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Reconfiguration of infrastructure in an existing neighborhood to achieve more sustainable environment (in terms of carbon emission reduction)

Master dissertation

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PREAMBLE

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Notations and conventions

- The present report is divided into 2 *chapters* of theoretical and practical outcomes and chapters are broken down into 8 *sections*.
- Where necessary, sections are further broken down into *subsections* which the headers are highlighted in green and contain some *paragraphs, figures, tables and charts*.
- *Figures*, *tables* and *charts* are numbered inside a section. For example, a reference to *Figure j* of section *i* is noted *Figure i.j*.
- Formulas are located in highlighted boxes.

About this documentation

In this research an attitude is discussed which leads to a method. In order to verify this method some data were in use. Majority of these data compilation had been done through personal observations. Therefore we assume that the basic data used as material are accurate.

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CHAPTER I: THEORETICAL PART

1
INTRODUCTION

On the one hand, all aspects of our lives are dependent on infrastructure. We need to reconfigure infrastructure, to be able to live more sustainably. We require public transportation vehicles to run on time, safe and secure public spaces, space to segregate our waste, pleasant cityscapes, clean water from sustainable sources, regular urban utility services and low carbon energy supplies. Majority of these requirements can be achieved by reconfiguring what we currently have, retrofitting the unsuitable items, recognizing linkages between different systems and considering the requirements for new or different service provision.

On the other hand, current emissions of anthropogenic greenhouse gases including carbon dioxide, have already committed the planet to an increasement in average temperature of the Earth in the recent years that may exceed the critical threshold of numerous unmanageable and irreversible consequences such as abrupt change in the climate system.

Therefore, the effect of human activities on global warming of our planet is the subject of huge number of recent studies over the past twenty years. This has created a worldwide debate on the above-mentioned subject which is emphasizing on long-term reductions of CO_2 emissions among many nations in various methods, mainly through increased energy efficiency, renewable energy sources, and many other low-carbon strategies. Moreover, among the entire human made factors resulting CO_2 emissions, infrastructures and specifically buildings are considered to be one of the most effective of all.

As well, the physical infrastructure in our neighborhoods requires continual maintenance, repair, and significant upgrading to avoid falling into disrepair which causes economic, environmental and social costs and as well to achieve the global carbon reduction targets. In doing so, we have the opportunity to address climate change adaptation, deliver reliable and efficient transport networks, improve health and well being, secure a healthy natural environment, improve long-term housing supply, maximize employment opportunities and make our communities safer and more cohesive.

Thus, it is required to adapt our existing neighborhood to turn it in to healthier, safe & carbon efficient environment.

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OBJECTIVES

The significance of this research is to verify the following aim:

- Possibility of improving existing infrastructure at a local level by retrofitting so as to deliver carbon emission reduction and adaptation measures while at the same time achieving wider economic, environmental and social benefits and improving the sustainability of the existing places & thereby improving quality of life in the long-term.

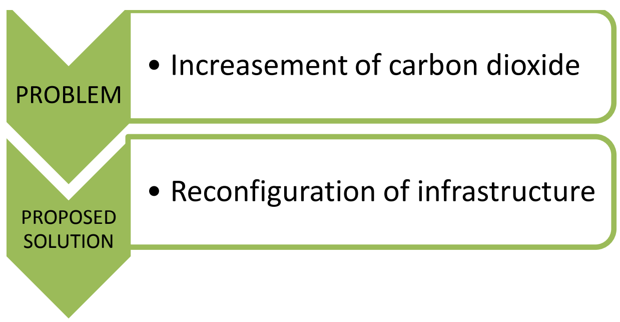

Figure 2.1 – Poblematic of the research and the proposed solution

This research is trying to introduce the socio-technical model of carbon reduction simulation in buildings of a neighborhood at local level which has the potential of being extendable to larger scales. At first place, it will predict current local carbon emission rate and the changes resulting from energy efficiency measures, the deployment of renewable energy technologies and the use of non-technical interventions in a neighborhood level. The model will be developed, validated and demonstrated using both existing data and new data collected in a neighborhood from randomly selected buildings which are representative of the rest of the neighborhood. Potentially effective socio-technical interventions can be implemented and the long-term impact of it to achieve a low-carbon community is the discussion of this research.

3

METHODOLOGY

The research methodology combines different approaches in order to allow for a full understanding of the issue.

The theoretical part was investigated through a literature study on the field of sustainability and low carbon strategies which was consisted of web-based and library studies. In addition, archival data-based researches (practical articles and reports) provided an extensive range of experiences in these criteria within different contexts.

In the rudimentary phase, primary problematic and hypotheses – as mentioned in the previous section – were conjectured roughly. Then the next phase was external and desk-based research by getting benefit from the knowledge of technical experts and professors.

In the next section (section 4), the detailed definition of all the keywords and implementations will be discussed.

The approach selected for the second part of this research (practical part) is by means of case studies. Therefore, in the following section (section 5), similar samples in the mentioned field will be analyzed.

After appraisal of these samples, the research tries to address the issue. Afterwards, a related case study is used as a main strategy of the research. Data collection and personal observations led to some databases which were used for calculations of some issues using qualitative method and mathematical sciences. Some of these issues can be summarized as rate of carbon emission, energy requirement, energy consumption, etc.

Combination of both methods, were used to complete the literature, gain some outcomes and reach a particular conclusion. So in this section all the results will be revealed and there will be a modification on the data and a simulation of the new scenario. Finally, the research attempts to use the data to propose innovative tools and solutions.

4

DEFINITIONS

4.1. Sustainability

The word “sustainability” has several meanings. Three of the definitions – which are closer to our point of view in this research – are as followed:

- “meet present needs without compromising the ability of future generations to meet their needs”(Source: WECD, 1987)
- “Capability of being continued with minimal long-term effect on the environment.”(Source: The American heritage dictionary)
- “For humans, sustainability is the potential for long-term maintenance of well being, which has environmental, economic, and social dimensions”(source: Wikipedia)

In other words, sustainability can simply be defined as a desirable or suitable state of urban conditions which has the potential to persist and remain longer.

Sustainability is often used with key phrases such as inter-generational equity, ecological cycle and preserved biodiversity, protection of the natural environment, resilient to climate change and natural hazard, minimal use of non-renewable or virgin resources, economic vitality and diversity, self-reliance of communities, individual wellbeing, reduction of ecological footprints and satisfaction of basic human needs.

4.2. Sustainable neighborhood

Now here there would be a question of sustainability assessment which asks: **How does a sustainable neighborhood look or feel?** According to the above definition of sustainability from Wikipeida, a zone can be studied in different points of views to be considered as a sustainable neighborhood.

- In terms of **economy**, a neighborhood which offers the residents with local jobs, the opportunity of reinvestment & bringing new incomes is defined as sustainable. In such a place the fuel poverty is minimized. It is centered on local economy and the buildings in this neighborhood cost less to run.
- In **social** point of view, a community which provides maximum services, appropriate transportation choices and maximum quality and value of spaces is considered sustainable. In this neighborhood, there is maximum community cohesion, interaction and civic pride. Fewer

residents are suffering from health inequalities and fear of crime. This society is more safe, secure and healthy.

- In terms of **energy consumption**, a neighborhood can be called sustainable when there is minimum use of virgin resources such as fossil fuels like oil, coal, natural gas, etc. and maximum use of renewable, recycled and waste resources such as bio-fuels, geothermal, solar, wind and biomass. In such a neighborhood, there is maximum linkage between resources used in the neighborhood and accordingly energy security and energy efficiency is improved. In this place, the biodiversity is enhanced and preserved. So water and air quality is maximized and there are minimum greenhouse gas emissions. Therefore, such an environment is as well resilient to the climate change impacts.

4.3. Infrastructure

The term refers to any physical structures, facilities or potentials in an environment which are essential for and effective on living conditions of human being. So according to this definition, all built or natural environment in a neighborhood can be considered as infrastructure. Therefore, infrastructure can be generally being divided to seven main categories:

- **Building:** It refers to any built construction independent of its function. Even derelict buildings are considered in this category.

- **Utility:** Any public services such as electricity, water, natural gas and telecommunications is called utility.

- **Transportation:** All modes of movement networks are done in railways, airways, water canals, roads and pipelines which are considered as transport infrastructure. Roads, pedestrian routes and cycle paths are some of the examples.

- **Waste:** The means of flowing away sewage and waste is called waste infrastructure.

- **Green space:** All green spaces consisted of natural or human-made such as all designed and theme parks, landscapes, preserved biodiversity, green public spaces, gardens, playing fields, etc. are in this category.

- **Blue space:** General term of blue space is referring to lakes, rivers, sea water, oceans, canals, waterscapes, etc.

Even though in this research the term infrastructure is used as the combination of all the seven categories to describe an integrated reconfiguration, our scope of work is restricted to the buildings.

4.4. Carbon dioxide emissions

Carbon dioxide which chemically is called CO_2 is one component of the greenhouse gas. The greenhouse effect is a natural phenomenon which has a potential to be a natural hazard. Some gases including carbon dioxide– already exist in the atmosphere in small concentrations. In greater concentrations they can create solar radiation. These gases have an influence to retain the Earth's average temperature on approximately 15°C. Recently the amount of these gases is rising abruptly. Consequently, the Earth's surface temperature is rising extremely rapidly. Since the early 20th century [according to US department of state], the temperature has risen by 0.6 ± 0.2°C. This phenomenon is called global warming which could lead to abrupt climate change and therefore natural hazards such as storms, floods, heat-waves, tsunamis and etc are occurring more frequently recently. *(See chart 4.1)*

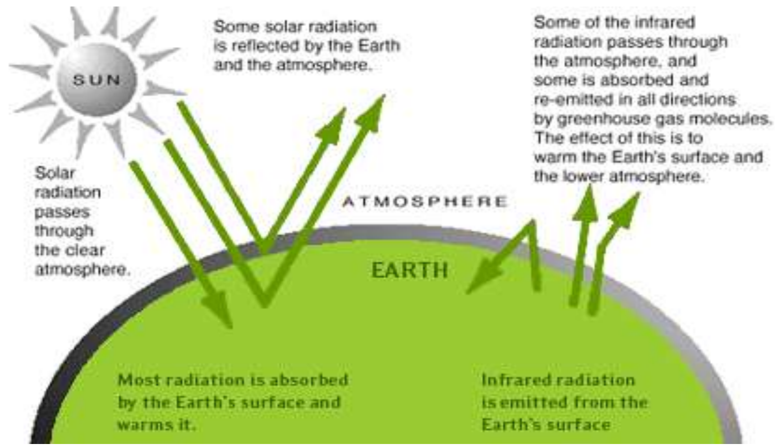

Figure 4.1 – The greenhouse effect (source: US department of State, 1992)

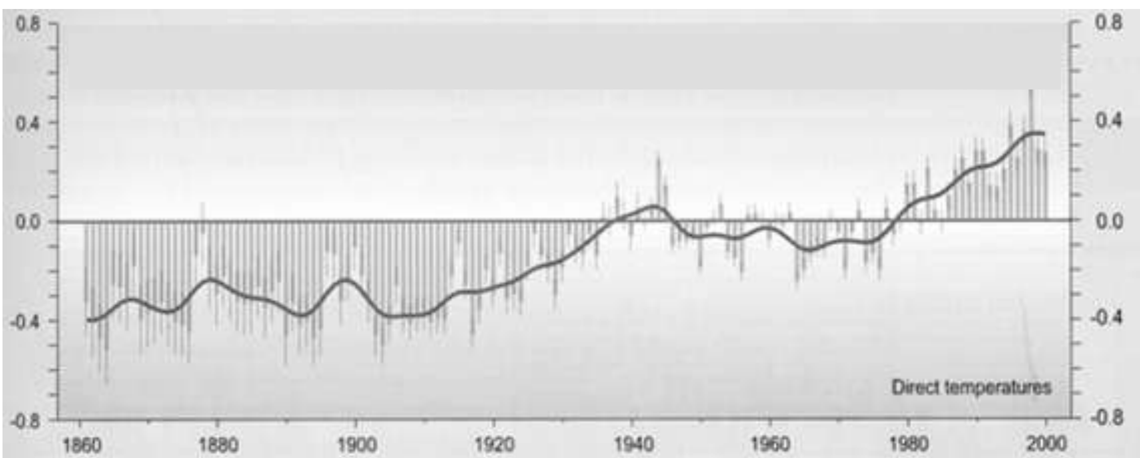

Chart 4.1 – Variations of the Earth's surface temperature in the last 140 years(per degrees Celsius)(Source: The doomiest graphs of 2010 by Desdemona Despair)

CO_2 is emitted in two main ways. The first and major cause of CO_2 emissions is natural which is not usually toxic and can be emitted by respiration of animals and plants, volcanoes, forest fires and oceans due to warming. Another origin of CO_2 is human-caused. Vehicles, engines, machines and generally combustion of fossil fuels, land clearing, energy consumptions in transportation sector or building sector are some of the main causes of these emissions and generation of air pollutants including CO_2 which has a great impact on fraction of the rapid increasing in global warming.

These activities have caused a substantial rise in global atmospheric concentrations of carbon dioxide in recent years. Current atmospheric concentrations of CO_2 are approximately 30% higher than 150 years

ago equivalent to the beginning of industrial revolution (pre-industrial era). The current CO_2 levels of the entire globe are higher than they have ever been. *(See Chart 4.2 and table 4.1)*

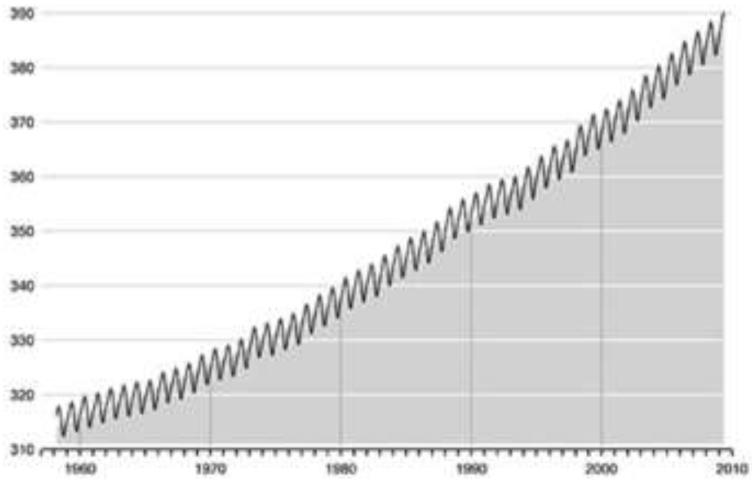

Chart 4.2 – Monthly global carbon dioxide concentration level per ppm in a 50 year horizon (Source: Carbon dioxide information analysis center, 2010)

	Pre-industrial level (before 1750)	**Current level[1]**	**Increasement since 1750**	**Annual increasement since 1960**	**Increasement by 2050**	**GWP[2](100-year time horizon)**	**Atmospheric lifetime[3](years)**	**Increased radiative forcing[4] (W/m^2)**
Carbon dioxide	280[5] ppm	388.5 ppm	108 ppm	0.4 – 2.9 ppm	130%	1	~100	1.66

Table 4.1 – Global CO_2 emission increasement level (According to: International Energy Agency & Carbon Dioxide Information Analysis Center)(See endnotes)

On the contrary to the other pollutants, carbon dioxide emission is not a result of inefficient combustion. In fact, it is a product of ideal combustion of carbon. CO_2 emission is directly proportional to energy consumption. The more energy we consume, the more carbon dioxide we emit.

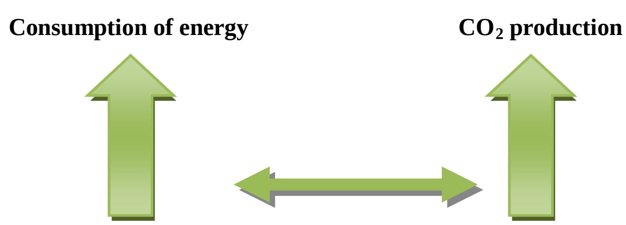

Figure 4.2 – proportionality of consumption of energy and production of CO_2

Majority of CO_2 emitted by human beings are result of fossil fuel consumptions. In following chart and table the contribution of some of the common fuels to the carbon dioxide emissions are listed. *(See chart 4.3 and table 4.2)*

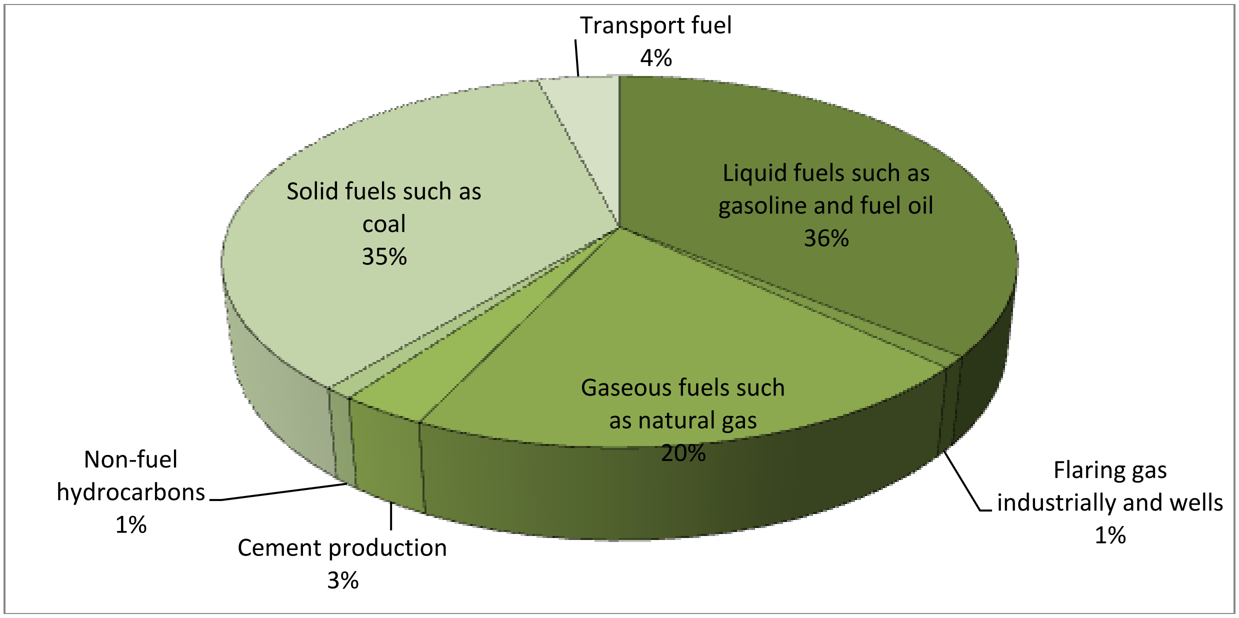

Chart 4.3 – Contribution of main fossil fuel combustion sources in CO_2 emissions (According to EPA)

Fuel (1 million BTU)	Production of CO_2 (lbs)
Natural gas	117
Liquid petroleum gas – Propane	139
Aviation gasoline	153
Automobile gasoline	156
Kerosene	159
Fuel oil	161
Wood	195
Coal (bituminous)	205
Coal (sub-bituminous)	213
Coal (lignite)	215
Coal (anthracite)	227

Table 4.2 - Carbon dioxide production from burning fuel (According to Power Partners resource guide)

According to the US Environmental Protection Agency (EPA) major sources of greenhouse gas emissions in one neighborhood include home heating and cooling systems, electricity appliances, energy consumption and transportation. Some of the corresponding conservation measures which are usually suggested to this issue are improving home building insulation, installing geothermal heat pumps, compact fluorescent lamps or solar panels, choosing energy-efficient vehicles, etc. (See chart 4.4)

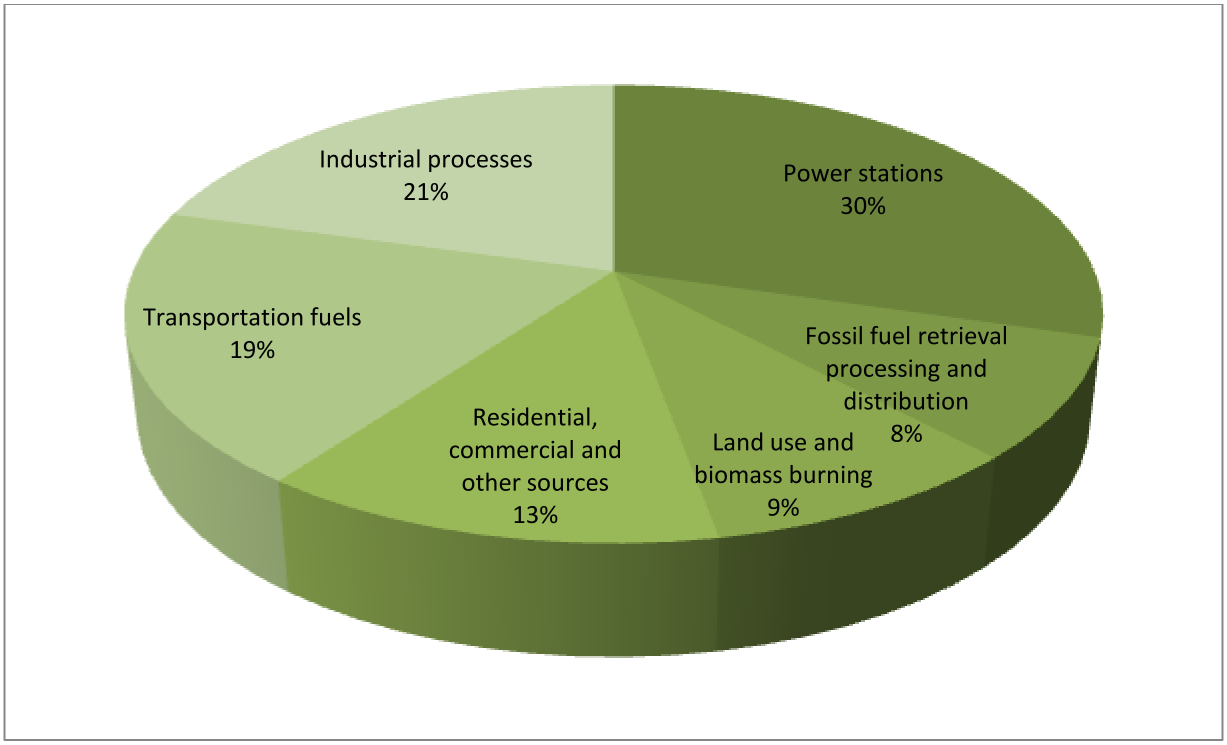

Chart 4.4 – Annual carbon dioxide emissions by various sectors(According to US Environmental Protection Agency (EPA))

The top 10 annual CO_2 emitters by year 2006 are as below. Therefore Canada and United States respectably have first and second rank in global emissions.

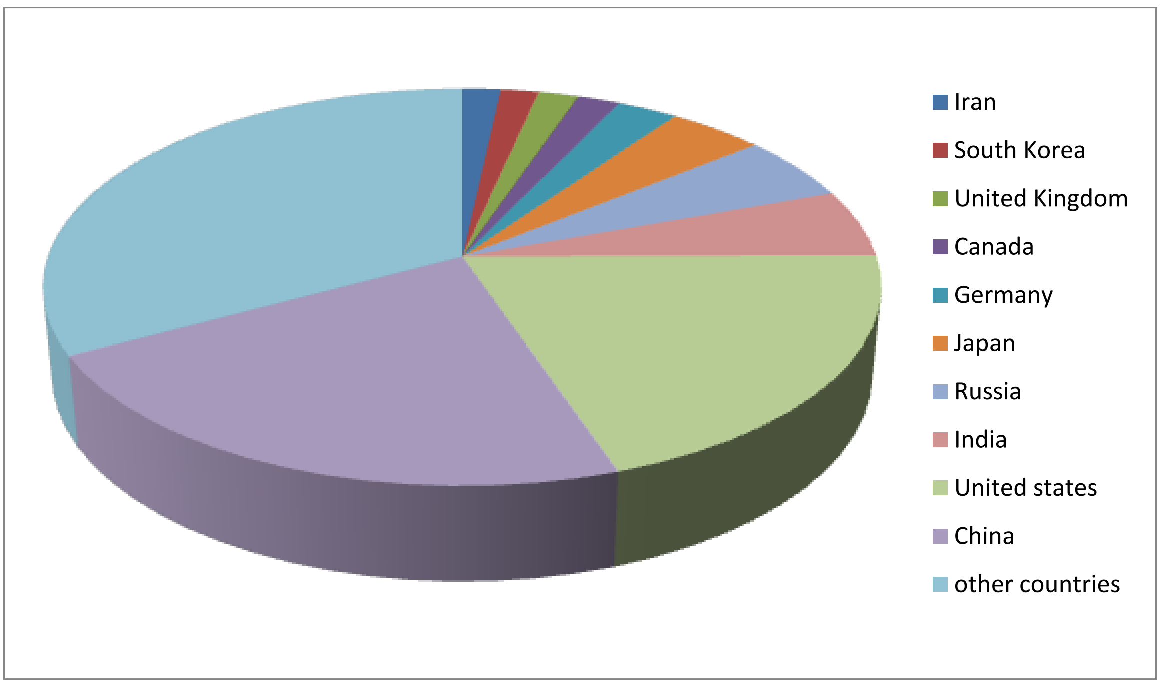

Chart 4.5 – Countries emitting the most annual CO_2 per million tons (According to Wikipedia)

4.5. Infrastructures associated to CO_2 emission

Four below key infrastructure elements contribute to the carbon dioxide emissions in one neighborhood. The first three elements increase and the last one decreases the rate of emissions:

- Building
- Transportations
- Waste
- Green spaces

4.6. Effects of CO_2 on people's lives

In order to realize the negative effects of carbon dioxide on people's lives, it would be more tangible to imagine a carbon-neutral district and its particular characteristics and positive effects.

This place improves wellbeing and health especially regarding heart and respiratory diseases. As well the residents in this place have higher physical and mental functionalities. Having access to more green spaces, they are more likely to be active.

It is likely that anthropogenic warming, such as that due to elevated greenhouse gas levels, has had a discernible influence on many physical and biological systems. Warming is projected to affect various issues such as freshwater resources, industry, food and health.

"Specifically, carbon dioxide in synergy with other pollutants consisted of some micro-particles and nano-particles can affect health and environment. CO_2 in high concentrations is toxic. 1% (10,000 ppm) can cause drowsiness. 7% to 10% can lead to dizziness, headache, visual and hearing dysfunction and unconsciousness." (Wikipedia-carbon dioxide)

4.7. CO_2 reduction related policies

There are several concerns from different responsible environmental parties regarding the raise in the temperature of the Earth from 1.5^{o}C to 6^{o} C by the end of this century. This increasement, is in fact dependant on the green house gas (GHG) emissions and accordingly it is as well affected by the public policies implemented by the countries that are mostly involved in consumption of energy and production of carbon dioxide. This will cause disturbance to our living environment and consequences to our future. Recently the building sectors of many countries specially those that contribute the most to carbon dioxide emissions, are set to play a significant part in tackling the environmental issues which we may face in coming decades. Therefore, many countries came to this idea that this sector might be the most capable of reduction of CO_2 and meet the national commitments.

In order to reduce these effects and guarantee a sustainable society – as a solution – an agreement was signed among several nations in which it is agreed to reduce the green house emissions including carbon

dioxide to half by 2050. So many countries have adopted this objective as part of their National Strategy for Sustainable Development and Climate Plan. To be able to make these policies practical, several strategies and solutions can be proposed by governmental sectors which are summarized as below:

- **Increasing energy efficiency of buildings:** It is the main solution which can be done through assessment of energy performance of buildings and improvement of them accordingly afterwards.

- **Reduction of consumption of energy in Buildings:** Recently the building industry uses a great amount of energy and therefore turned into the biggest consumer across all the other sectors of the economy. This energy consumption produces millions of tones of CO_2.

- **Usage of multi-resources in buildings:** Buildings can have access to several means of energy resources and can use a combination of renewable resources, recycled or waste resources, etc.

- **Linkage between energy sources:** Energy networks and central sources of energy will lead to a saving in energy production and hence in the future pollution emitted.

- **Reconfiguration in transportation vehicles and networks:** A modification in the system of circulation or a change in type of public or private vehicles may be beneficial to reduction of carbon dioxide.

Moreover, reconfiguration in infrastructure also has congruence with government's long-term objectives. These key aspirations are listed as below:

- **Climate change:** Most countries have targets to reduce greenhouse gas (GHG) emissions to be able to cope with climate change impacts. The costs of not taking action on climate change could be equivalent to losing some percentage of global GDP each year. Through retrofitting our existing infrastructure it is possible to achieve high levels of carbon emission reductions.

- **Energy security:** To maintain supply, minimize costs and guard against geopolitical uncertainties as domestic and international supplies are depleted, the way we generate and distribute energy will need to be made more efficient and low-carbon. Many governments target to promote renewable or recycled energy, and a set of supporting policies to achieve this in national level.

- **Fuel poverty:** It is a substantial and growing problem. Annually unaffordable fuel costs contribute to several increasing number of deaths. Therefore the number of people in fuel poverty is expected to rise dramatically. So governments are concerned by this issue and have arrangements to struggle against it.

- **The economy:** The recent financial recession has had a major impact on the building and construction sector. Thus there is a huge number of unemployed in many countries. So a retrofitting program can provide an opportunity for the government to safeguard and create jobs in low-carbon industry.

- **Health:** In all countries there is a concern to remove health inequalities. People in deprived areas still have a shorter life expectancy and experience higher levels of circulatory disease, cancer, obesity and overweight population which is increasing specially among children. So in many nations there is an aim for government to come up with a plan to reduce the proportion of

overweight and obese children. A sustainable built environment can have significant positive impacts on both health and health equity. Infrastructure reconfiguration and accordingly carbon reduction programs can help to deliver a range of national and local government targets.

So to sum up, these aims include reliable public services; efficient transport networks; improving children's safety; improving long-term housing supply; tackling poverty for children and old people; improving health and wellbeing; raising the productivity of economy; maximizing employment opportunities; improving resilience to impacts of climate change and making communities safer and more cohesive. It will also help to deliver the legally binding target to eradicate fuel poverty by energy consumption reduction.

4.8. Retrofitting /reconfiguration

The term reconfiguration or retrofitting has several definitions but the below is selected to describe our specific implementation in this research:

Reconfiguration:

- "To change the physical shape of a property; contrast remodeling or renovation".(Source: Barron's real state dictionary)
- "To re-arrange the elements or settings" (Source: The American heritage dictionary)

Retrofit:

- "Substitute new or modernized parts or equipments for older ones" (Source: Princeton University, Farlex Inc.)
- "To install or fit for use in or on an existing structure, especially an older dwelling." (Source: The American heritage dictionary)

Infrastructure retrofitting would differ according to location, but common elements might include the below items:

- Energy/water efficiency upgrades to buildings
- Increased local energy generation
- Improved energy networks
- District heat generation and supply
- Improved sustainable transport routes across the neighborhood (such as walking or cycling paths)
- Green infrastructure improvements (such as minimizing surface water run-off and flooding, green roofs, spaces for food growing, street trees, etc.)

- Improved systems for waste collection and processing at neighborhood level
- Improved wireless internet broadband access in local level
- Promoting electric vehicles

Retrofitting buildings can reduce carbon emissions by:

- Insulating buildings so they require less energy for heating
- Connecting buildings to low carbon sources of heat
- Installing new equipments such as smart meters, new boilers and heating controls
- Using buildings as sites for the generation of renewable electricity and heat
- Installing water efficient fittings in buildings
- Using grey and rain water devices to capture and use non-potable water

4.9. New carbon-neutral zone versus existing zone

Recent years have seen much debate about sustainable neighborhoods and how they can be created through the provision of sustainable infrastructure in new developments such as Millennium Communities, Carbon Challenge sites, zero-carbon cities and eco-towns. On the contrary, we need to focus on how we can improve sustainability and quality of life in our existing places – especially given that at least 80 per cent of the buildings standing today will remain with us within 40 years from now *(according to SDC sustainable neighborhood infrastructure report by Buro Happold)*. Wherever it takes place, upgrading of existing infrastructure must have at its core the mitigation of, and adaptation to, climate change. However, such programs can deliver a wide range of economic, environmental and social co-benefits, including better health, safer streets, more active citizens, better places for children to grow up, and reduced impact from extreme weather events. Our existing places can be transformed into environments that make better use of resources, have stronger, more resilient and more cohesive communities, and competitive, robust low carbon economies. Therefore economically it is more beneficial to upgrade the existing than to demolish and reconstruct it.

4.10. Co-benefits of reconfiguration

In the current economic climate it is critical that we take a long-term view to improve the functioning of our existing places. Enabling communities to renew their neighborhood property and infrastructure is the most cost-effective way to ensure our place is fit for the future and to create the conditions for people to thrive. It has great proportion of engagement from residents, investors and the businesses in the supply chain in an urgently needed boost to economic activity delivering a long-term benefit for the neighborhood.

This process of carbon reduction can be done in a way to bring multiple outcomes:

- Bringing indoor comfort for residents
- Saving in annual GDP in national scale
- Generating jobs and skills and maximizing employment opportunities
- Reducing our pollution and waste
- Engaging with communities in a way that ensures that they are part of the process of achieving a better quality of life for themselves and those around them.
- Meeting requirements of national planning of long-term energy consumption in existing buildings and also climate change mitigation programs
- Having the opportunity to tackle climate change
- Promoting good governance and bringing encouragement and support for local leadership in delivering sustainability.
- Non-financial benefits with no market value such as avoidance of future healthcare costs, reduced flood risk, etc.

4.11. Advantages of a neighborhood scale approach

Neighborhood scale approach has below characteristics and can bring the following benefits:

- **Residents' participation:** Engagement of local residents is guaranteed through governance approaches promoting local ownership and high levels of take-up of retrofit measures most appropriate to the neighborhood
- **Feasibility:** Technical resource and carbon-efficiency measures become more feasible and measureable at neighborhood level that simply do not stack up at individual home scale, including most low-carbon or renewable energy technologies and transport.
- **Private money:** Access to private investment is increased as neighborhood scale provides the opportunity to enabling scarce public money to be more effectively spent.
- **Social local cohesion:** This provides the opportunity to strengthen communities, to build their social space, to interact with one another and to expose their capacity to respond to local challenges.
- **Promoting sustainable behavior:** Governments are able to train and teach sustainability to their communities and this enables public to create new social norms. It is more practical to arrange training courses in local level comparing with larger scales.
- **Marketing and public awareness:** Local approach has more potential for public awareness and intensive marketing and advertisement.

- **Costs reduction:** Comparing to individual retrofitting and national level reconfiguration, neighborhood level approach is more economical. Therefore the released saved costs can be spent to extend the scale.
- **Local business opportunity:** Neighborhood program can offer local jobs to local residents.
- **Visibility:** After reconfiguration, improvements in streetscape can be seen and effect on public realm.
- **Viability:** In a larger scale than individual housing, there would be more capability to modify energy networks and central sources.
- **Practicality and time-saving:** This can minimize the personal requirement to find suppliers and residents can share common solutions.

CHAPTER II: PRACTICAL PART

5

CASE STUDY APPROACH

A case study is used as a research strategy.

Firstly, some related examplaries are considered as samples in which either probably similar approach has been taken place or the same issue had existed. These samples were selected among projects that had achieved or are in progress to achieve the sustainable environment goals in the defined criteria. Several factors were affecting the selection of the exemplary. A district was chosen that had been considered as one of the below cases:

- Neighborhood with a high level of carbon dioxide reduction through a local scale reconfiguration
- Neighborhood with a high level of carbon dioxide emissions and in vigorous requirement of an infrastructure configuration

Secondly, a particular study area is selected and being studied. Therefore an approach is proposed as a solution to the problematic which is practiced on the specific chosen study area. In this process numerous practical findings are gained which are achieved by previous mathematical methods. Later, a modification in the data will lead to several discussions and finally, the future offered solutions will be underpinned and generalized for different contexts.

Exemplary:

- Blacon, UK
- Miami-Dade, Florida

Case study:

- Vieux Tours, Tours, France

5.1. Exemplary with similar goals

Within European context:

- **Blacon, United Kingdom**

Blacon with 5,200 households is located in North West of Chester. This community has 18,000 inhabitants. Department of Energy and Climate Change of United Kingdom chose 22 communities including Blacon to turn them into low carbon environments. In this project the objective is to reduce energy consumption about 20% through extensive community engagement focused on long-term energy-related behavioral change using a community-based dissemination model.*(According to Sustainable Blacon's report)*

Figure 5.1 – Aerial image of community of Blacon, UK

This community is an extension of Chester, gradually extended since 1960. It is consisted of low dense and low storey terraced housing featuring a suitable amount of green and open space giving the opportunity to execute upgrading strategies.

The area is relatively deprived making the development of social enterprises and therefore it is assumed to be a fair opportunity for employment and reinvestment. There is an emphasis on cost saving and addressing fuel poverty issues as well as environmental concerns. Another problem in this community is the demographics which can be described as generally aging population being replaced with young people who migrate to capital cities and thus there would be a priority of having healthcare and support for elderly people rather than construction of schools and youth entertainments. Therefore this community's upgrading potentials are summarized as below in which each proposed measure has four dimensions of environmental, social, economical and governmental benefits (*see table 5.1*).

Figure 5.2 – Typical housing style in Blacon
(Source: Cheshire community actions)

Sectors	Proposed solutions	sustainability outcomes' dimensions			
		Env.	**Soci.**	**Econ**	**Gov.**
Transportation	Giving priority to pedestrian routes than road to encourage walking	■	■	■	
	Community travel plan which promotes access to and knowledge of existing transport – public, private, freight, cycle, walking.	■	■	■	■
	Reduction of transportation fuel poverty	■		■	
	Making good quality signalized cycle lanes	■	■		
	Co-ordination of bus timetables between local operators		■		■
	Usage of lower cost measures such as 'text alerts' to mobile phones when specific public transport vehicle is approaching		■	■	
Electrical Production/ energy use	Installation of solar thermal collectors for domestic hot water	■		■	
	Usage of photovoltaic (PV) panels in community scale	■		■	
	Installation of wood pellet boilers	■		■	
	Usage of ground source heat pumps as a low carbon equipment	■		■	
	Combination heat and power energy resources	■		■	
	Improvement of thermal efficiency	■	■	■	
	Insulation of hot water tanks	■	■	■	
	Insulation of loft, cavity and solid wall insulation (external/internal depending on aesthetic/conservation drivers)	■	■	■	
	Adding double or secondary glazing and- draught proofing	■	■	■	
	Usage of timed and zoned temperature regulated heating controls	■	■	■	
	Replacement of old mechanical equipments	■	■	■	
	Training public regarding energy consumption	■	■	■	■
	Defining reward, such as a discount if energy usage is below a given level	■		■	■
Land use/ planning	Promoting demonstration homes to reduce energy bills	■		■	■
	Promoting competitions between neighborhoods to achieve more sustainability	■	■	■	
	Using tree and shrub nursery; gardening club, etc.	■	■	■	
	Promoting gardening and sale of plants by volunteer local staff	■		■	
	Usage of local skills and labor to improve green space	■	■	■	
	Using "exemplary retrofit" for similar social housing			■	■
	Providing public with more informative general plans	■	■	■	■
Solid waste	Having local repair shops which re-vitalize under used or empty properties	■	■	■	
	Having local recycling initiatives for furniture	■		■	
	Making water butts in private gardens	■		■	
	Promotion of rainwater harvesting for non-potable uses as there is enough green private space	■			

Table 5.1 – Proposed measures by different sectors of sustainable Blacon (According to sustainable Blacon)

Within American context:

- Miami-Dade, Florida

In 1993 a committee was established in Miami-dade County to create plans to reduce CO_2 emissions and green house gas emissions in local level to minimize global warming's negative effects.

Firstly, the carbon dioxide rate was calculated. The emission inventories According to "A long term CO_2 reduction plan for Miami-Dade County Florida" report were as below:

Sector	1988 Equivalent Million Tons of CO_2		2005 Equivalent Million Tons of CO2		Difference Million Tons of CO2
Residential	0.196	1%	0.227	1%	0.031
Commercial	1.022	4%	0.681	2%	-0.341
Industrial	1.297	6%	1.554	5%	0.257
Transportation	10.449	45%	14.057	44%	3.608
Electrical usage	10.459	45%	15.448	48%	4.989
Others	0	0%	0	0%	0
Total	23.423	100%	31.967	100%	8.544

Table 5.2 – CO2 emission inventories by various sectors in Miami-Dade

Afterwards various sectors (transportation, electrical production/energy use, solid waste and land use/planning) identified their own role in reduction of CO_2 and announced their solutions to this issue.

Sectors	Solution	sustainability outcomes' dimensions			
		Env.	Soci.	Econo.	Gov.
Transportation	Expansion of roads		■		■
	Extending Transit		■	■	■
	Promotion of bicycle use	■	■	■	
	Increasement of bicycle facilities such as parking		■		
	Increasement of fuel efficiency	■		■	
	Utilization of more fuel-efficient cars	■		■	
	Usage of Hybrid Electric Vehicles	■		■	
	Development of a public education and awareness campaign to limit idling of automobiles/trucks	■	■		■
	Evolution of a sub-centered urban form		■		■
	Encouraging provision of civic buildings within urban neighborhoods through site planning and capital improvement programming		■		■
Electrical Production/use	Increasement of energy efficiency in buildings through retrofitting	■		■	
	Usage of cogeneration	■		■	
	Switch to alternate lighting	■		■	
	Usage of solar powered Bus stops	■	■	■	
	Usage of solar lights at parks	■	■	■	
	Converting traffic signals to LED technology lighting		■	■	
	Implementing energy star management tool	■		■	■
	Decreasing residential sector energy use	■		■	
	Reduction of annual electricity consumption	■		■	
	Incorporating energy efficiency into public housing projects			■	■
	Development of outreach program for contractors/builders			■	■
	Improving enforcement			■	
	Expanding the use of alternative fuels	■		■	
	Installation of solar water heaters	■		■	
	Investigating cost effective energy efficient HVAC systems	■		■	
	Promotion of energy conservation and waste reduction to businesses and homeowners	■	■	■	
	Encouraging tree planting program	■	■		■
	Revising Landscape Code to require strategic tree planting, street trees, and parking lot trees	■			
	Reinstating renewable energy source exemption	■		■	
	Expansion of landscaping and white surfaces	■			
	implementing revised landscape code				■
	Increasment of public participation		■		■
Solid waste	Recycling waste stream	■			
	Recovering & flaring or usage methane gas to generate electricity	■		■	
	Recovering and utilization of landfill methane gas	■		■	
	Reduction of generated solid waste	■			
	Providing waste reduction information	■	■		■

Table 5.3 – Proposed measures by different sectors of Miami-Dade (According to A long term CO_2 reduction plan for Miami-Dade County Florida)

5.2. Key lessons from the exemplary

Some messages can be gained through these sample case study research which are summarized as followed:

- A number of bodies are undertaking work to improve existing places. Therefore coordination in these kinds of programs is of high importance.

- Motivations behind reconfiguration or retrofitting programs vary including reducing carbon emissions; promoting regeneration, job creation and economic investment; conserving natural resources; struggle against fuel poverty and energy consumption; improving community cohesion and interaction; making streets safer and more secure, etc. But any of the targets can lead to other outcomes as well.

- Projects coordinating more than one type of infrastructure upgrade (building, transportation, waste, etc.) are usually led by public sector organizations or local authorities.

- Funding is usually sourced from a range of public sector grants, but as well there are efforts and to some extents success in encouraging private investors and stakeholders to co-finance.

- Infrastructure ownership is an issue. Although it varies among countries.

- Many of these CO2 emission increase is a result of overgrowing population, increasing demand in usage of electrical devices and technological appliances in households, lack of a national standard on fuel consumption by government, preference of usage of private vehicles instead of public transportation choice.

- Even though both examples revealed that it is most effective to undertake community engagement on a neighborhood scale but practically, for funding and accordance with strategic planning in both communities local authorities had to coordinate with larger scales such as regional or sub-regional.

5.3. Case study as a research strategy

In this section another case study is chosen for carbon dioxide emission calculation and further simulation of reduction. Hence, a zone in the city of Tours in France is selected as the study area.

Figure 5.3 – Aerial image of Tour, France

Numerous factors were involved and effective in the selection of this specific zone as a case study, which can be summarized as below:

- Feasibility & accessibility
- Variety in functions
- Variety in construction periods
- Variety in construction methods
- Variety in architectural styles
- Variety in materials
- Distinguishable by edges
- Being in need of a reconsideration

Figure 5.4 – Aerial image of the case study zone in Tours

5.4. Random selection

In fact, there is less possibility to survey the entire existing buildings for three main reasons: Firstly, data collection would have taken very long. Secondly, assuming the practice as a real project, the cost would have been so high and finally, using a sampling method improves the quality of research more. As the smaller amount of data, makes it possible to ensure homogeneity and to improve the accuracy of the result.

So, all buildings are given equal probability to be selected. Then 10% of the whole number of existing buildings in a zone is chosen randomly. In this method there is an assumption in which this ten percent are representative of the entire district.

According to GIS existing map of buildings of Tours, each building is represented by one polygon with a specific identification number. Therefore, there are 280 polygons in the chosen area.

So, a sample of 28 buildings – which is equal to 10% of the statistical population under study – are selected randomly and studied.

Thus using Excel Rand function (random number generator), 28 numbers between 1 and 280 were selected.

Figure 5.5 – Randomly selected building blocks in Tours for further analysis

5.5. Data compilation

Through site observation and usage of Google map the necessary data was collected. Thus, after studying and analyzing the twenty-eight samples, several types can be defined according to their similarities in their characteristics and features. Afterwards, the images can turned into three dimensional models. It is then possible to gain information from the simulated buildings.

Figure 5.6 – Some of the random selected buildings in the neighborhood

5.6. Typology

Numerous factors are involved in calculation of rate of carbon produced by a building. Some of these factors can be summarized as below:

- Area and volume of the building
- Glazing area
- Inertia of the building (thermal mass)
- Heating systems
- Insulation
- Width of walls
- Material of walls
- Area of exterior walls
- Size of windows
- Type of windows
- Size of doors
- Type of doors
- Roof type and material
- Area of roof
- Ground type and material
- Built up floor area
- Orientation of the building
- Blinds, shutters or curtains
- Occupancy load
- Lighting requirement
- Ventilation systems

Many of which are varied from building to building according to the building age. Considering construction period of buildings and their characteristics, it is possible to define 8 different periods of architecture and archetypes for this particular case study:

- ### Type 1 (Before 1800)

Figure 5.7 – A sample of building type 1

This first category is broad and diverse. It corresponds in fact to residential buildings built either before the French Revolution in the 17th and 18th century or in medieval ages and have been restored later after the world wars .

Most of the buildings remained from medieval ages have wood-beams and half timber and wooden carvings and soft limestone walls covered with thick layers of plaster coating. These buildings are usually consisted of a ground floor and 3 low-height stories and high slope gable roof. They are located in small, narrow plots and mostly all the sites are allocated to buildings which are attached to one another.

- ### Type 2 (1801 – 1850)

Figure 5.8 – A sample of building type 2

The first half of the 19th century was contemporaneous to the arrival of the railroad**,** canals**, s**team engine and industry to the city. The city was growing and its population was increasing rapidly. The plots were enlarged from 300 square meters to 600 square meters. Urbanization process started with development of two to three story buildings along the main streets.

Characteristics of buildings of this period are as followed: narrow windows, having 4 or 5 levels, 30 to 40 cm semi-firm stone façade covered with a thick layer of plaster, small terraces.

Construction methods were changed gradually during these years**.**

- ### Type 3 (1851 – 1914)

Figure 5.9 – A sample of building type 3

This period is characterized by high facades, mansard roofs and in some rare cases pavilions. In these buildings proportion of height and width of the buildings are in a way that give the building a narrow shape. The combination of brick and stone became more popular during these years.

- ### Type 4 (1918 – 1939)

Figure 5.10 – A sample of building type 4

Due to the First World War no new construction was done during the four years of 1914 to 1918. After 1918 classical styles mostly disappeared and replaced by eclectic treatments. In this period – due to French slow economic situation – there was less progress toward modern designs and buildings are simpler. Many in this period are those that are damaged during the First World War and had been restored after this time. The façades are decorated with projecting bay windows in some cases. The buildings are provided with more and larger openings.

- ### Type 5 (1945 – 1967)

Figure 5.11 – A sample of building type 5

Due to the Second World War no new construction was done during the six years of 1939 to 1945. More concrete-related materials and styles were used within these years. Mostly mass public housing projects started after 1950 due to post-war requirements. Many of these residential buildings were constructed by industrial methods of construction. Major characteristics of buildings in this period are simplicity, symmetry, repetitive layouts, geometrical effects and minimal landscaping. Climatic factors were considered in buildings since these years.

- ### Type 6 (1968 – 1974)

Figure 5.12 – A sample of building type 6

During these years prefabrication was developed. Curved and asymmetrical layouts became more common. Space, geometry and height were more emphasized. At the same time the developments of low-cost-public housing was continued during this period.

- ### Type 7 (1975 – 1989)

Figure 5.13 – A sample of building type 7

Color was given a more significant role in architecture of buildings, though still grey and white colors were widely in use. Preformed concrete components were being used with wide expansion gaps between them. In this period new modern architecture stated to be created which was based on traditional ideas and organic relationship between building and site. Human scale was emphasized more. New buildings were attached directly to the existing frontages. Steel and glass in canopies were used more widely. Reinforced concrete was used in a more restrained style. Also high quality bricks were often used to stress artisanal traditions.

Again the architecture moved from blocks of flats toward individual housing. So the number of individual buildings with recreation of traditional forms increased. Modern architecture was developed with respect to historic buildings. So using traditional materials, mansard roofs and traditional forms was still common.

- ### Type 8 (1990 – present)

Figure 5.14 – A sample of building type 8

In this period there was a rehabilitation of social housing. The buildings built in 1960s were developed to increase comfort, enhance heating and sound insulations. There were modifications such as installation of double glazing in the wooden facades; using insulating partitions in interiors or adding exterior insulations on the 60s buildings.

During recent years, there are new building codes which dictate new thermal standards. So recently the appearances of the buildings are changing gradually. Indeed, buildings are often equipped with exterior insulation, which encourage the façade to have new materials, large panels and materials with more

porosity. In recent years flat roof buildings are becoming more common in which the roofs are highly insulated against humidity.

General characteristics of each period are summarized in the following table:

	U-value of walls	Thermal mass	Insulation on walls	Insulation on roof	Average number of floors	Glazing percentage	Roof type
Before1800	1.80	Very low			4	12%	Sloped slates
1801-1850	2.00	Very low			2	10%	Sloped slates
1851-1914	2.25	Very low			3	10%	Sloped slates
1918-1939	2.10	Low			3	15%	Sloped slates
1945-1967	2.80	Average			4	20%	Sloped slates
1968-1974	2.80	Average			5	15%	Sloped slates
1975-1989	1.50	High			5	20%	Sloped slates
After 1990	0.65	High			6	55%	Asphalt flat/ sloped slates

Table 5.4 – General characteristics of buildings of archetypes

5.7. Calculations

In order to calculate the rate of carbon emitted by a building, we should consider many factors. These factors that affect the result are defined as below[6] *(See endnotes-page 68)*:

1. **Building area (m^2):** It is the built up area of the building.

2. **Building volume (m^3):** The volume of the air in the building which is calculated by external dimensions of a building is considered as volume.*(According to a definition by European high quality Low Energy Buildings)*

3. **Glazing area (m^2):** Windows, insulation glass, doors, glass bricks, glass tiles, skylights and any other glass components which are used in the envelope is count as building glazing.

4. **Inertia:** Thermal inertia – quoted as I – has an influence on the annual energy requirement for heating of a building and is calculated as the square root of the product of density (ρ), thermal conductivity (k), and heat capacity of a material(C). It is a measure of the rate of heat transfer. High inertia corresponds to a thick concrete floor and iron or concrete structure while low inertia describes a light or timber-framed structure.

$$I = (k \rho C)^{1/2} \quad [J\ m^{-2}\ K^{-1}\ s^{-1/2}]$$

where:

k = bulk thermal conductivity $\approx k_g + k_s + k_r$
ρ = bulk density
C = heat capacity

5. **Climate:** Each city has its own weather characteristics. Therefore it is significant to know in which climatic zone we are studying. So accordingly, the hourly outdoor temperature, direct and diffuse sunlight intensity, rate of humidity and other factors are varied from place to place.

6. **Temperature difference [K]:** Thermal energy moves from any higher temperature to a lower temperature and the bigger the difference of the two temperatures would be, the faster the heat will transfer. The temperature difference (ΔT) is calculated by defining the required internal temperature for the buildings which is normally between 18 and 22 degrees Celsius (equivalent to 291 and 295 Kelvin) and the anticipated exterior temperature. As an instance, the outside temperature in the example of Tours is considered as 272 Kelvin which is supposed to present the normal lowest winter temperature. In this research, this value is quoted in Kelvin (K).

$$\Delta T = T_h - T_c \quad [K]$$

Where:

ΔT = Temperature difference
T_h = Temperature of hotter side
T_c = Temperature of colder side

7. **Building orientation:** Since various factors such as daylight and shadows are affecting the result, the orientation of the building should be considered in calculation. The orientation indicates the direction in which the glazing exists. In other words, it is used to refer to solar orientation which is the sitting of building with respect to absorption of free energy. Buildings have different orientations for their each different side. So in this research 8 orientations (North, South, East, West, North-East, North-West, South-East and South-West) are considered and taken into account for the calculation.

   Moreover, the building orientation can have an impact on heating, lighting and cooling costs. By maximizing southern exposure, for example, one can take optimal advantage of the sun for daylight and passive solar heating. This will result in lower cooling costs by minimizing western exposures, where it's most difficult to provide shade from the sun. Therefore orientation affects the energy consumption.

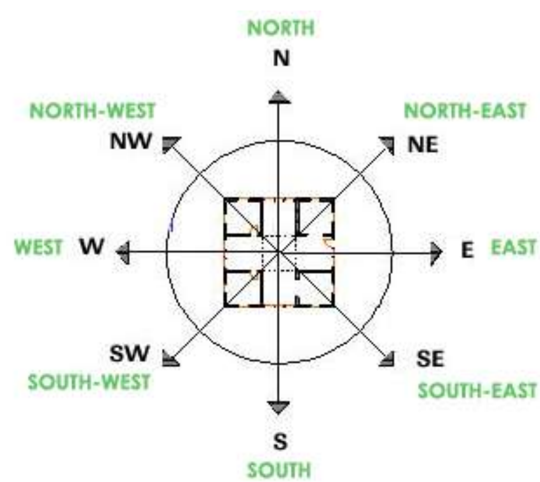

Figure 5.15 – Various building orientations according to glazing directions (According to orientation of Vatsu building)

8. **Area of the building envelope (m^2):** The building envelope is the outer layer of the building that separates the living spaces from the outdoor environment. The area of exterior walls of the buildings is simply defined as building envelope area.

9. **Area of the openings (m^2):** All door and unfixed windows which are openable to the exterior space and are located on the building envelope are called openings in this research.

10. **Area of the roof (m^2):** The surface of the final covering of the building is to be calculated as roof area.

11. **Area of the floor (m^2):** It is the area calculated by multiplying the outer-to-outer dimensions of the floor; not considering the boundary walls, but definitely taking into account the building outer walls as well as the inner walls.

12. **Thermal transmittance of the openings, walls, roof and floor [W/m^2K]:** This rate which is also known as U-value is in watts per square meter per Kelvin and is the rate of heat flow in watts through one square meter (1 m^2) of a structure divided by absolute temperature difference between in and out. Well-insulated parts of a building have low and poorly-insulated parts of a building have high thermal transmittance. According to Fourier's law of conduction, heat flow is proportional to area and temperature difference and inversely proportional to the thickness of the material. The constant of proportionality is called conductivity (K-value).

$$\dot{Q} \alpha \frac{A \ \Delta T}{\Delta x} \qquad Q = k A \frac{\Delta T}{\Delta x} \qquad \mathbf{U = Q/A(\Delta T)} \qquad \mathbf{[W/m^2K]}$$

where:

U = Thermal transmittance
K = Conductivity
Δx = Thickness of the material
Q = Heat flow [watts]
ΔT = Temperature difference of interior and exterior
A = Area [m^2]

The most important factor in calculation of U-value is the various layers and thickness of each part of the building. So, in order to measure the total U-value of a part of a building such as a wall, each layer should be calculated separately.

13. **Thermal conductivity of the openings, walls, roof and floor (W/mK):** Thermal conductivity known also as K-value as described in section 12 is the ability to conduct heat which is measured in watts per meter Kelvin. Materials with higher K-value transfer heat faster. Therefore those with low thermal conductivity are widely used as thermal insulations. As well, this value is temperature dependent. So, as the temperature increases in materials, they would be more conductive to heat.

$$K = Q\,(\Delta x - \Delta T) \qquad [W/mK]$$

where:

K = Thermal conductivity
Δx = Thickness of the material
Q = Heat flow [watts]
ΔT = Temperature difference of interior and exterior

Some materials' K-value is listed as below:

Material	Cement	Wood	Aluminum		Stone	Glass
K-value (W/mK)	0.29	0.04 – 0.4	237(pure)	120-180(alloys)	1.7	1.1

Table 5.5 – Thermal conductivity of common materials(According to ISO 8302)

Building components	**Details**	**K-value (W/mK)**
Roof	Aerated concrete slab	0.16
	Asphalt	0.70
	Bitumen layers	0.23
	screed	0.41
	Stone chippings	2.0
	Clay tiles	1.0
	Concrete tiles	1.5
	Wood wool slab	0.10
Floor	Cast concrete	1.35
	Screed	0.41
	Softwood timber	0.13 – 0.24
Insulation	Expanded polystyrene board (EPS)	0.040
	Mineral wool batt	0.038
	Polyurethane board	0.025

Table 5.6 – Thermal conductivity of common components in building (According to www.bath.ac.uk)

14. **Type of opening:** There are numerous types of doors and windows and this differentiation affect several values. As an instance, thermal transmittance is one of these values. Therefore, in order to calculate CO_2 emissions in a specific building it is essential to recognize type of the openings. In the following some of the most common windows and their U-value are collected:

Type of the window	**Blind/curtain/shutter**		**U-value [W/m^{2}K]**
	Without	**With**	
Single glazed swing			4.95
			4.15
Single glazed swing (with air)			3.45
6 mm double glazed swing			3.25
			2.80
6 mm double glazed swing (with air)			2.45
Full height single glazed with frame			4.75
			4.00
Full height single glazed with frame (with air)			3.35
Full height 6 mm double glazed			3.10
			2.75
Full height double glazed with frame (with air)			2.40
Full height single glazed without frame			5.05
			4.20
Full height single glazed without frame (with air)			3.55
Full height double glazed without frame			3.20
			2.85
Full height double glazed without frame (with air)			2.50
Thermal insulated double glazed (4mm glazing + 12mm air + 4mm glazing)			1.70
Thermal insulated double glazed (4mm glazing + 12mm argon + 4mm glazing)			1.40
Thermal insulated double glazed (4mm glazing + 16mm air + 4mm glazing)			1.40
Thermal insulated double glazed (4mm glazing + 16mm argon + 4mm glazing)			1.20
Double glazed hard coat low-emissivity thermal reinforced			1.10
Double glazed soft coat low-emissivity thermal reinforced			0.75

Table 5.7 – Thermal transmittance of common window types (According to 2CO2 by Mindjid Maizia)

15. **Type of walls:** Walls are composed of several layers. The structural component of the wall which is the main part of the wall defines type of the wall. For instance, some of the most common walls are: brick, concrete, gypsum board, soft or hard limestone, steel, wood, etc.

Wall components (layer)	Brickwork(interior)	Brickwork (exterior)	Concrete block (medium density)	Concrete block (low density)	Concrete block (high density)	Reinforced concrete (1% steel)	Reinforced concrete (2% steel)	Protected mortar	Exposed mortar	Gypsum plasterboard	Soft limestone	Hard limestone	Steel	Wood (softwood timber)
Thermal conductivity [W/mK]	0.56	0.77	0.57	0.18	1.93	2.3	2.5	0.88	0.94	0.25	1.1	1.7	50.0	0.13

Table 5.8 – Thermal conductivity of common wall components(According to Consultancy Study for Irish Concrete Federation)

16. **Roof type**: Several components can contribute in roofing composition. So, roof type can be defined due to the roof's material or main structure component. As well roofs can usually be located in one of the three main categories of flat, sloped or eco-roofs according to their shape.

Type of roofs
Asphalt composition shingles
Wood shake
Metal roofing
Slate roofing
Composition slate
Ceramic Spanish-style roofing

Table 5.9 – Common roof types due to material (according to Wikipedia)

Type of roofs	**Examples**
Flat roofs	Modified bitumen – Asphalt – Built up roof
Sloped roofs	Gable – Cross gable – Mansard – Pyramid hip – A frame – Hip roof
Eco-roofs	Cool – Green – Sod roof

Table 5.10 – Common roof types due to shape (According to Wikipeida & MIT design advisor)

17. **Floor type:** Floors can be categorized according to their variety in materials, configurations characteristics, etc.

- **Major floor materials:** concrete, wood, steel, plastics, adobe, autoclaved concrete, etc.
- **Typical configurations:** in-situ concrete, precast concrete, wood joists, steel joists, wood frames/truss, steel frame/truss, insulating concrete, structural insulated panel, etc.
- **Key characteristics:** field built, shop built, combo (shop and field), laminate construction, structurally adhered, pressed, stressed skin construction, etc.

18. **Type of ventilation:** There are three main types of ventilation:

- **Mechanical**, in which the building envelope is sealed and none of the windows are openable. Thus, the ventilation is done by air conditioning systems.
- **Hybrid**, in which the air conditions are available but the windows are operational as well and there might be adjustable blinds or curtains to control the incoming light.
- **Natural**, in which no mechanical systems exist.

19. **Air change rate:** There is a number assigned to air changes in spaces that have not been draught proofed which should be considered in calculations. This number is important since it affects the energy calculated to heat the volume of air by the temperature difference and an amount of 0.34 watts is required to heat one cubic meter (1 m^3) of air by one degree Celsius.

    To be on the safe side, a universal figure of 3 air changes per hour can be used with confidence. Therefore in our research we assume the air change is 3.

20. **Type of insulation:** Insulators can be divided according to their variety in materials. In the below table some major types of insulations and their method of application and characteristics are collected:

Type of insulation	Applicable on	Advantages
Blankets: Batts or Rolls Fiber glass Rock wool	All unfinished walls, floors and ceilings	Suited for standard stud and joist spacing, which is relatively free from obstructions.
Loose-Fill (blown-in) or Spray-applied Rock wool Fiber glass Polyurethane foam	Enclosed existing wall cavities or open new wall cavities; Unfinished attic floors and hard to reach places	Commonly used insulation for retrofits (adding insulation to existing finished areas).Good for irregularly shaped areas and around obstructions.
Rigid Insulation Extruded polystyrene foam (XPS) Expanded polystyrene foam (EPS or bead-board) Polyurethane foam Poly-isocyanurate foam	Basement walls Exterior walls under finishing (Some foam boards include a foil facing which will act as a vapor retarder.	High insulating value for relatively little thickness. Can block thermal short circuits when installed continuously over frames or joists.

Reflective Systems Foil-faced paper Foil-faced polyethylene bubbles Foil-faced plastic film Foil-faced cardboard	Unfinished ceilings, walls, and floors	All suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present. Effectiveness depends on spacing and heat flow direction

Table 5.11 – Type of insulations in buildings, their method of application and advantages (Source: the DOE)

21. **Type of heating system:** Mechanical systems have significant effect on production of CO_2 emissions.

Heating systems	**Type of fuel**	**Location**
Traditional furnaces	Gas – coal – oil - wood	Installed in the floor or on the living area's walls
Heat pump	Gas – electricity – oil	Pump: installed in the mechanical room, basement or kitchen
Radiant ceiling or floor heat	Electricity – natural gas – wood – propane	Installed in floors or ceilings
Hydronic heating (steam/hot water radiators)	Natural gas – oil -	Radiators : installed in each room Heating pump: installed in mechanical room or basement
Fixed space heater	Electricity – gas – kerosene	Installed on the wall
Air force (central heating)	Electricity – natural gas – propane – oil	Installed in the ceiling or on the floor
Solar PV	Solar energy	Panel: installed on the roof
geothermal	Geothermal energy	
Combi	Varied (depending on the combination)	

Table 5.12 – Some types of domestic heating systems

5.8. Results

The achieved results are summarized in the following tables and charts:

- **Type 1:**

Figure 5.16 – Location map of building type 1

Figure 5.17 – 3D model of building type 1

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
36	425	18	0	0	10	Very low

Table 5.13 - General information of building type 1

Vertical walls	**Area of the exterior walls (m^2)**	**Thickness of plaster molding & hard wood beams (cm)**	**Thickness of soft limestone (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the wall (W/m^2K)**	**Heat loss (W/K)**
	243	10	30	6	1.75	426
Openings	**Area of the windows (m2)**	**Type of the windows**		**Loss of the window (W/K)**	**Area of the doors (m^2)**	**U-value of the door (W/m^2K)**
	20	Single glazed swing with no curtains or blinds		139	8	1
Roof	**Area of the roof (m^2)**	**Thickness of slates (cm)**	**Thickness of wooden beams (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the roof (W/m^2K)**	**Type of the roof**
	68	2	10	2.5	1	packed
Floor	**Area of the floor (m^2)**	**Thickness of stone (cm)**	**Thickness of solid concrete (cm)**	**U-value of the floor (W/m^2K)**	**Heat loss (W/K)**	**Type of the floor**
	36	2	10	0.8	29	On the ground

Table 5.14 - Façade information of building type 1

Total building U-value	0.47	
Total heat loss	822	W/K
Heat transfer coefficient	774	W/m^2K
F (coefficient of free inputs of solar or internal)	0.06	
Glazing percentage	0.12	%
Annual requirements per habitable area	1354	kWh/m^2
Total annual requirements	48733	kWh/m^2
Annual consumptions per habitable area	1962	kWh/m^2
Total annual consumptions	70627	kWh/m^2
Total emissions of CO_2	14.3	Tones

Table 5.15 – Results for building type 1

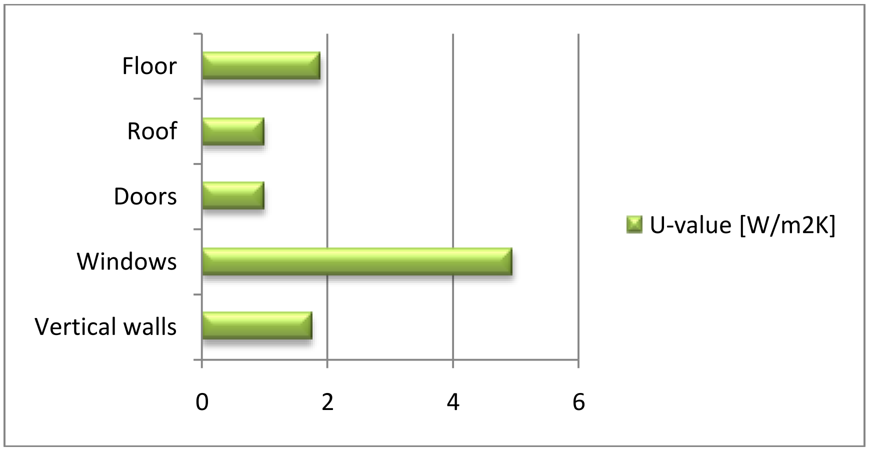

Chart 5.1 – Thermal transmittance of each building components for building type 1 (watts per square meter Kelvin)

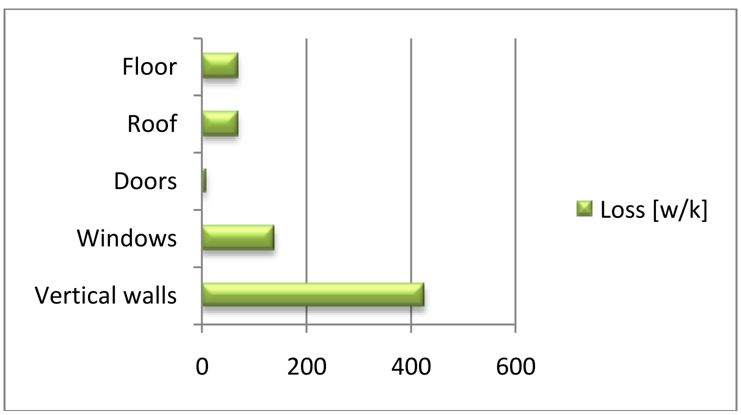

Chart 5.2 – Total heat loss of each building components for building type 1 (watts per Kelvin)

- **Type 2:**

Figure 5.18 – Location map of building type 2

Figure 5.19 – 3D model of building type 2

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
80	704	12	0	11	12	Very low

Table 5.16 - General information of building type 2

Vertical walls	**Area of the exterior walls (m^2)**	**Thickness of hard stone (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the wall (W/m2K)**	**Heat loss (W/K)**	
	231	50	6	2.4	550	
Openings	**Area of the windows (m^2)**	**Type of the windows**		**Loss of the window (W/K)**	**Area of the doors (m2)**	**Loss of the door (W/K)**
	35	Single glazed swing with curtains or blinds		142	5	5
Roof	**Area of the roof (m^2)**	**Thickness of slates (cm)**	**Thickness of wooden beams (cm)**	**Thickness of plaster & mortar (cm)**	**Loss of the roof (W/K)**	**Type of the roof**
	107	2	10	2.5	107	packed
Floor	**Area of the floor (m^2)**	**Thickness of stone (cm)**	**Thickness of solid concrete (cm)**	**U-value of the floor (W/m^2K)**	**Loss (W/K)**	**Type of the floor**
	80	2	10	0.8	64	On the ground

Table 5.17 - Façade information of building type 2

Total building U-value	0.47	
Total heat loss	883	W/K
Heat transfer coefficient	799	W/m^2K
F (coefficient of free inputs of solar or internal)	0.09	
Glazing percentage	0.11	%
Annual requirements per habitable area	630	kWh/m²
Total annual requirements	50364	kWh/m²
Annual consumptions per habitable area	663	kWh/m²
Total annual consumptions	53014	kWh/m²
Total emissions of CO_2	9.5	Tones

Table 5.18 – Results for building type 2

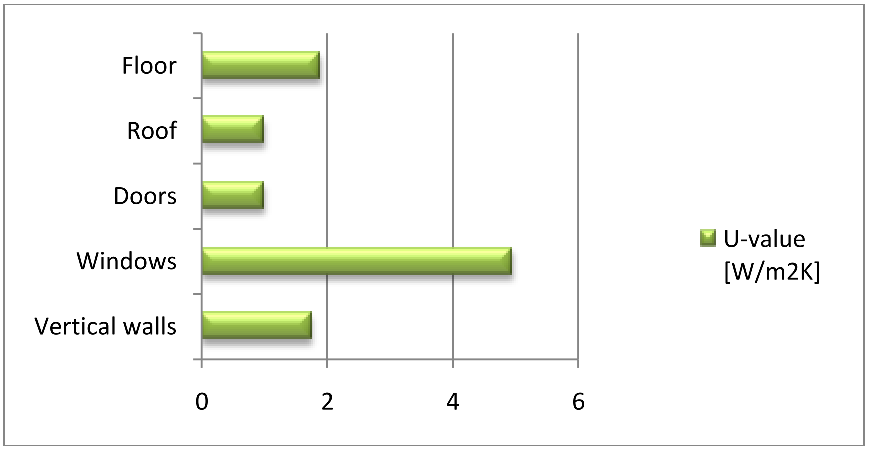

Chart 5.3 – Thermal transmittance of each building components for building type 2 (watts per square meter Kelvin)

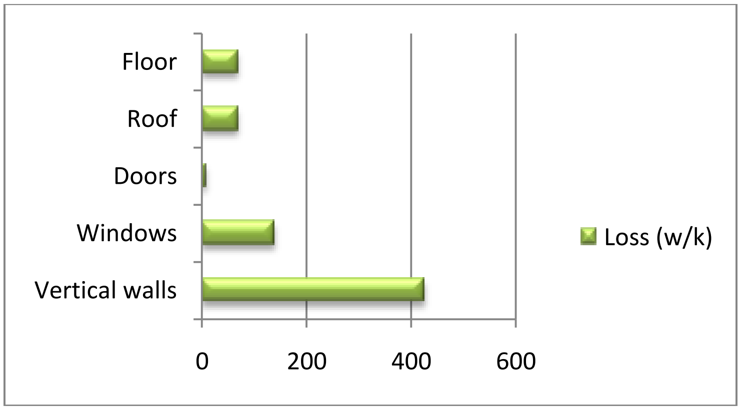

Chart 5.4 – Total heat loss of each building components for building type 2 (watts per Kelvin)

- **Type 3:**

Figure 5.20 – Location map of building type 3

Figure 5.21 – 3D model of building type 3

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
34	286	0	5	0	5	Very low

Table 5.19 - General information of building type 3

Vertical walls	**Area of the exterior walls (m^2)**	**Thickness of hard stone (cm)**	**Thickness of brick (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the wall (W/m^2K)**	**Heat loss (W/K)**
	116	30	11	6	2.2	251
Openings	**Area of the windows (m^2)**	**Type of the windows**		**Loss of windows (W/K)**	**Area of the doors (m^2)**	**U-value of the door (W/m^2K)**
	10	Single glazed swing with blinds or curtains		41	3	1
Roof	**Area of the roof (m^2)**	**Thickness of slates (cm)**	**Thickness of wooden beams (cm)**	**Thickness of plaster & mortar (cm)**	**Heat loss (W/K)**	**Type of the roof**
	48	2	10	2.5	48	packed
Floor	**Area of the floor (m^2)**	**Thickness of stone (cm)**	**Thickness of solid concrete (cm)**	**U-value of the floor (w/m2/k)**	**Heat loss (W/K)**	**Type of the floor**
	34	2	10	0.8	27	On the ground

Table 5.20 - Façade information of building type 3

Total building U-value	0.49	
Total heat loss	474	W/K
Heat transfer coefficient	448	W/m^2K
F (coefficient of free inputs of solar or internal)	0.06	
Glazing percentage	0.09	%
Annual requirements per habitable area	830	kWh/m²
Total annual requirements	28205	kWh/m²
Annual consumptions per habitable area	873	kWh/m²
Total annual consumptions	29690	kWh/m²
Total emissions of CO_2	5.3	Tones

Table 5.21 – Results for building type 3

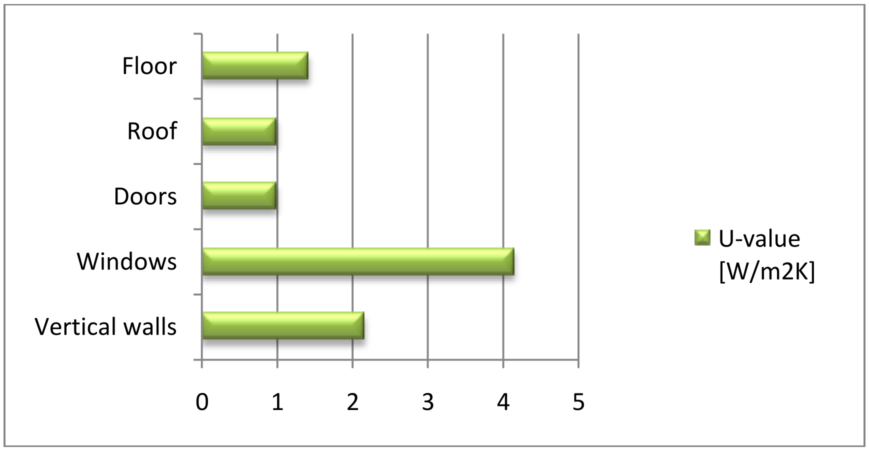

Chart 5.5 – Thermal transmittance of each building components for building type 3 (watts per square meter Kelvin)

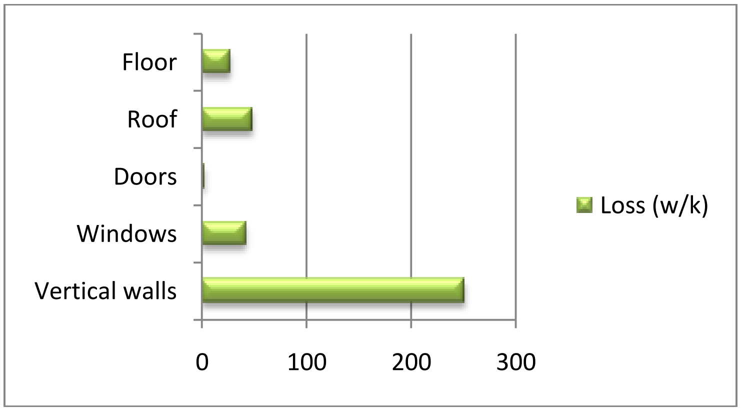

Chart 5.6 – Total heat loss of each building components for building type 3 (watts per Kelvin)

- **Type 4:**

Figure 5.22 – Location map of building type 4

Figure 5.23 – 3D model of building type 4

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
79	982	2	23	0	0	Low

Table 5.22 - General information of building type 4

Vertical walls	**Area of the exterior walls (m^2)**	**Thickness of hard stone (cm)**	**Thickness of brick (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the wall (W/m^2K)**	**Heat loss (W/K)**
	191	3	25	3	2.06	394
Openings	**Area of the windows (m^2)**	**Type of the widow**		**Loss of the windows (W/K)**	**Area of the doors (m^2)**	**Loss of the doors (W/K)**
	25	Single glazed swing with blinds or curtains		104	3	3
Roof	**Area of the roof (m^2)**	**Thickness of slates (cm)**	**Thickness of wooden beams (cm)**	**Thickness of plaster & mortar (cm)**	**Loss of the roof (W/K)**	**Type of the roof**
	168	2	10	2.5	169	packed
Floor	**Area of the floor (m^2)**	**Thickness of stone (cm)**	**Thickness of solid concrete (cm)**	**U-value of the floor (W/m^2K)**	**Loss (W/K)**	**Type of the floor**
	79	2	10	0.8	63	On the ground

Table 5.23 - Façade information of building type 4

Total building U-value	0.48	
Total heat loss	1072	W/K
Heat transfer coefficient	1008	W/m^{2}K
F (coefficient of free inputs of solar or internal)	0.06	
Glazing percentage	0.13	%
Annual requirements per habitable area	804	kWh/m²
Total annual requirements	63506	kWh/m²
Annual consumptions per habitable area	846	kWh/m²
Total annual consumptions	66849	kWh/m²
Total emissions of CO_2	12.0	Tones

Table 5.24 – Results for building type 4

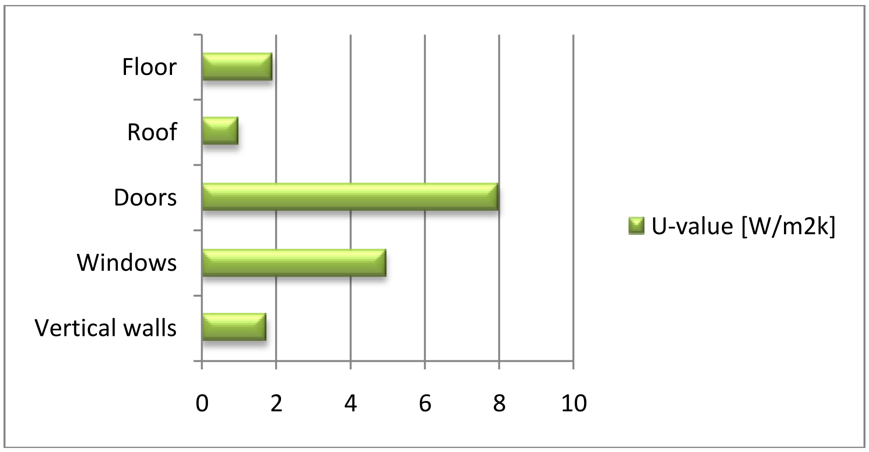

Chart 5.7 – Thermal transmittance of each building components for building type 4 (watts per square meter Kelvin)

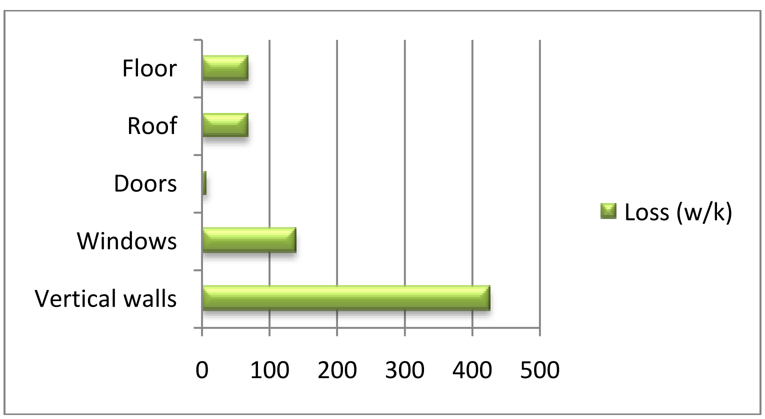

Chart 5.8 – Total heat loss of each building components for building type 4 (watts per Kelvin)

- **Type 5:**

Figure 5.24 – Location map of building type 5

Figure 5.25 – 3D model of building type 5

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
138	1794	0	35	0	57	Average

Table 5.25 - General information of building type 5

Vertical walls	**Area of the exterior walls (m^2)**	**Thickness of hard stone (cm)**	**Thickness of solid concrete (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the wall (W/m^2K)**	**Heat loss (W/K)**
	547	3	25	4	2.8	1527
Openings	**Area of the windows (m^2)**	**Type of the window**		**Loss of windows (W/K)**	**Area of the doors (m^2)**	**U-value of the door (W/m^2K)**
	92	Single glazed swing with blinds or curtains		382	9	1
Roof	**Area of the roof (m^2)**	**Thickness of slates (cm)**	**Thickness of wooden beams (cm)**	**Thickness of plaster & mortar (cm)**	**Loss of roof (W/K)**	**Type of the roof**
	202	2	10	2.5	203	packed
Floor	**Area of the floor (m2)**	**Thickness of stone (cm)**	**Thickness of solid concrete (cm)**	**U-value of the floor (w/m2/k)**	**Loss of floor (W/K)**	**Type of the floor**
	138	2	10	0.8	109	On the ground

Table 5.26 - Façade information of building type 5

Total building U-value	0.53	
Total heat loss	2734	W/K
Heat transfer coefficient	2480	W/m^{2}K
F (coefficient of free inputs of solar or internal)	0.09	
Glazing percentage	0.17	%
Annual requirements per habitable area	1132	kWh/m²
Total annual requirements	156242	kWh/m²
Annual consumptions per habitable area	1192	kWh/m²
Total annual consumptions	164465	kWh/m²
Total emissions of CO_2	29.6	Tones

Table 5.27 – Results for building type 5

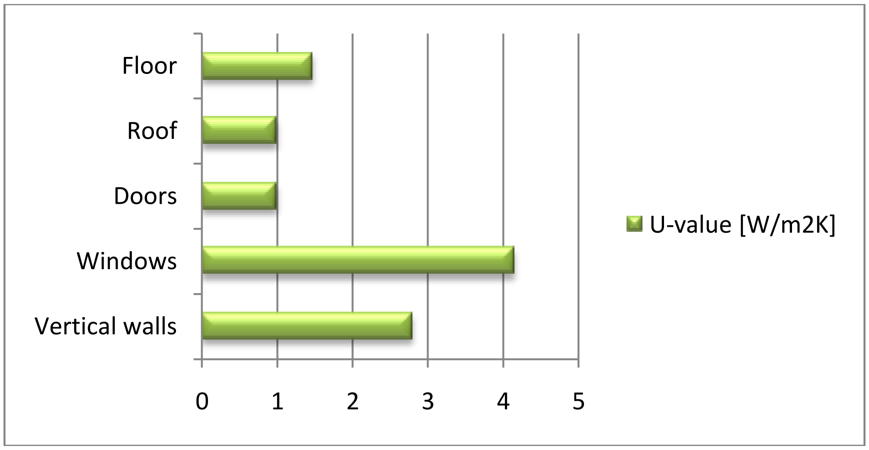

Chart 5.9 – Thermal transmittance of each building components for building type 5 (watts per square meter Kelvin)

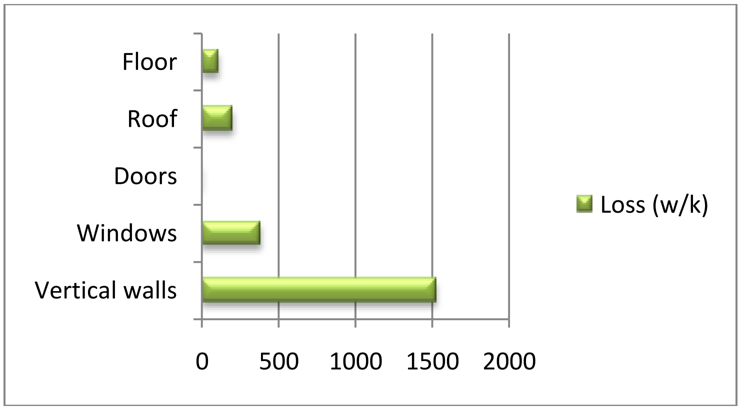

Chart 5.10 – Total heat loss of each building components for building type 5 (watts per Kelvin)

- **Type 6:**

Figure 5.26 – Location map of building type 6

Figure 5.27 – 3D model of building type 6

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
214	3257	82	10	0	0	Average

Table 5.28 - General information of building type 6

Vertical walls	**Area of the exterior walls (m^2)**	**Thickness of concrete (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the wall (W/m^2K)**	**Loss (W/K)**	
	604	25	4	2.9	1745	
Openings	**Area of the windows (m2)**	**Type of the window**		**Loss of window (W/K)**	**Area of the doors (m2)**	**Loss of door (W/K)**
	92	Single swing glazed with curtains or blinds		382	4	4
Roof	**Area of the roof (m2)**	**Thickness of slates (cm)**	**Thickness of wooden beams (cm)**	**Thickness of plaster & mortar (cm)**	**Loss of roof (w/m2/k)**	**Type of the roof**
	283	2	10	2.5	284	packed
Floor	**Area of the floor (m2)**	**Thickness of stone (cm)**	**Thickness of solid concrete (cm)**	**U-value of the floor (w/m2/k)**	**Loss**	**Type of the floor**
	214	2	10	0.8	169	On the ground

Table 5.29 - Façade information of building type 6

Total building U-value	0.52	
Total heat loss	3385	W/K
Heat transfer coefficient	3247	W/m^2K
F (coefficient of free inputs of solar or internal)	0.04	
Glazing percentage	0.15	%
Annual requirements per habitable area	956	kWh/m^2
Total annual requirements	204544	kWh/m^2
Annual consumptions per habitable area	1006	kWh/m^2
Total annual consumptions	215309	kWh/m^2
Total emissions of CO_2	38.8	Tones

Table 5.30 – Results for building type 6

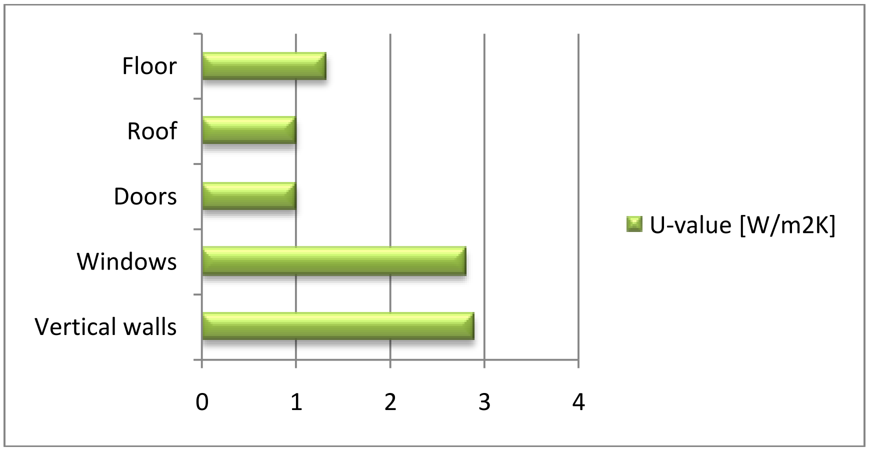

Chart 5.11 – Thermal transmittance of each building components for building type 6 (watts per square meter Kelvin)

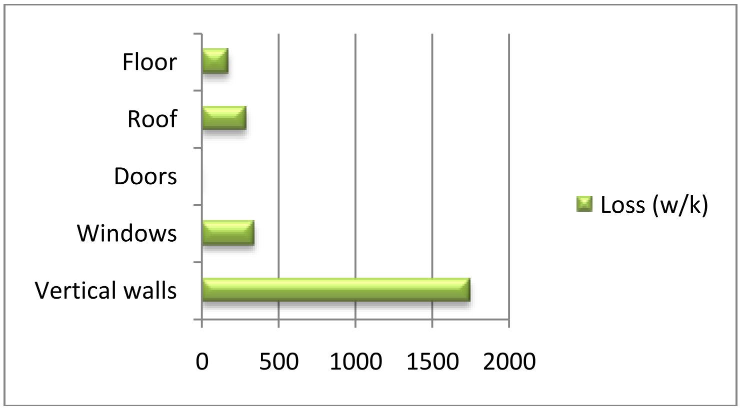

Chart 5.12 – Total heat loss of each building components for building type 6 (watts per Kelvin)

- **Type 7:**

Figure 5.28 – Location map of building type 7

Figure 5.29 – 3D model of building type 7

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
600	11460	0	0	41	183	High

Table 5.31 - General information of building type 7

Vertical walls	Area of the exterior walls (m^2)	Thickness masonry blocks (cm)	Thickness of PSE (cm)	Thickness of stone (cm)	Thickness of plaster & mortar (cm)	U-value of the wall (W/m^2K)	Heat loss (W/K)
	798	15	2	2	2	1.2	930

Openings	Area of the windows (m^2)	Type of the window	Loss of the window(W/K)	Area of the doors (m^2)	Loss of the door (W/K)
	212	Swing double with blinds	627	12	12

Roof	Area of the roof (m^2)	Thickness of slates (cm)	Thickness of wooden beams (cm)	Thickness of plaster & mortar (cm)	Heat loss (W/K)	Type of the roof
	678	2	10	2.5	681	packed

Floor	Area of the floor (m^2)	Thickness of stone (cm)	Thickness of solid concrete (cm)	U-value of the floor (W/m^2K)	Heat loss (W/K)	Type of the floor
	600	2	10	0.7	420	On the ground

Table 5.32 - Façade information of building type 7

Total building U-value	0.40	
Total heat loss	5445	W/K
Heat transfer coefficient	4675	W/m^2K
F (coefficient of free inputs of solar or internal)	0.14	
Glazing percentage	0.16	%
Annual requirements per habitable area	491	kWh/m²
Total annual requirements	294535	kWh/m²
Annual consumptions per habitable area	517	kWh/m²
Total annual consumptions	310037	kWh/m²
Total emissions of CO_2	55.8	Tones

Table 5.33 – Results for building type 7

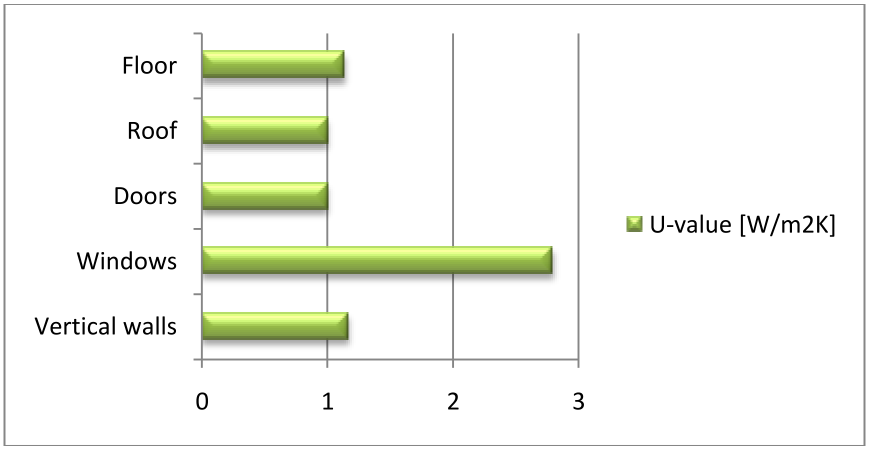

Chart 5.13 – Thermal transmittance of each building components for building type 7 (watts per square meter Kelvin)

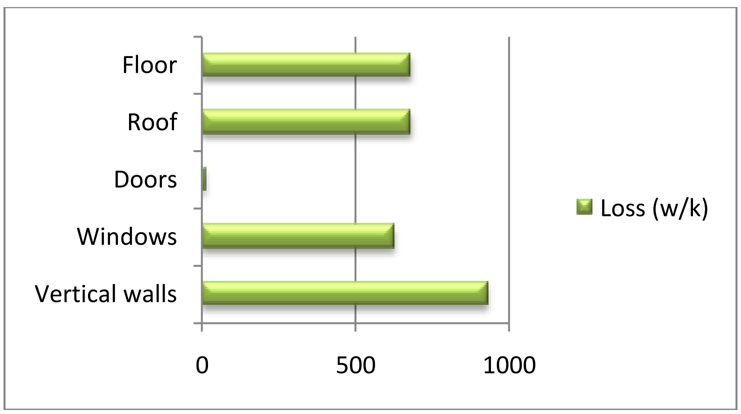

Chart 5.14 – Total heat loss of each building components for building type 7 (watts per Kelvin)

- **Type 8:**

Figure 5.30 – Location map of building type 8

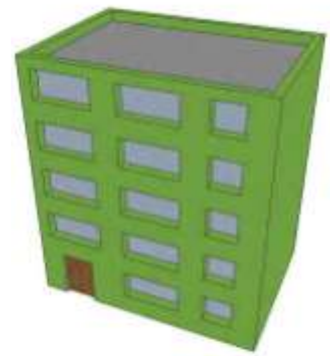

Figure 5.31 – 3D model of building type 8

Area of the building (m^2)	Volume of the building (m^3)	Area of glazing in North (m^2)	Area of glazing in East (m^2)	Area of glazing in West (m^2)	Area of glazing in South (m^2)	Inertia of the building
90	1120	0	90	94	0	high

Table 5.34 - General information of building type 8

Vertical walls	**Area of the exterior walls (m^2)**	**Thickness plaster coating (cm)**	**Thickness of thermal insulation (cm)**	**Thickness hollow blocks of masonry concrete (cm)**	**Thickness of plaster & mortar (cm)**	**U-value of the wall (W/m^2K)**	**Heat loss (W/K)**
	332	3	4	15	2	0.60	200
Openings	**Area of the windows (m2)**	**Type of the window**			**Loss of the window (w/k)**	**Area of the doors (m^2)**	**Loss of the door (w/k)**
	184	Thermal insulated double glazed with blind			312	4	4
Roof	**Area of the roof (m2)**	**Thickness of final finish (cm)**	**Thickness of concrete slab (cm)**	**Thickness of light weight concrete (cm)**	**Thickness of plaster & mortar (cm)**	**Insulation (cm)**	**Loss (w/k)**
	74	2	10	8	2.5	1	94
Floor	**Area of the floor (m^2)**	**Thickness of final finish (cm)**	**Thickness of solid concrete (cm)**		**Thickness of light weight concrete (cm)**	**Heat loss (W/K)**	**Type of the floor**
	90	2	10		8		On the ground

Table 5.35 - Façade information of building type 8

Total building U-value	0.29	
Total heat loss	938	W/K
Heat transfer coefficient	638	W/m^2K
F (coefficient of free inputs of solar or internal)	0.32	
Glazing percentage	0.55	%
Annual requirements per habitable area	446	kWh/m²
Total annual requirements	40178	kWh/m²
Annual consumptions per habitable area	470	kWh/m²
Total annual consumptions	42293	kWh/m²
Total emissions of CO_2	7.6	Tones

Table 5.36 – Results for building type 8

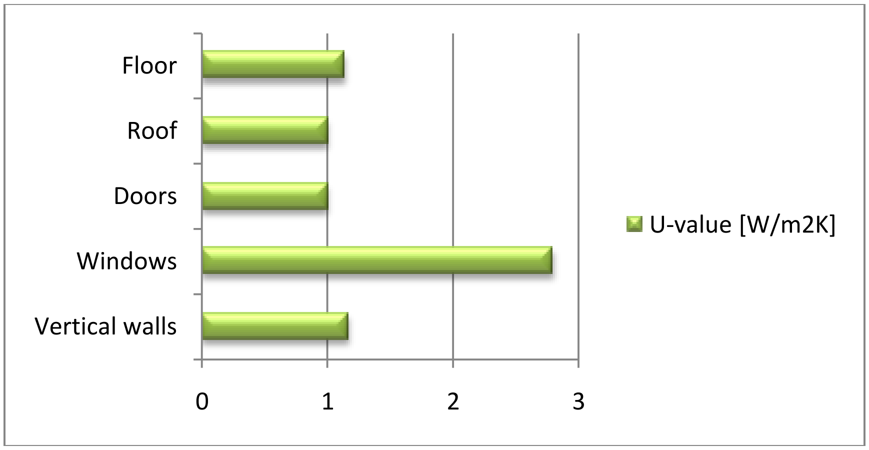

Chart 5.15 – Thermal transmittance of each building components for building type 8 (watts per square meter Kelvin)

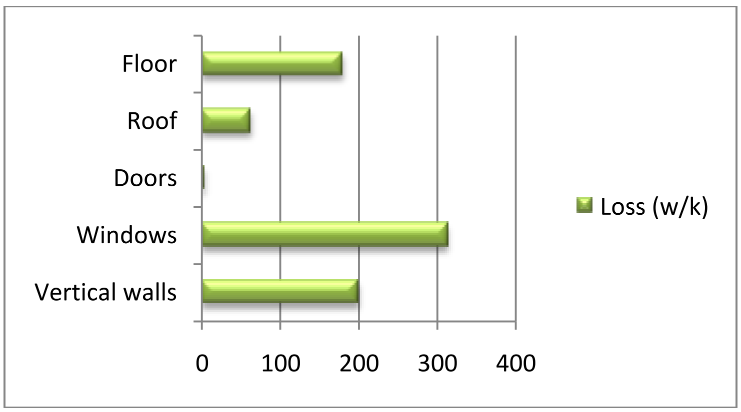

Chart 5.16 – Total heat loss of each building components for building type 8 (watts per Kelvin)

5.9. Generalization

After the calculation of the rate of carbon for each defined type, we generalize the gained data to the whole neighborhood. In this stage according to the existing plans of the district within local authorities and with regard to the polygons representing each building and data base which indicate height of each building, it is possible to calculate the volume of each particular type. Due to the rate of emission per cubic meter of each type of building, a specific number would be gained which is the total CO_2 emission for the entire neighborhood. Such generalizations can be considered for larger scales. Afterwards we can extend the study to regional and national scale if required.

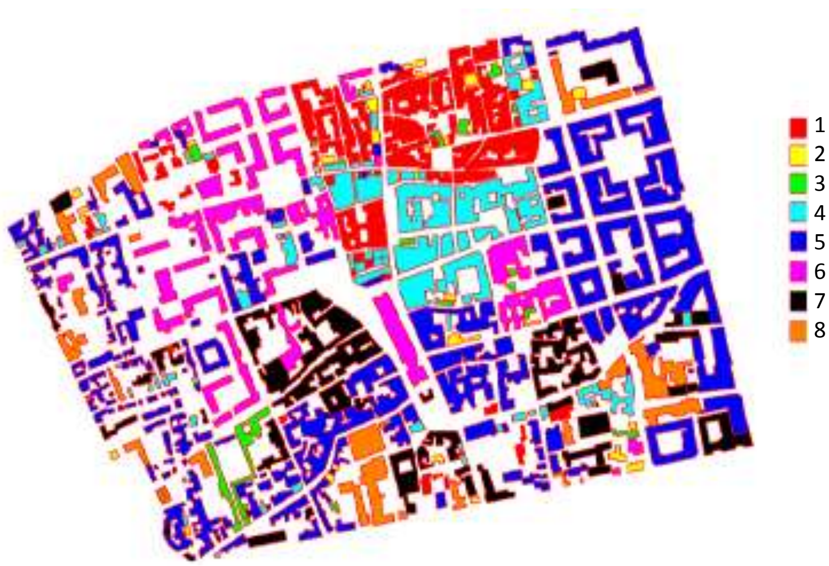

Figure 5.32 - Typology map of the study area in Tours

Archetype	Model building volume (m^3)	Total CO2 emitted by model building(tones)	Kg CO_2 per m^3 of model building	Total volume of each type (m^3)	Total CO_2 emitted by each type (Tones)
1	425	14.3	33.6	477964.68	16059.61
2	704	9.5	13.4	50015.16	670.20
3	286	5.3	18.5	66225.51	1225.17
4	982	12	12.2	397943.55	4854.91
5	1749	29.6	16.9	1512729.36	25565.13
6	3257	38.8	11.9	620036.70	7378.44
7	11460	55.8	4.8	762434.55	3659.69
8	1120	7.6	6.7	441881.82	2960.61
Total CO2 of the district					62373.76

Table 5.37 – The emitted rate of CO2 by each archetype and total CO2 emission of the district

5.10. Reconfiguration

- **Type 1:**

Walls: Applying thin layer of insulating plaster from inside which is applicable on the existing wall finish

Windows: Adding blinds, shutters or curtains from inside

Roofs: Installing polyurethane foam boards under the roof

Floors: Sticking woods and a layer of foam on the existing finish

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

	Scenario 1: Before reconfiguration	**Scenario 2: After reconfiguration**	`
Total building U-value	0.47	0.42	W/m^2K
Total heat loss	822	676	W/K
Heat transfer coefficient	774	628	W/m^2K
F (coefficient of free inputs of solar or internal)	0.06	0.07	
Annual requirements per habitable area	1354	1099	kW
Total annual requirements	48733	39579	kWh/m²
Annual consumptions per habitable area	1962	366	kW
Total annual consumptions	70627	13193	kWh/m²
Total emissions of CO_2	14.3	2.4	Tones

Table 5.38 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 1

In below there is a comparison between two scenarios (before and after reconfiguration) in different criteria:

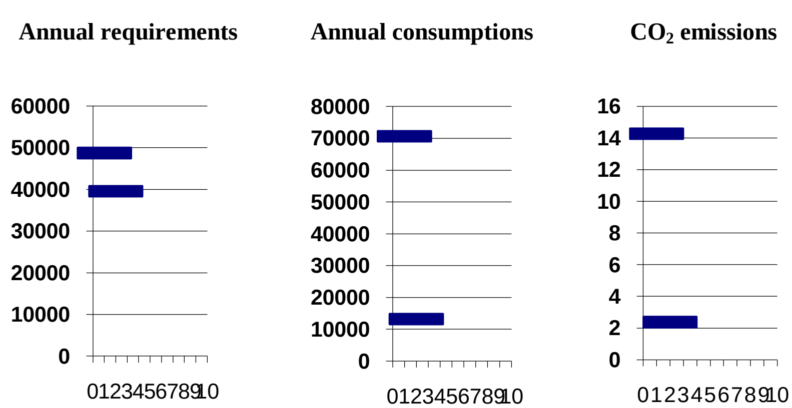

Chart 5.17 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 1

- **Type 2:**

Walls: Adding PSE insulation on the existing interior finish and applying final coating on it

Roofs: Installing polyurethane foam boards under the roof

Floors: Sticking stone on the existing finish floor to increase thermal mass

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

	Scenario 1: Before reconfiguration	**Scenario 2: After reconfiguration**	`
Total building U-value	0.47	0.27	W/m^2K
Total heat loss	883	455	W/K
Heat transfer coefficient	799	376	W/m^2K
F (coefficient of free inputs of solar or internal)	0.09	0.18	
Annual requirements per habitable area	630	296	kW
Total annual requirements	50364	23658	kWh/m^2
Annual consumptions per habitable area	663	99	kW
Total annual consumptions	53014	7886	kWh/m^2
Total emissions of CO_2	9.5	1.4	Tones

Table 5.39 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 2

In below there is comparison between two scenarios (before and after reconfiguration) in different criteria:

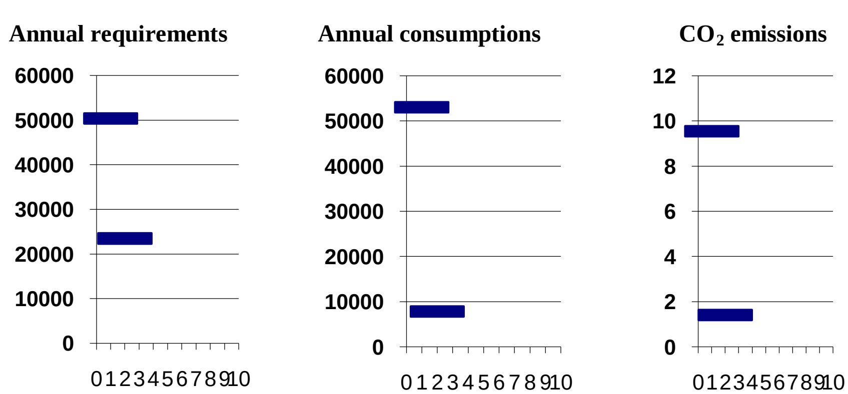

Chart 5.18 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 2

- **Type 3:**

Walls: Applying thin layer of insulating plaster from inside which is applicable on the existing wall finish

Windows: changing the existing windows with thermal insulated sealed windows

Roofs: Installing polyurethane foam boards under the roof

Floors: Sticking woods on the existing finish

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

	Scenario 1: Before reconfiguration	**Scenario 2: After reconfiguration**	`
Total building U-value	0.49	0.43	W/m^2K
Total heat loss	474	364	W/K
Heat transfer coefficient	448	338	W/m^2K
F (coefficient of free inputs of solar or internal)	0.06	0.07	
Annual requirements per habitable area	830	627	kW
Total annual requirements	28205	21310	kWh/m^2
Annual consumptions per habitable area	873	209	kW
Total annual consumptions	29690	7103	kWh/m^2
Total emissions of CO_2	5.3	1.3	Tones

Table 5.40 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 3

In below there is comparison between two scenarios (before and after reconfiguration) in different criteria:

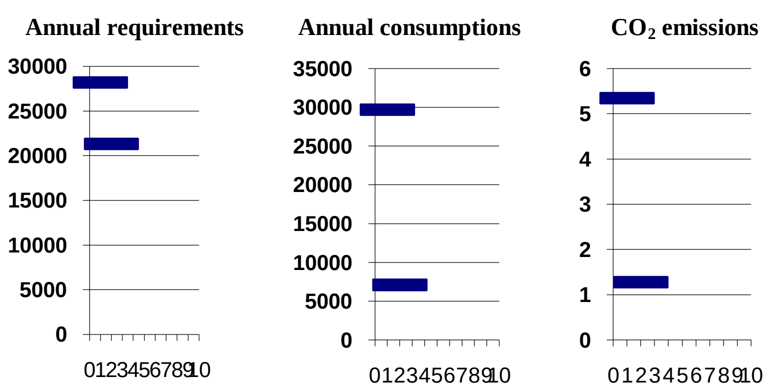

Chart 5.19 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 3

- **Type 4:**

Walls: Adding PSE insulation on the existing interior finish and applying final coating on it

Windows: changing the existing windows with thermal insulated sealed window

Roofs: polyurethane foam boards under the roof

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

	Scenario 1: Before reconfiguration	Scenario 2: After reconfiguration	`
Total building U-value	0.48	0.35	W/m^2K
Total heat loss	1072	675	W/K
Heat transfer coefficient	1008	612	W/m^2K
F (coefficient of free inputs of solar or internal)	0.06	0.09	
Annual requirements per habitable area	804	488	kW
Total annual requirements	63506	38581	kWh/m^2
Annual consumptions per habitable area	846	163	kW
Total annual consumptions	66849	12860	kWh/m^2
Total emissions of CO_2	12.0	2.3	Tones

Table 5.41 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 4

In below there is comparison between two scenarios (before and after reconfiguration) in different criteria:

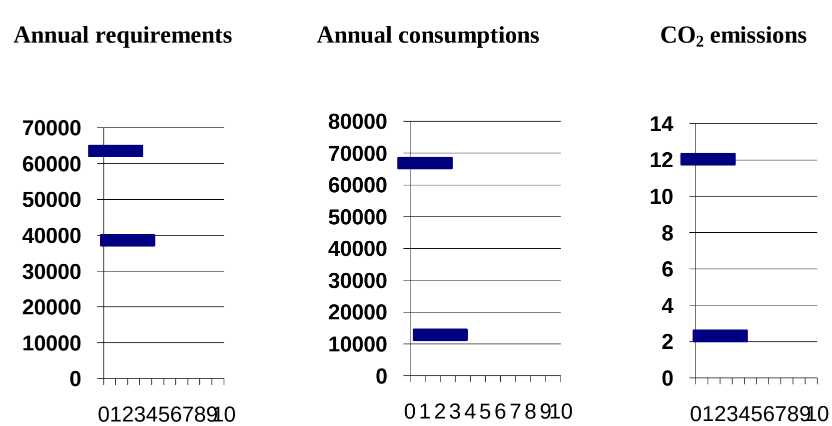

Chart 5.20 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 4

- **Type 5:**

Walls: Adding PSE insulation on the existing interior finish and applying final coating on it

Roofs: Installing polyurethane foam boards under the roof

Windows: Changing the existing windows with thermal insulated sealed windows

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

	Scenario 1: Before reconfiguration	Scenario 2: After reconfiguration	`
Total building U-value	0.53	0.39	W/m^{2}K
Total heat loss	2734	1523	W/K
Heat transfer coefficient	2480	1278	W/m^{2}K
F (coefficient of free inputs of solar or internal)	0.09	0.16	
Annual requirements per habitable area	1132	583	kW
Total annual requirements	156242	80496	kWh/m²
Annual consumptions per habitable area	1192	194	kW
Total annual consumptions	164465	26832	kWh/m²
Total emissions of CO_2	29.6	4.8	Tones

Table 5.42 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 5

In below there is comparison between two scenarios (before and after reconfiguration) in different criteria:

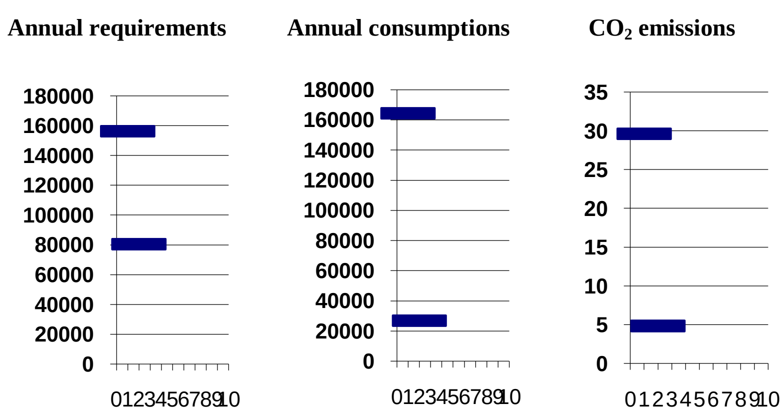

Chart 5.21 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 5

- ## Type 6:

Walls: Renovating exterior walls with new stone finish and a layer of PSE insulation below from outside

Roofs: Installing polyurethane foam boards under the roof

Windows: Changing the existing windows with thermal insulated sealed windows

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

	Scenario 1: Before reconfiguration	**Scenario 2: After reconfiguration**	`
Total building U-value	0.52	0.38	W/m^2K
Total heat loss	3385	2055	W/K
Heat transfer coefficient	3247	1918	W/m^2K
F (coefficient of free inputs of solar or internal)	0.57	0.07	
Annual requirements per habitable area	956	565	kW
Total annual requirements	204544	120817	kWh/m²
Annual consumptions per habitable area	1006	188	kW
Total annual consumptions	215309	40272	kWh/m²
Total emissions of CO_2	38.8	7.2	Tones

Table 5.43 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 6

In below there is comparison between two scenarios (before and after reconfiguration) in different criteria:

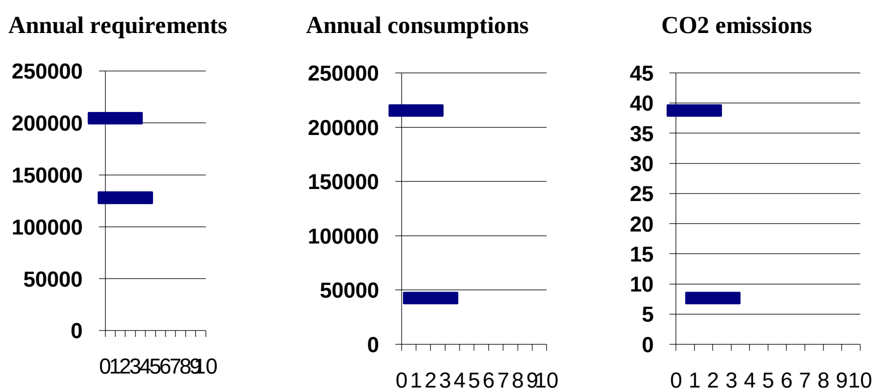

Chart 5.22 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 6

- ## Type 7:

Windows: Changing the existing windows with thermal insulated sealed windows

Roofs: Installing polyurethane foam boards under the roof

Floors: Sticking woods and a layer of foam on the existing finish

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

	Scenario 1: Before reconfiguration	Scenario 2: After reconfiguration	`
Total building U-value	0.40	0.29	W/m²K
Total heat loss	5445	4133	W/K
Heat transfer coefficient	4675	3374	W/m²K
F (coefficient of free inputs of solar or internal)	0.14	0.18	
Annual requirements per habitable area	491	354	kW
Total annual requirements	294535	212532	kWh/m²
Annual consumptions per habitable area	517	118	kW
Total annual consumptions	310037	70844	kWh/m²
Total emissions of CO_2	55.8	12.8	Tones

Table 5.44 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 7

In below there is comparison between two scenarios (before and after reconfiguration) in different criteria:

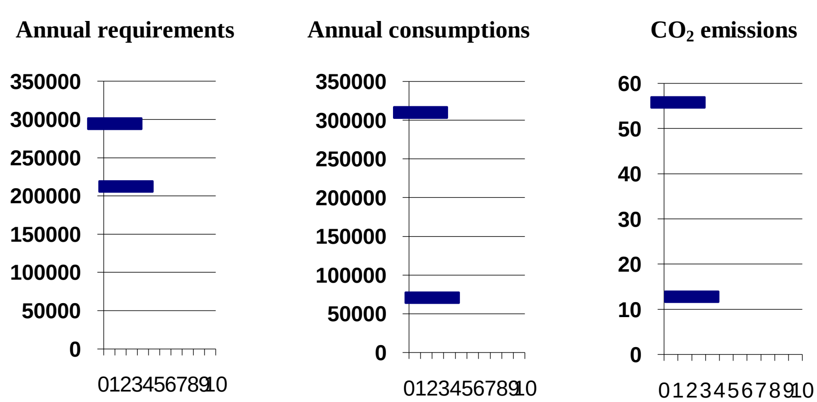

Chart 5.23 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 7

- **Type 8:**

Walls: Adding polyurethane foam from inside to the exterior walls

Equipments: Using multi-resources for heating (heat pump and electricity), Connecting to central network of energies

Roofs: Having the potential to turn into green roof or installation of solar panels to gain energy to compensate heat loss

Gardening: Adding plants and trees

	Scenario 1: Before reconfiguration	**Scenario 2: After reconfiguration**	`
Total building U-value	0.29	0.25	W/m^2K
Total heat loss	938	806	W/K
Heat transfer coefficient	638	511	W/m^2K
F (coefficient of free inputs of solar or internal)	0.32	0.37	
Annual requirements per habitable area	446	357	kW
Total annual requirements	40178	32165	kWh/m²
Annual consumptions per habitable area	470	119	kW
Total annual consumptions	42293	10722	kWh/m²
Total emissions of CO_2	7.6	1.9	Tones

Table 5.45 – General comparison between scenario 1 & 2 (before & after reconfiguration) in building type 8

In below there is comparison between two scenarios (before and after reconfiguration) in different criteria:

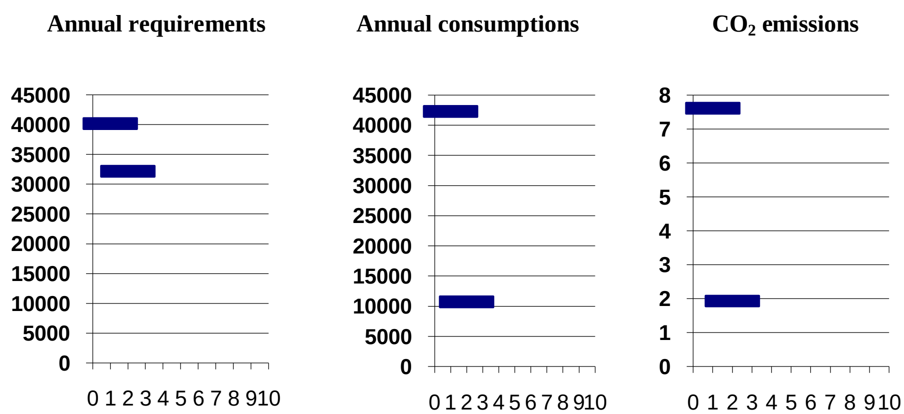

Chart 5.24 – Comparison of requirements (per kWh/m2), consumptions (per kWh/m2) and CO2 emissions (per tones) between 2 scenarios in building type 8

5.11. Simulation

In this section through an estimation of the new carbon emissions, a simulation of a carbon dioxide reduced neighborhood has been executed. In this neighborhood the rate of carbon dioxide has reduced to an approximate rate of 80 percent.

Archetype	Model building volume (m^3)	Kg CO_2 per m^3 of model building	Total CO_2 of model building per Tones after reconfiguration	Kg CO_2 per m^3 of model building after reconfiguration	Total volume of each type (m^3)	Total CO_2 emitted by each type after reconfiguration (Tones)
1	425	33.6	2.4	5.6	477964.68	2676.60
2	704	13.4	1.4	2.0	50015.16	100.03
3	286	18.5	1.3	4.5	66225.51	298.01
4	982	12.2	2.3	2.3	397943.55	1790.75
5	1749	16.9	4.8	2.7	1512729.36	4084.37
6	3257	11.9	7.2	2.2	620036.70	1363.08
7	11460	4.8	12.8	1.1	762434.55	838.68
8	1120	6.7	1.9	1.7	441881.82	751.20
Current total CO_2 of the district						62373.76
Total CO_2 of the district after reconfiguration						11903.72

Table 5.46 – The emitted rate of CO2 by each archetype and total CO2 emission of the district after reconfiguration

6

DISCUSSIONS AND REMARKS

In order to reduce CO_2 emissions, energy consumption should be reduced. Therefore seven main subjects play substantial role in this decrease (*see table 6.1*).

CO_2 emission reduction																							
Building envelope				Heating systems				Ventilation systems				Solar control & cooling				Light & electrical appliances				Management			
Doors	Windows	Insulation	Over-cladding systems	Heating installations	Domestic hot water installations	Energy sources	Control systems	Natural ventilation systems	Mechanical ventilation	Hybrid ventilation systems	Control & information	Shading & glare protections	Cooling systems	Air-conditioning systems	Control systems	Lighting systems	Electrical appliances	Day-light technologies	Control systems	Energy audit techniques	Commissioning	Education & training	Non-investment measures

Table 6.1 – Seven influential subjects in CO_2 emission reduction

Diverse methods are available for reconfiguration of a building:

- Enveloping: This includes removing faults from all external envelopes such as roofs, gutters, chimneys, openings, glazing, walls, etc. It would reduce the heat loss and therefore reduce the consumption of energy which would lead to less production of carbon dioxide.
    - Adding wall insulations: It is also possible to use kind of plaster inside which works like an insulator. In addition there are some foam panels or insulating paints that can be applied inside. Moreover, some kinds of insulations can be applicable on an already existing finish of a wall. Therefore they are suitable for retrofitting and can be applied mostly by spraying. Some of these insulations are consisted of rock wool, fiber glass and polyurethane foams.
    - Adding thermal mass to the interiors: Adding bricks, blocks, stones or such materials in various places as well as tiling the floor can be beneficial.
    - Using green roofs: To convert the roof to green space, we need to know whether the structure can support the considerable additional weight of soil, and the existing roof can be sufficiently water tight. So this option can be considered only in newer buildings.
    - Upgrading the glazing

  - Installing solar photovoltaic: Solar PV is capable of generating electricity by daylight and can be installed on roofs. Each kilowatt-peak of electricity produced by solar panels can reduce carbon dioxide emissions around 450 kilograms comparing with fossil fuels.

- Using green infrastructure: Usage of trees with falling leaves in front of the buildings' windows to exclude summer sun with their shades and catch winter sun would be very effective.

- Compensating heat loss: This can be done through several ways including using passive solar heating

7

CONCLUSION

Why not?

To sum up, in below very briefly, we describe possible reasons of not observing reconfiguration of infrastructures in every context:

- **Benefits:** It is impossible to measure all dimensions of benefits of retrofitting buildings in a neighborhood. The benefits can only assessed by values such as "costs per ton of carbon reduction saved". Some co-benefits such as health, aesthetics, social cohesion, etc. do not have market value and therefore might be ignored by responsible sectors.

- **Execution:** Practically, there is lack of enough coordinators and actors in this specific field.

- **Ownership:** There is a key barrier of ownership. Buildings are mostly owned by individuals but usually such programs of CO_2 reduction targets are integrated. Therefore all infrastructures in one neighborhood which are consisted of transportation routes, utilities, green infrastructure, etc are involving. The complexity of ownership of these infrastructures and the regulatory requirements result in involvement of a large number of organizations and authorities.

- **Finance:** Budgeting and funding in such programs is a great issue as individuals are often unable to afford retrofitting expenses and as well, public sector might have difficulties from economical point of view.

- **Privatization:** It is difficult to engage private sector stakeholders and investors into retrofitting programs and connect public and private sectors. Items such as lack of proven business models or accreditation systems are deterring private sector investments.

Lastly and more importantly:

- **Planning:** Lack of enough skills and absence of an accurate planning within local authorities is a significant obstacle in infrastructure retrofitting. There is a strong consensus that unlocking the organizational and planning issues would be the key to enabling neighborhoods to benefit from a more sustainable environment.

What to be done?

We have to exert several actions individually to achieve a lower carbon community to derive benefits from its priceless outcomes.

- Step 1. **To know the rate of CO_2 emitted by our buildings**: Before deciding how much CO_2 to be reduced, the current effect of the building on the environment should be realized.

- Step 2. **To find low/no-cost solutions**: Perhaps turning of lighting appliances, ventilation and heating systems when not required or during peak hours would be of a great help. Usage of occupancy sensors or dimmers in rooms which are occupied during certain hours or just for a short time is another method. These simple practices reduce the energy consumption and consequently the related pollution. This is often called behavior change which can be trained and promoted by governmental sectors.

- Step 3. **To use energy cost savings to pay for new equipments**: Replacing old systems with new ones such as energy efficient lightings or air conditioning systems can reduce the emissions to a great extent. This substitution leads to a great fuel saving in long-terms in future. So this amount can be used in advance to buy new equipments.

- Step 4. **To use green power**: Green power is any source of energy like solar panel, wind power, geothermal, biodiesel, etc. which produce very low carbon. This substitution of fuel or energy resource reduces the pollution emitted.

ENDNOTES

1. “Atmospheric concentrations of most gases such as carbon dioxide tend to vary systematically over the course of a year figures given represent averages over a 12-month period. Monthly CO_2 averages are taken from July 2007 to June 2008”. (National Oceanic and Atmospheric Administration, Earth System Research Laboratory)

2. The Global Warming Potential (GWP) provides a simple measure of the radiative effects of emissions of various greenhouse gases, integrated over a particular time period, relative to an equal mass of CO_2 emissions. The GWP with respect to CO_2 is calculated as below:

$$GWP_i = \frac{\int_{TR}^{TH} a_i C_i(t)\,dt}{\int_{TR}^{TH} a_{CO_2} C_{CO_2}(t)\,dt}$$

Where:

a_i = The instantaneous radiative forcing due to the release of a unit mass of trace gas i into the atmpsphere
TR = time
Ci = The amount of that unit mass remaining in the atmosphere at time
t = time it takes to release
TH = TR + time horizon of calculation (in the table 100 years)

3. The atmospheric lifetime is used to characterize the decay of an instantaneous pulse input to the atmosphere, and can be likened to the time it takes that pulse input to decay to 0.368 (l/e) of its original value. The analogy would be strictly correct if every gas decayed according to a simple expotential curve, which is seldom the case. For CO_2 the specification of an atmospheric lifetime is complicated by the numerous removal processes involved, which necessitate complex modeling of the decay curve. Because the decay curve depends on the model used and the assumptions incorporated therein, it is difficult to specify an exact atmospheric lifetime for CO_2. Accepted values range around 100 years. Amounts of an instantaneous injection of CO_2 remaining after 20, 100, and 500 years.

4. Changes (since 1750) in radiative forcing represent changes in the rate per square meters, at which energy is supplied to the atmosphere below the stratosphere. Greenhouse gases, aerosols, and changes in the sun's energy output may each be involved. Note Aerosols frequently have the effect of decreasing this radiative forcing. Energy is measured in Joules; the rate at which it is made available is in Joules/second, or Watts; hence, radiative forcing is measured in Watts per square meter (W/m^2). The "current" value refers to a global average.

5. The value of 280 ± 10 ppm is supported by measurements of CO_2 in old, confined, and reasonably well-dated air. Such air is found in bubbles trapped in annual layers of ice in Antarctica, in sealed brass buttons on old uniforms, airtight bottles of wine of known vintage, etc. Additional support comes from well-dated carbon-isotope signatures, for example, in annual tree rings. Estimates of "pre-industrial" CO_2 can also be obtained by first calculating the ratio of the recent atmospheric CO_2 increases to recent fossil-fuel use, and using past records of fossil-fuel use to extrapolate past atmospheric CO_2 concentrations on an annual basis. Estimates of "pre-industrial" CO_2concentrations obtained in this way are higher than those obtained by more direct measurements; this is believed to be because the effects of widespread land clearing are not accounted for. Ice-core data provide records of earlier concentrations.

6. The formulas and definition in this section are predefined formulas and definitions that are used as reference to calculate some factors (see the reference in bibliography section)

8

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