineral Finish Capsheet (R-Value 0.45km² / W)

R-Value Total = 3.65 km² / W
U-value Total = 0.274 W/ km²



1. 20cm Concrete Slab (R-Value 1.2 km² / W)
2. 6cm Insulation (R-Value 4 km² / W)
3. Vapor Barrier (R-Value's Negligible)
4. Primer (R-Value's Negligible)
5. Vapor Barrier (R-Value's Negligible)
6. 15cm Drainage Granular (R-Value 3km² / W)
6. 20cm soil and Vegetation (R-Value 3.5km² / W)

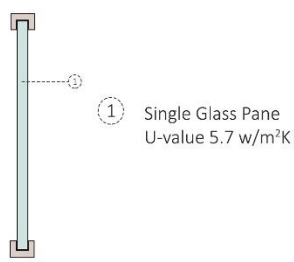
R-Value Total = 11.7 km² / W
U-value Total = 0.08 W/ km²

Conventional roof has been proposed to convert into green roof. The addition of Granular and soil layers with vegetation has increase the R-value almost 4 times of original and this help Significantly reducing the heat gain from roof.

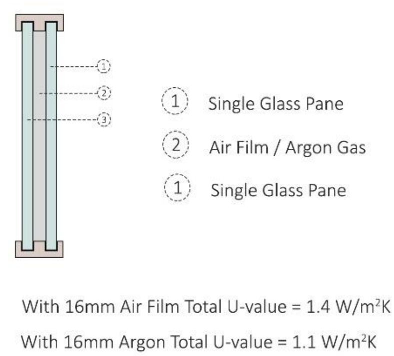
c) Windows Design

Single glazed windows have on south, east and west side have been replaced by double glazed windows. One more addition is of shading devices. South side have horizontal shading, east and west sides have vertical shading devices.

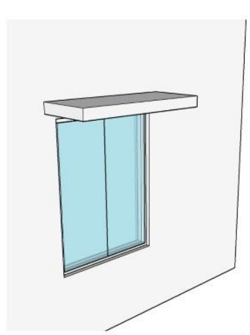
Existing Windows



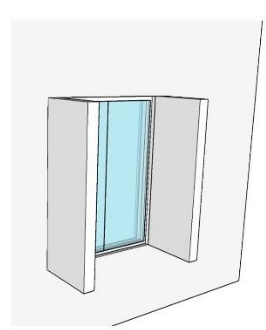
New Windows



South Side Shading



East / West Side Shading



7.3.4.2 Comparative Analysis of Energy Performance:

a) Existing Building Energy Performance:

Building Performance Factors

Location:	Pisa, Tosc., Italy
Weather Station:	155014
Outdoor Temperature:	Max: 35°C/Min: -7°C
Floor Area:	1,219 m²
Exterior Wall Area:	766 m²
Average Lighting Power:	9.69 W / m²
People:	44 people
Exterior Window Ratio:	0.20
Electrical Cost:	$0.28 / kWh
Fuel Cost:	$1.41 / Therm

Table 17: Building Performance Factors

Energy Use Intensity

Electricity EUI:	138 kWh / sm / yr
Fuel EUI:	341 MJ / sm / yr
Total EUI:	839 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	4,595,748 kWh
Life Cycle Fuel Use:	11,334,339 MJ
Life Cycle Energy Cost:	$644,616

*30-year life and 6.1% discount rate for costs

Table 18: Energy Intensity and Life Cycle Energy Cost for Existing Building

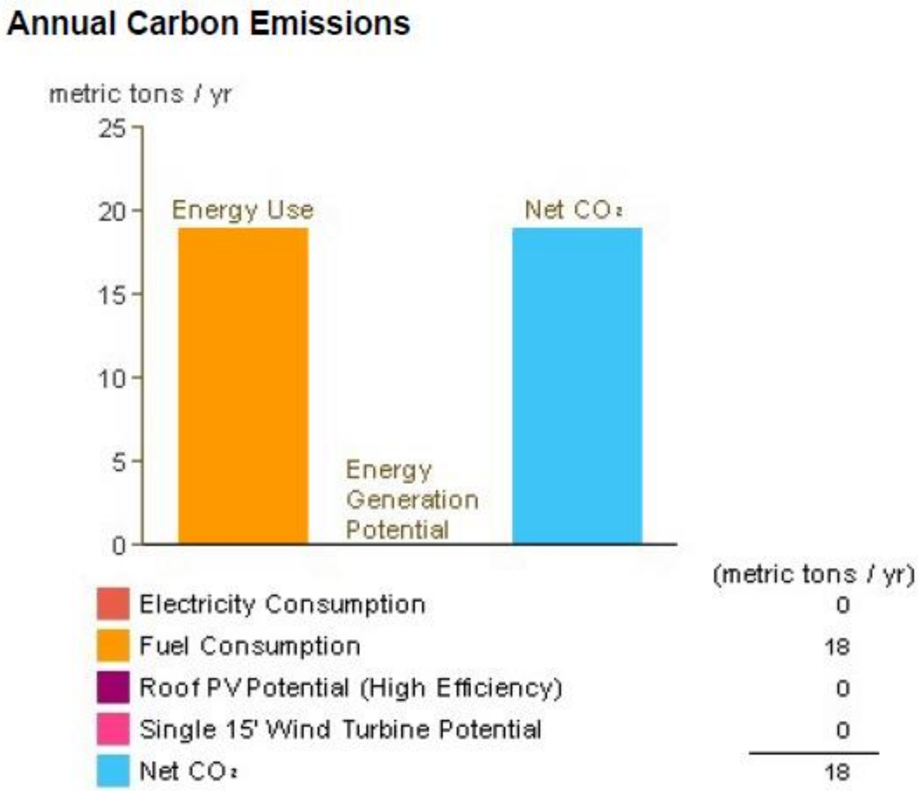


Figure 85: Annual CO_2 Emission per Year for Existing Building

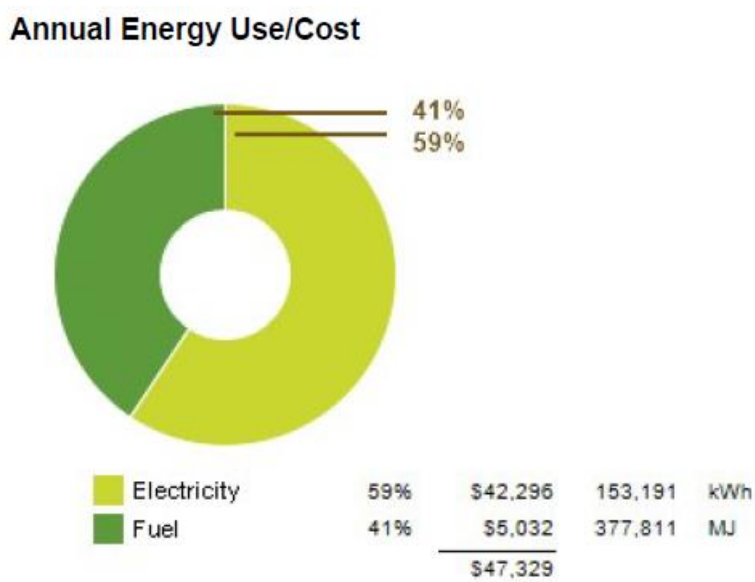


Figure 86: Annual Energy Use and Respective Cost for Existing Building

b) Modified Building Energy Performance:

Energy Use Intensity

Electricity EUI:	96.6 kWh / sm / yr
Fuel EUI:	238.7 MJ / sm / yr
Total EUI:	587.3 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	3,217,023 kWh
Life Cycle Fuel Use:	7,934,037 MJ
Life Cycle Energy Cost:	$ 451,231

*30-year life and 6.1% discount rate for costs

Table 19:: Energy Intensity and life Cycle Energy Cost for Modified Building

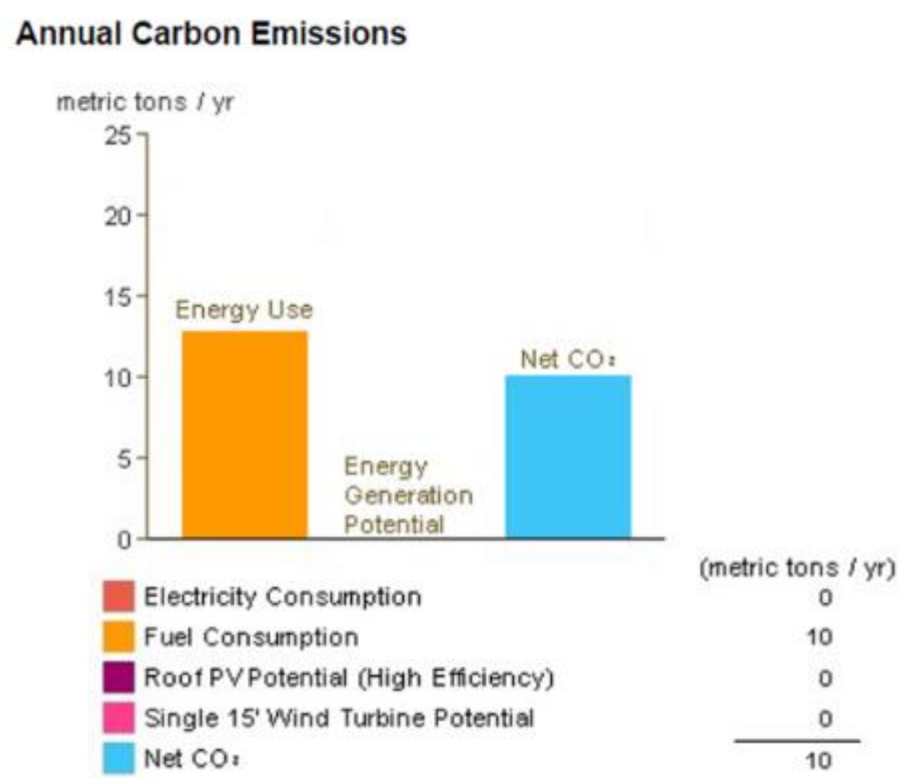


Figure 87: Annual Carbon Emission for Modified Building

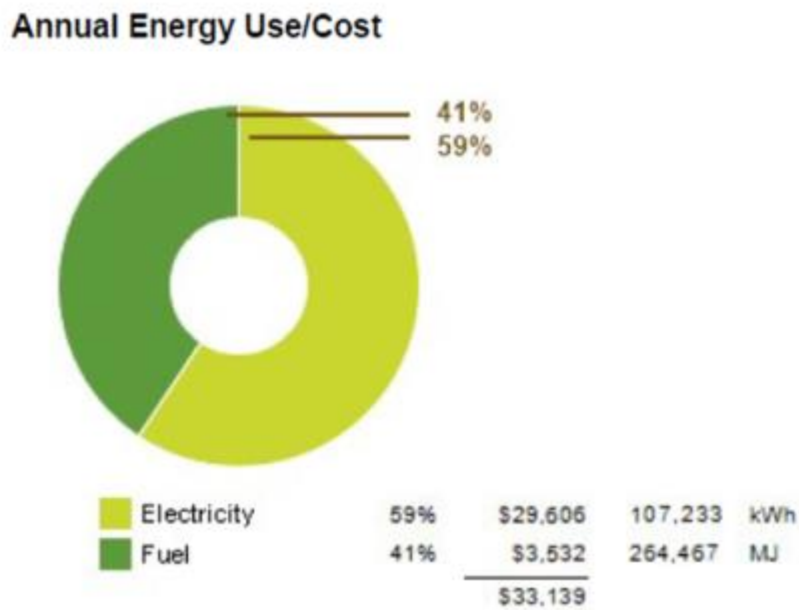


Figure 88: Annual Energy Use and Respective Cost for Modified Building

Energy Data can be sued to design the Solar panels system for building in order to achieve at least 50% of Total energy because of limitation of building area. It can increase by installing PV panels on south façade.

Conclusion:

Sustainable and self-sufficient developments are crucial to ensure a better life for future generations and it's been many years now since researches and planners have been experimenting new techniques to minimize the effects of built environment on fossil fuel consumption, water resources depletion and bad environmental conditions.

In such era experimental projects and research-based work is important to open new doors for future developments. From existing examples of sustainable, green and smart developments, we can learn the pros and cons of adapted planning methodologies and technologies to reinvent them in order to achieve higher efficiency. This thesis is one step forward towards learning these techniques as primary object and their practical application. Research and collection of dispersed data in one place and analysis of operational sustainable developments to learn and assess the efficiency of existing ones is very important in order to gain knowledge and research further to improve the already adapted techniques. Our thesis has been done keeping in mind the importance of need of such research works in the field of sustainability given the challenges of our time and I would serve as knowledge source in the relevant field.

The Research has been divided into two major parts, macro and micro level. Macro level investigation concludes that proper planning for cities and new districts within the fabric of old towns, with clear cut goals of sustainability is essential and for this political willingness and community engagement is necessary. From the preliminary phase of design, the demographical features, strength and weaknesses of site, challenges faced by community and achievable goals should be very clear so from the very start of projects everything could be done in systematic way because such projects are long term and of huge magnitude. Long term planning and ability to predict future trends and problems could pay a crucial part because such projects take so much long, planners should consider all the factors which could contribute in any way in shaping the community and could affect our set out targets.

Systematic approach towards the solution of each challenge is important for example how energy consumption can be minimized through planning is important question to ask and then through planning we can address that problems for example, uniform distribution of utilities at walking distance can reduce use of car ultimately cutting down CO_2 production and fuel consumption. Pedestrian friendly, car free zone, shared car services, transit-oriented development are few of these methodologies we can adapt to tackle an issue. Proper ratios of open and built space, green areas, excessive tree plantation schemes and water bodies can ensure the better environmental conditions. Proximity to main infrastructure of city and easy access to train stations and airports is very important for such developments. Water recycling, reusing and waste management also plays an essential part in establishing such communities. In terms of renewable energy resources, the important part is to evaluate the site conditions properly and resources needed before deciding which one is feasible solution.

Such projects should be divided in different segments and through set by step process we should analysis the performance and then move forward with completion. There should always be room for improvements, because each day there are new techniques being discovered and tested. Designing for targeted group of people limits the scope of such project so inclusion is necessary.

New urban strategies (New vegetation plots, Restricted car access, Pedestrian Friendly streets, Tree plantation schemes, Electric Car sharing Services) would help bring the CO_2 from 319kg to almost 70kg per person a year and cut down the huge amount of fuel consumption. 5500 tons of organic waste can be converted into 62 tons of biogas per year, which can almost provide enough gas for all public transport for whole year.

Micro level analysis of theoretical data and case studies explores the sustainable building strategies. From buildings construction phase to operational cycle, each phase has its own challenges. In the preliminary design phase, clients and architects should discuss and finalize the sustainability goals and main strategies to achieve them so from the start of project all stake holders work together towards those targets. Construction phase has low impact because it lasts for short period but minimum carbon foot print, use of sustainable materials, waste management and proper execution of all building phases are important because they are going to determine the performance of building in years to come.

"Passive design systems" are sustainable strategies which helps minimize the role of active system in buildings. Each one of these strategies contribute to the better energy performance of building. Building orientation is important for example buildings facing south side perform better. Day and night spaces in building w.r.t sun path helps to create comfortable indoor spaces. Building envelop is one of most crucial things in this regard. Determining the position of walls which has most sun exposure to selection of materials with proper insulations, based upon their U-value is part of whole process. Central courtyard or patio for better air circulation and natural light access is part of passive design.

Variety of sustainable materials are available which can replace conventional construction materials. These materials have better structural endurance and low Carbon foot print. Consumer trust can be an issue with new materials but with proper guidance it can be achieve. Rammed earth fly ash brick, ferrous concrete, bamboo and cork are few of such materials and they have been tested positive for their respective use.

Building management system has proven to be one of best addition to buildings operational structure because it makes our building as efficient as possible. It ensures maximum comfort at the expense of minimum energy possible. The best part is, it collects user information to access and predict future trends. Specially-design smart systems for lighting, cooling and heating can help prevent excessive use of energy.

Due to Proposed changes in buildings we observe a significant change in performance of building. Approximately 30 to 35% decrease in energy consumption has been observed and decrease in CO_2 is 8 metric ton/year. Annual cost of energy dropped from 47 thousand to 33 thousand. Though no renewable sources for building has not been proposed but according to data available a new PV panels system can be installed.

Significant amount of water can be water can be saved through use of low-flush toilets, dual flush toilets, low flow fixtures. Recycling of grey water to reuse for flushing toilets is one best strategies in this regard.

Only right decision making, willingness to build and with purpose can enable us to achieve these goals. From start to end, in all phases of project all objectives and scope of project should be clear. Achievable goals should be set out keeping mind the resources at our disposal. Not only new developments but existing ones either buildings alone or cities as whole, should also be converted into smart, efficient systems which produce what they consume.

"where there is will, there is a way" is saying which summarizes all I would like to add. To build a better life for us and our future generations we need to work more towards sustainability and only building smart, self-sufficient, sustainable buildings and cities won't be enough we have to build a sustainable life style. This work is a little attempt to build a bridge towards better future, much more is to be done. I hope my work will inspire others to investigate more in this field and invent new techniques to build a safe world for many centuries to come.

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