POLITECNICO DI TORINO

Master Course in

**ARCHITECTURE FOR THE SUSTAINABLE PROJECT**

Master Thesis

# A transformative approach to reach an energy-conscious district

## A case study in the city of Turin, Italy

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September 2022

## Acknowledgment

Without the assistance of numerous people, this project would not have been feasible. Many thanks to Professor Mario Artuso, my consultant, who read through my various edits and assisted in clearing out the confusion. Also grateful to Professor Giacomo Chiesa who provided advice and assistance on my analysis and framing.

Finally, I would like to express my gratitude to my partner, parents, and the many friends who supported and loved me throughout this prolonged process.

## Abstract

Worldwide, energy consumption is rising quickly, but in certain nations more so than others. The built environment accounts for 40% of the energy used in Europe. The built environment's carbon footprint can be significantly reduced by lowering the energy requirements of the building industry. This study aims to show methods for reducing energy consumption in an existing district in Turin, namely in the Lingotto neighborhood.

A city that is more ecological and energy-conscious is one step closer with an energy-conscious district. There are three basic steps in the process to get appropriate recommendations for the districts in Turin. First, the problems in each district were identified and examined. The causes a particular building, building block, or district more energy demand than it should be requiring, according to interpretation and previous studies. Four key factors have been taken into account for this step. Shape and orientation of the buildings, exposure to the sun and wind, functions, and heating. The most significant factor impacted by other factors come last. According to study, heating accounts for 80% of the energy used in residential buildings, and 64% of the energy comes from fossil fuels, leading to $CO_2$ emissions.(de Nigris and Fraire 2013) The introduction of many design options at the building and urban scales is the second step. The three-phase plan has been taken into consideration for this step-in order to achieve an energy conscious district and find the appropriate technologies. Thirdly, the districts that were chosen as well as the buildings that made up those districts were the main focus of the application of some of those applicable technologies. This plan entails energy recycling in the form of heating depending on the building functions in each zone of the district, followed by energy production based on the geometry and orientation of the buildings. Finally, how a district can function as a system in order to reduce the primary energy needs.

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# Chapter 1: Introduction

Energy consumption is growing rapidly worldwide, in some countries more than others. 40% of the energy used in Europe is a result of the built environment. Reducing the energy demands of the building sector can have a significant positive impact on Carbon footprint of the built environment. (Claudia Bouwens et al. 2020)

Passive house and Zero-energy building designs are ways to reach lower carbon footprint left by buildings. In the case of zero-energy buildings a balance of energy consumption and energy generation is created whereas in passive house design the energy consumption is reduced with passive measures and the building hardly requires any heating or cooling to meet comfortable conditions. After zero-energy buildings, zero-energy districts are the next step towards a more sustainable and energy conscious city. In order to achieve that, firstly we need to understand how buildings in a district are communicating with each other and how each individual building is part of the district. Following the Three-Stepped strategy or Trias Energetica which is an introduced guide towards an energy efficient building, Andy van den Dobbelsteen from Tu Delft has developed a "New stepped strategy" towards a sustainable building.(Andy van den Dobbelsteen et al., n.d.) Based on this stepped strategy, firstly the energy demands of the district will be reduced as much as possible in two different steps and the remaining energy demands will be met by the use of integrated renewable energy sources. **This research demonstrates this strategy implemented on existing districts in the city of Turin alongside passive house strategies in order to transform it into an energy-conscious district.**

## 1.1.Methodology

The methodology of this research is based on qualitative data provided by books, articles, case studies and interpretation of existing structures and districts. Some quantitative data has also been used to help with better understanding and identifying the thesis problems. This method helped to determine the requirements of the area, identify the issues, and provide and implement solutions.

The approach to achieve appropriated suggestions for the districts in Turin consists of three main steps. Firstly, it is required to recognize the issues in each district and analyze the reasoning why a certain building, building block or a district is using more energy that it needs to be using based on interpretation and existing articles. For this step four main aspects have been taken into consideration. Shape and orientation of the buildings, sun and wind, functions and lastly heating. The second step is introducing different design solutions in building and urban scale. For this step, the three stepped strategy has been taken into account. And thirdly the implementation of some of those appropriate technologies focalized on the chosen districts and the buildings they consist of.

This method helped to better analyze the existing areas and find the appropriate suggestions in order to be able to answer to the main thesis questions.

## 1.2.Thesis structure

This thesis research starts with defining Zero energy buildings and districts. Zero energy districts are our next step towards a more sustainable and energy conscious city. That is followed by some case studies in relatively similar climate and condition which introduce different technologies and approaches for newly built and old districts. Chapter three explains the climate in Turin and the characteristics of climate conditions in this region. Understanding the climate helps us to better manage the difficulties caused by the weather conditions, the building needs and energy demands. Another research aspect that needs to be taken into consideration is the energy needs in the city by different sector and the main sources that provide that energy. This helps us understand the main source of CO2 emissions in the city in any case that the primary energy is provided by fossil fuels.

Three main steps are considered to achieve the goal of this research which is demonstrating an approach to an energy conscious district. Two main districts have been chosen in the city; an old district in the historic city center and a relatively newer district with less restrictions in modification. Through a comparative approach of these zones from different construction periods the issues have been identified. This includes the high energy demands caused by an inefficiency in their design. This analyze is carried out by firstly studying the shape and orientation of the buildings which significantly affect the solar gain and natural ventilation; therefore, tied together with recognizing the sun and wind intake in the area. This is proceeded by understanding the demands of different functions and lastly how heating is provided in the area and if it can be improved. Water and space heating are the most important since 70-80% of primary energy demands for residential and public sector are for these purposes.

In chapter four, various design solutions in building and urban scale are introduced. Some of these solutions are inspired by passive house design since they can reduce the energy demands of a building by 90%. These strategies are carried out through two main steps: reduction of energy and reuse of energy. Simple design strategies inspired by bioclimatic architecture in the area alongside modern technologies help to significantly reduce the energy requirements. After the energy needs are reduced, energy production solutions are introduced which will be implemented on district depending on the positioning and shape of the buildings. This is an important way to show how each individual building contributes to the district.

And finally, appropriate technologies for the climate, existing urban tissue and lifestyle of Turin are implemented on the existing districts. This includes the energy reduction solutions followed by energy production. Eventually the way each district is working as a system when it comes to energy needs is demonstrated; therefore, how it can be more energy conscious. To achieve that, it is important to showcase how each building individually is a part of each district.

## 1.3. Main questions and objectives

Questions:

1. To identify what makes a single building part of system in the district.

2. To understand how buildings can communicate and work as a system in a district to reduce the energy demands.

3. Comprehending how we can transform an existing district to a more energy conscious district.

Objectives:

This thesis is a comparative approach to identify and reflect on current energy requirements of two districts with different construction periods. Interpret the issues of each district when it comes to high energy demands and design solutions and strategies.

- Determining the problems and reasons behind districts' high energy needs.
- The demonstration of urban-scale proposals for an energy-conscious neighborhood.
- The introduction of technologies that are suited for the city of Turin and a demonstration of their use.

# Chapter 2: Defining Zero energy building and district

## 2.1. Definitions

### 2.1.1. Zero energy building definition

A net zero-energy building (ZEB) is a residential or commercial structure with much lower energy requirements as a result of improvements in energy efficiency. This enables the balance of energy needs to be satisfied by renewable technology while reducing energy demands. Despite the enthusiasm surrounding the concept "zero energy," there isn't a uniform definition or even comprehension of what it entails. On the article "Zero Energy Buildings: A Critical Look at the Definition "(P. Torcellini et al. 2006) D. Crawley and colleagues study the concept of zero energy, what it entails, and why a clear and quantitative definition is needed, using a selection of current-generation low-energy buildings and how far they have gone toward the ZEB goal.

The definition of the zero-energy goal has an impact on the decisions designers make to reach it, as well as whether they can claim success. To fulfill a ZEB target, the ZEB definition can highlight demand-side or supply-side techniques, as well as whether fuel switching, and conversion accounting are applicable. Four well-established definitions net-zero site energy, net-zero source energy, net-zero energy costs, and net-zero energy emissions; are compared for benefits and drawbacks. These definitions are applied to a set of low-energy buildings that provide extensive energy data. The design implications of the ZEB term employed in this study, as well as the significant differences between definitions, are highlighted. It also considers different utility pricing structures and how they affect zero-energy scenarios. (P. Torcellini et al. 2006)

The ZEB concept assumes that low-cost, locally available, nonpolluting, renewable energy sources may cover all a building's energy needs. ZEB produces enough renewable energy on-site to meet or surpass its annual energy requirements under the strictest conditions. A proper ZEB definition should emphasize energy efficiency first, followed by the usage of locally accessible renewable energy sources. Because a facility that gets all its electricity from a wind farm or another central place is not motivated to reduce building loads, it is called an off-site ZEB. Demand-side technology such as passive solar heating and daylighting are considered efficiency measures. Energy efficiency is normally available throughout the duration of the building's existence; nevertheless, efficiency measures must be persistent and "checked" to ensure that they continue to save energy. **Saving energy is almost always easier than producing it.**

Depending on the boundary and metric, a zero-energy building can be characterized in a variety of ways. Depending on the project aims and the values of the design team and the building owner, other definitions may be suitable. Building owners, for example, are usually concerned about energy expenses. Organizations like the DOE (United States Department of Energy) are interested in primary or source energy and are concerned with national energy numbers. For energy code requirements, a building designer may be interested in site energy use. Finally, persons concerned about pollution from power plants and fossil fuel combustion may be interested in lowering emissions. Net zero site energy, net zero source energy, net zero energy expenses, and net zero energy emissions are four often used definitions. (P. Torcellini et al. 2006)

### 2.1.2. Zero energy district definition

City districts known as Net-Zero Energy Districts (NZEDs) are those where CO2 emissions released each year are balanced by emissions eliminated from the atmosphere. A new generation of "smart-green cities" that use both smart city technologies and renewable energy technologies includes NZEDs as a key component. NZEDs encourage environmental sustainability, make a difference in creating cleaner surroundings, and lessen the effects of climate change and global warming.

The importance of city districts switching to self-sufficient NZEDs is crucial since it significantly reduces centralization and supports efforts to create carbon-neutral cities. NZEDs offer a path away from the environmental concerns of climate change and calamities brought on by high heat, droughts, and floods. They also help to promote environmental sustainability, contribute to cleaner surroundings, and minimize global warming.(Komninos 2022)

The conversion of Europe's neighborhoods into net-zero energy districts was sparked by the adoption of the EU 2020 energy and climate targets. Leading municipalities have set challenging goals to lower their energy consumption and increase the percentage of local renewable energy sources in their energy mix. Municipalities in Europe define their energy goals in various methods, and each municipality sets its own deadline for achieving the agreed-upon goal locally. (Saheb et al., n.d.)

### 2.2. Case studies

The diversity of climate was a major factor in the selection of the following case studies. They effectively show how energy-conscious districts are possible with proper design and how creating more sustainable communities is extremely doable. With the exception of Bahnstadt, which the passive house institute claims to be the largest passive house district, each district's area was also taken into account when these districts were chosen.

#### 2.2.1. Bahnstadt District (Germany)

Bahnstadt district located in Heidelberg, Germany with the area of **116 hectares** is one of the biggest area of passive houses in the world ("Passivhaus Institut" n.d.). This district is designed to accommodate **5000 citizens** and create job opportunities for 7000. Bahnstadt is a district with zero emissions because its district heating and electricity supply are based on combined heat and energy production from a wood cogeneration plant. Everything is constructed in accordance with the climate-friendly passive house design, including labs, apartments, stores, daycare centers, schools, the fire station and movie theaters. ("Heidelberg_Bahnstadt_2014_en," n.d.)

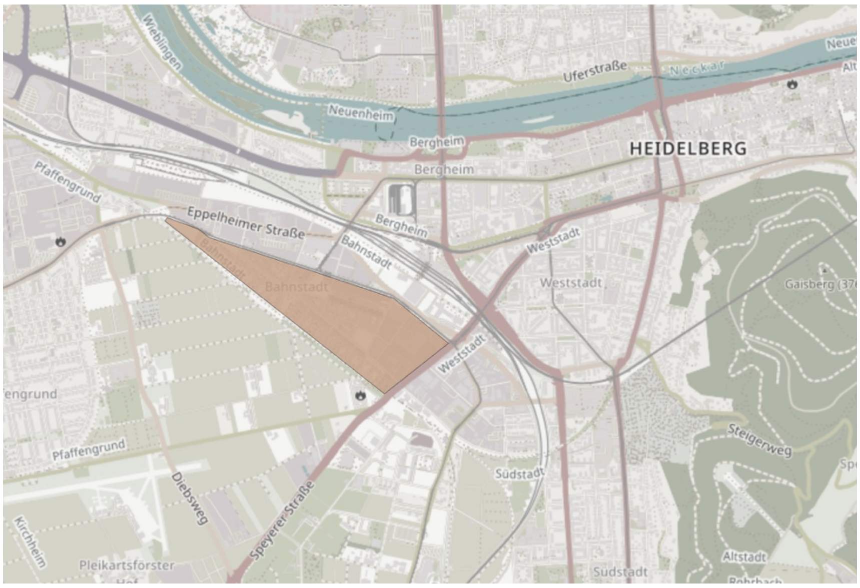



*Figure 1: District's position* ("OpenStreetMap" n.d.)

This is a newly constructed district which is a great example of a zero-energy district with zero emissions. This case study shows the possibly of having a sustainable built environment.

*Figure 2: Bahnstadt district ("Heidelberg_Bahnstadt_2014_en," n.d.)*

**2.2.2. Geos Neighborhood (US)**

Geos neighborhood approximately **10 hectares** is located in Arvada, Colorado. There are single-family homes, rowhomes, townhomes, duplexes, condos, a cohousing complex, and small retail establishments in this neighborhood which in total provides **282 dwellings**, which approximately accommodate 600-700 people. Dwellings meet the passive house standards with very low heating and cooling loads. These homes have proven to have a surplus of energy.

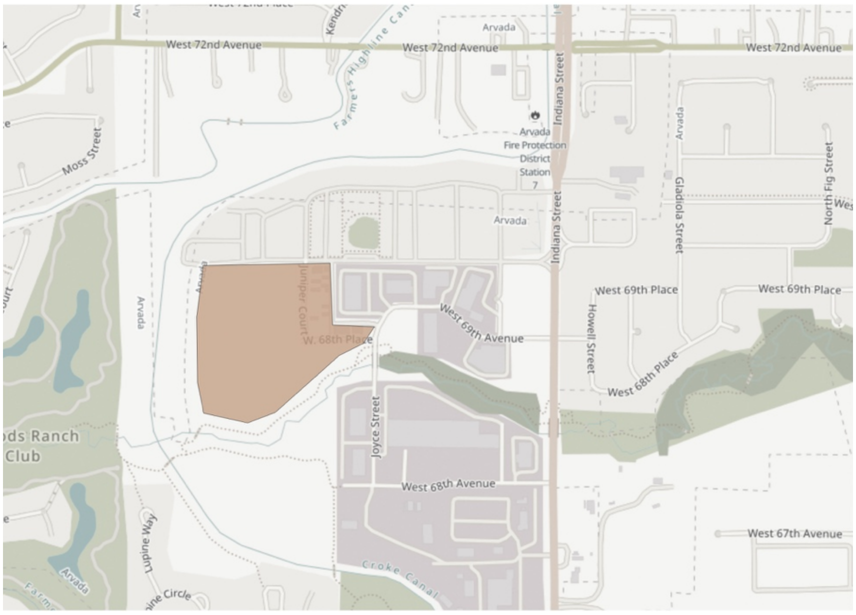


*Figure 3: District's position ("OpenStreetMap" n.d.)*

This neighborhood is designed to take advantage of solar gain during cold months of the year and minimize the sun exposure in summer months. During the first 3 years these homes were occupied, they have consumed only 25% of the energy of ENERGY STAR certified homes. It combines conventional village life with cutting-edge architecture and construction techniques. Residents of the neighborhood enjoy a pedestrian lifestyle that includes front porches, walkways lined with trees, corner shops, and neighborhood amenities. Geos uses the sun and the ground to produce as much energy as it consumes, with a total cost that is equivalent to or less than that of typical built-to-code communities, thanks to Colorado's special environment. (“Districts & Communities | ZeroEnergy.Org” n.d.)

This district having the same dimensions as our case studies is a great example of showing the possibility of a positive energy district.

*Figure 4: Photo of a passive-house district (“Districts & Communities | ZeroEnergy.Org” n.d.)*

### 2.2.3. Alta Valtellina (Italy)

The Alta Valtellina is located in Lombardy region in Italy. The municipal council decided to refurbish the school to the passive house standard and to open it up as an example project for workshops and training courses. At the same time, six other passive house projects were implemented in the region.(“LANG Consulting - Passivehouse Regions” n.d.)

The areas of the municipalities to the north-east of Valtellina that are part of the mountain community of Alta Valtellina make up the geographical subdivision known as Alta Valtellina. The communities between Tirano and Sondalo are generally included in this region.

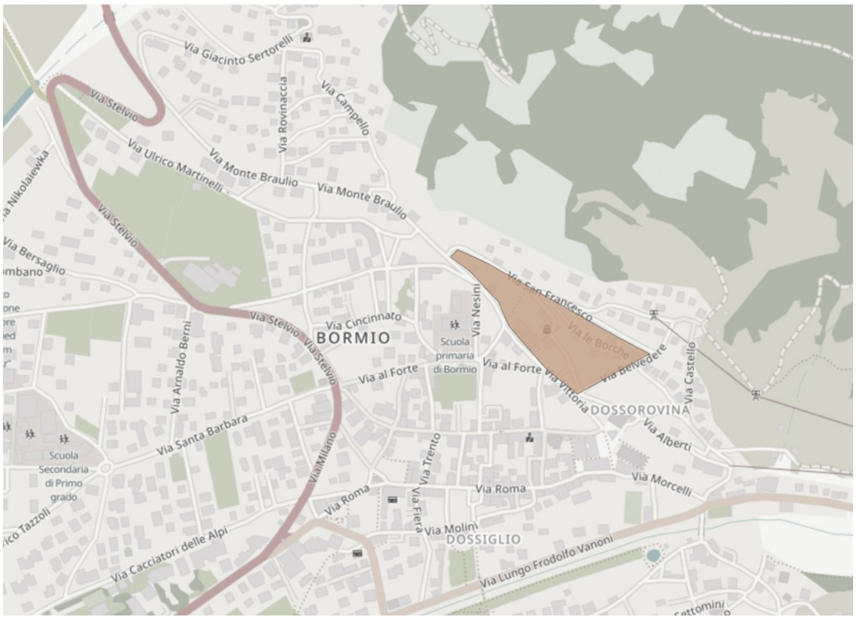



*Figure 5: District's position (“OpenStreetMap” n.d.)*

Together with the neighbouring Valmalenco, which has the highest mountain municipalities in height, this is often the most mountainous part of Valtellina. It also has significant summer and winter tourist attractions, including ski resorts in some cases.

Alta Valtellina is a portion of a town and commune in northern Italy's Lombardy region of the Alps with a **population of approximately 4,100**.

*Figure 6: Photo of a passive-house district* ("LANG Consulting - Passive house Regions" n.d.)

### 2.2.4. Main outcomes of case studies

The aforementioned case studies show various climatic conditions in various geographic locations with various types of housing. It has been clearly shown that creating a zero-energy district is both feasible and doable in all of those many circumstances. Our built environment just like geos neighborhood not only could be zero-energy but energy positive. Following these case studies, the main outcomes to consider are:

- Climate
- Buildings shape and orientations
- Passive and active use of solar energy

## Chapter 3: Climate and energy demand in Turin

### 3.1. Climate in Turin

Turin, the capital of Piedmont region is located in northern Italy. The climate type in central Europe and around northern Italy is considered to be Temperate. Temperate climates are generally defined as environments with moderate rainfall spread across the year or portion of the year with irregular drought, mild to warm summers and cool to cold winters. According to Köppen Climate classifications, Turin is considered to have **humid and subtropical climate** or **cfb**. Group **C** stands for Temperate climates, **f** means significant precipitation in all seasons and indicates warmest month average temperature above 22 °C.

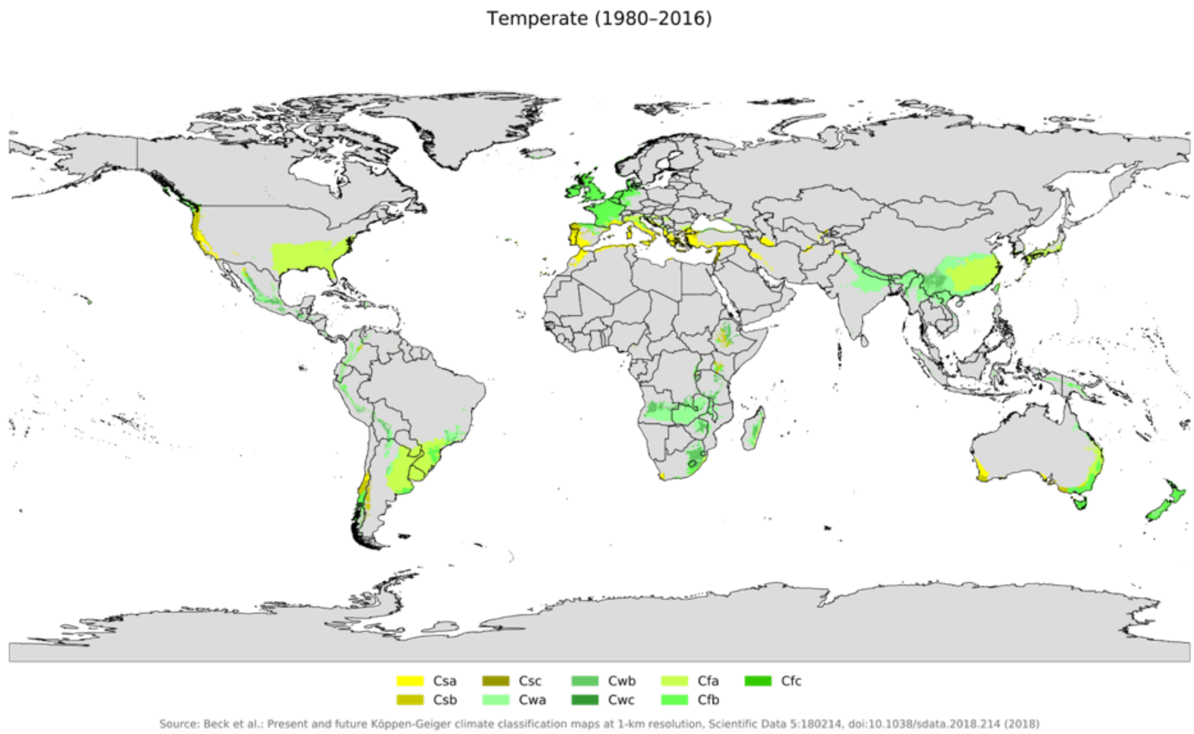



Figure 7: Group C of Köppen climate classification (Beck et al. 2018)

These climates are typically found in the high 20s and 30s latitudes, on the eastern shores and sides of continents. Unlike the dry summer Mediterranean climates, humid subtropical climates have a warm and wet flow from the tropics that creates warm and moist conditions in the summer months. As a result, summer is frequently the wettest season (as opposed to winter, as in Mediterranean climes). The flow out of the subtropical highs and the summer monsoon creates a southerly flow from the tropics that brings warm and moist air to the lower east sides of continents. In the more southern subtropical climes, such as the southern United States, southern China, and Japan, this flow is frequently what produces the frequent but fleeting summer thundershowers. ("Köppen climate classification explained") (McKnight et al. 2000)

The following chart demonstrates the maximum, average and minimum temperature in Turin. The chart is exported from the software climate consultant.

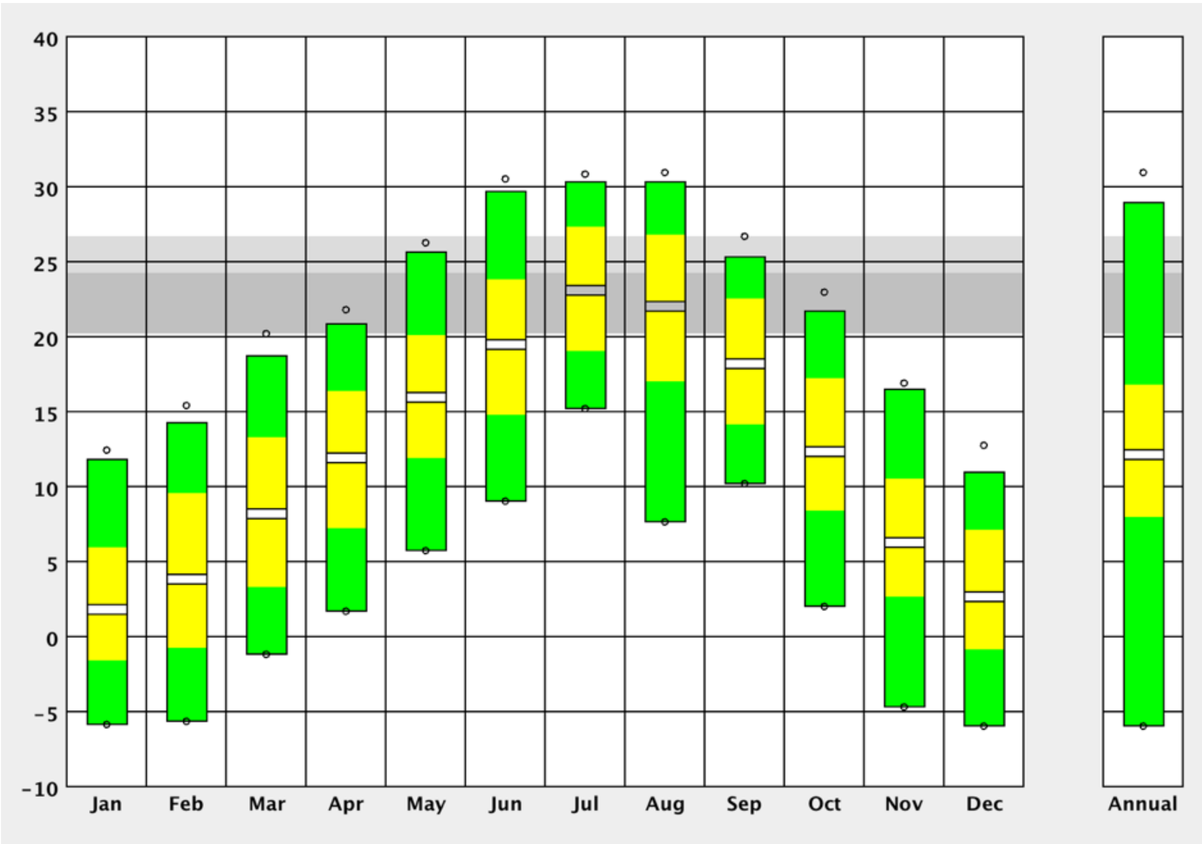



*Figure 8: Maximum and minimum average temprature in Turin* ("Climate Consultant 6.0" 2018)

Average annual temperature in Turin, Italy is about 12 degrees, therefore in cold winter season heating is essential. Since the maximum temperature can reach 31 degrees, cooling can be required during summer months. However, considering that during the summer months the area is very humid, increasing airflow in indoor spaces can be just as beneficial. Overall, during both summer and winter months, passive strategies and make a big difference in energy demands of a household. ("Climate Consultant 6.0" 2018)

This chart shows the sky coverage in the area, and the months that is the most possible to take advantage of solar passive and active energy.

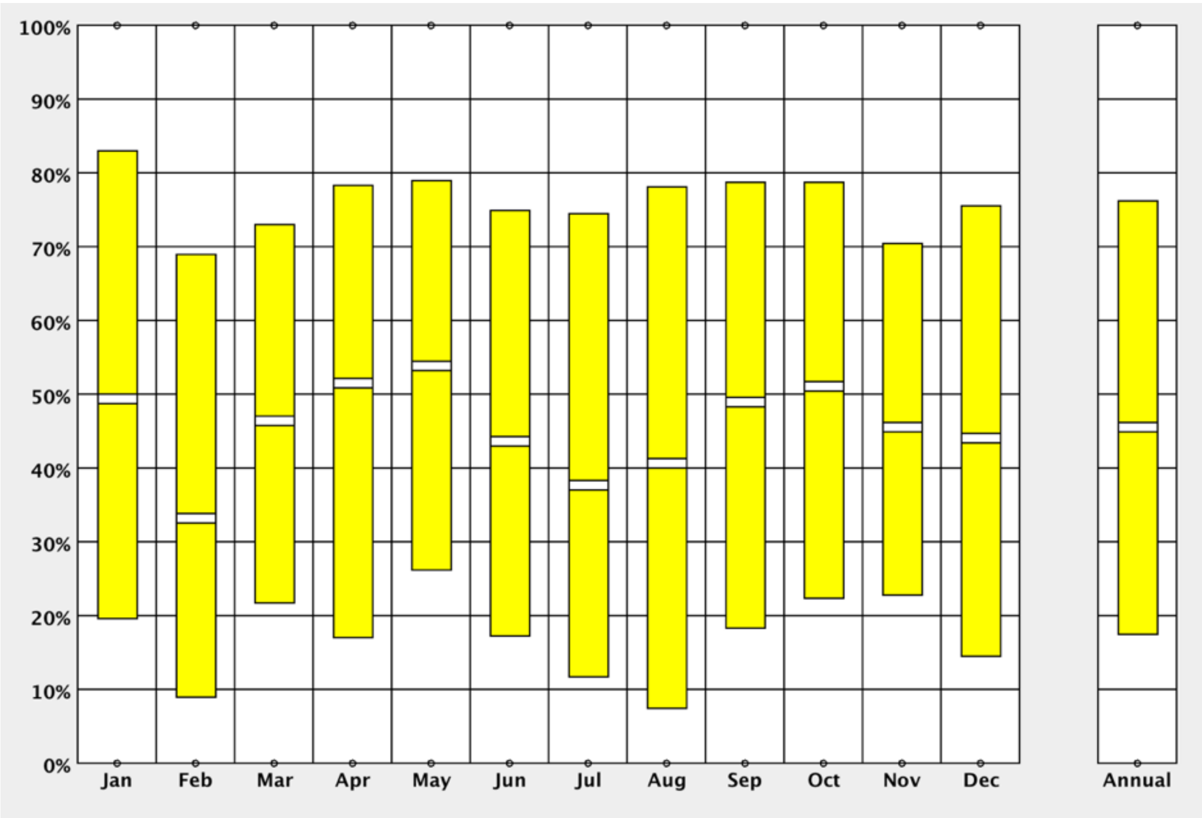



*Figure 9: Annual sky coverage in Turin* ("Climate Consultant 6.0" 2018)

The sky coverage of the city of Turin is approximately 45% throughout the year and around 40% during the summer months July and August. Therefore, use of overhangs during these months can be beneficial in order to prevent overheating in indoor spaces. Another way to prevent excessive heating in a passive house residential building is the use of vegetation to overshadow the windows during summer months and let the sun and the greenhouse effect to heat the building during winter months.

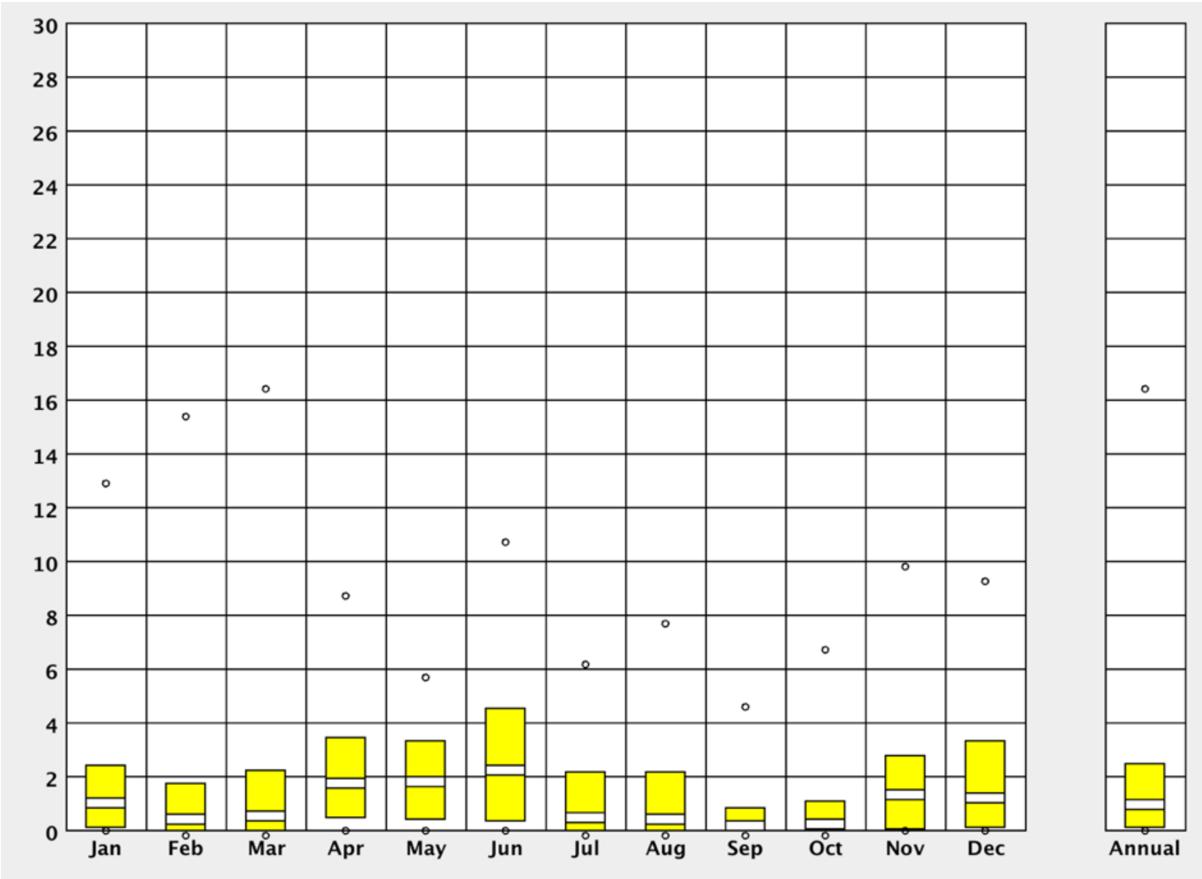



*Figure 10: Annual wind speed in Turin* ("Climate Consultant 6.0" 2018)

According to this chart the average wind speed in Turin is almost 1m/s. During hottest months of the year, the wind velocity is even less that 1m/s. Natural ventilation can be challenging during hot and humid months, However, some strategies such as use of stack ventilation and chimney affect can help increasing the airflow in an indoor space.

### 3.1.1. Bioclimatic architecture in Turin

This approach has made it possible to state that design and construction have an impact on global warming. Due to its use as heating, cooling, and lighting, architecture has an impact on the environment in terms of energy consumption. The field of ecology is greatly impacted by the building process. Because of this, architecture bears a heavy duty for how it is designed, projected, and constructed so as to benefit rather than harm the ecological sector. Bioclimatic architecture has been in the architectural records in different architectural periods. There were many analyses of the area of sunshine, solar angles and sciences, dominant winds, etc. In the last centuries, the industrialized construction was losing all these concepts that form as a whole measure that help for our environment and in the end fall in what harms the environment. Vernacular architecture has experienced a slow evolution during which it has gained social, cultural, religious, economic, technological and climatic knowledge related to particular places to yield quite singular architectural designs. (Ávalos et al. 2021) Without the need of additional technologies that use energy and have an impact on the environment, this style of architecture adjusts to the local temperature.

Piemonte region is located in north of Italy in the border of France. This region is located in the foots of Alps and it rich in materials such as stone. These materials are widely used in vernacular and monumental architecture. There are multiple case studies in the province of Turin that are characterized by the presence of adobe in the construction of both interior and exterior walls. The horizontal elements are mostly made of wooden beams and in some recent cases brickwork in-between the beams have been observed. The opening as well are made of wooden or brick frames. These houses are supported by a brick or stone foundation 40-50 cm above the ground level in order to protect the walls from the water rising. (Machat et al. n.d.)

The use of earthen material, due to it abundance in the area can have different benefits during the cold months of winter and warm summer months. In winter months these high mass brick walls absorb the heat from the sun during the daytime and release the heat during nighttime. Heat gains through the walls and solar radiations through the windows can reduce the heating demands during cold months. On the other hand, during summer times use of overhangs due to a different angle of solar radiation reduces the solar heat gain and as a result, also reduces demands of cooling systems during warm months.

Bioclimatic architecture could begin with bioclimatic urbanism, including tracing streets with intentional solar orientations and locating free garden spaces to create settings that favour comfort in public spaces that will be facilitated not only by architectural elements but also by deciduous vegetation elements.(Manzano-Agugliaro et al. 2015) An example of bioclimatic architecture in the city of Turin in regard to sunlight is shaded outdoor buffer zones that can be seen in the urban context. These shaded buffer zones proved shadows for the pedestrians and prevent overheating in the summer months in commercial buildings and maximizes the level of comfort.

*Figure 11: Photos representing bioclimatic features in northern italy. (Provided by the author)*

In addition to all mentioned above, use of pitched roof in this region can be mentioned. Pitched roof is initially used in order to prevent leakage caused by precipitations. However, it also increases the solar gains in indoor spaces due to expansion of the area of the room. Another element that is commonly observed in this city is the shaders on over the windows. Shaders can help the occupants to control the solar heat gain manually based on their needs and their comfort. They also act as an element of security in the building. During the winter months, if closed, shaders help to reduce the energy loss specially if there are only single glazed windows.  Overhangs and balconies are other elements that are commonly used in this region. Recognition of the delicate structure that holds the balconies is a way to differentiate the building of this region. These overhangs or balconies control the solar heat gains during summer and winter months.

These psychrometric charts that are presented below, represents the percentage of indoor comfort with and without active and passive strategies.

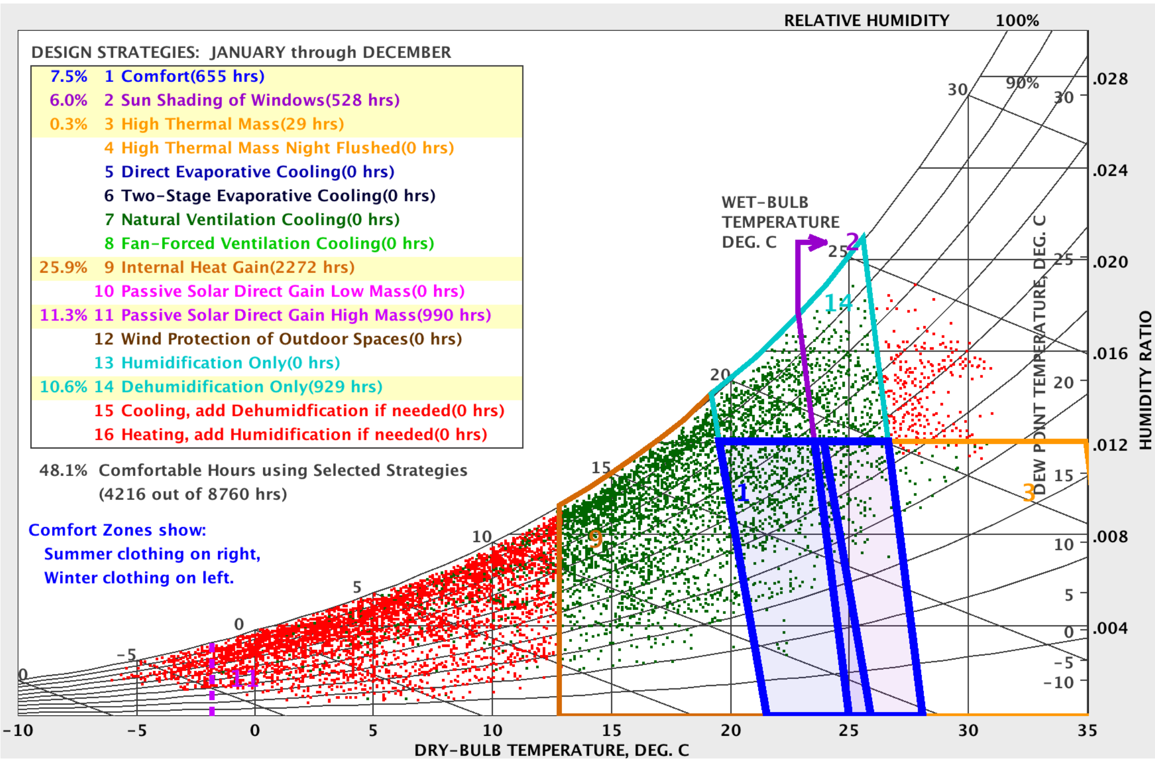



*Figure 12: Psychrometric chart-only passive strategies* ("Climate Consultant 6.0" 2018)

As depicted above 48% indoor comfort is possible without any active heating and cooling implemented on the building and only by passive strategies. These passive strategies can include, as mentioned above, and used in bioclimatic architecture on this region, use of high mass walls, internal solar heat gain and use of shading systems.

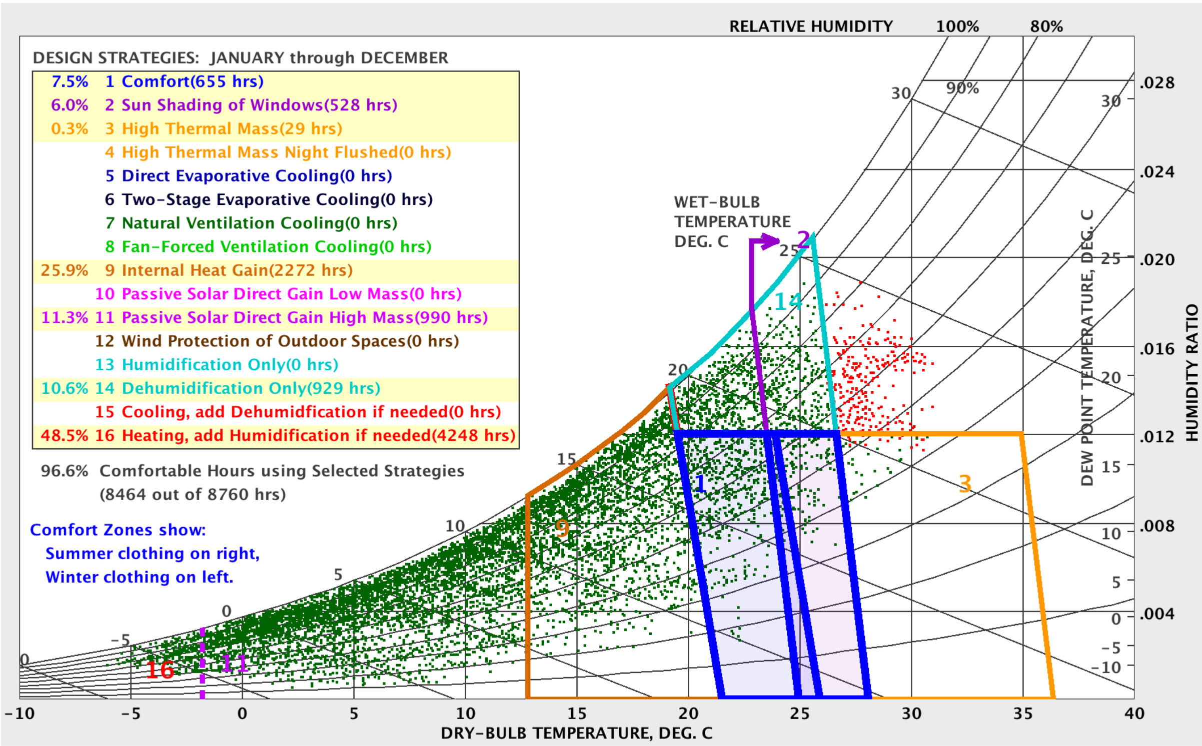



*Figure 13: Psychrometric chart-Passive and active strategies* (“Climate Consultant 6.0” 2018)

This indoor thermal comfort through-out the year can be increased to 96% on by the use of active heating systems. An increase of 48% in comfort level and the remaining 4% is easily done by cooling systems. This 4% according to climate consultant is 295 hours of one years which equals approximately 12 days of the year. As it was mentioned above in introduction of principles of a passive house, this cooling can be covered by a mechanical ventilation system to provide comfort in these 12 days.

### 3.2. Energy demand in Turin

The province of Turin's energy requirements is covered in detail in a study written by Silvio De Nigris and Stefano Fraire and released in April 2013. This study illustrates how the primary energy in this province is distributed across the various sectors. This study claims that a total of 55.8 TWh of energy, supplied by various energy carriers in various industries, was used in 2011.The residential sector accounts for 39% of the energy used in the City of Turin, as seen in the chart below. That results in up to 20 TWh of energy use of the city out of which 15 TWh is only for heating . Then comes industry and commerce, of which 10% is dedicated to trade and commerce, which is expanding quickly in parallel with the growth of the economy.

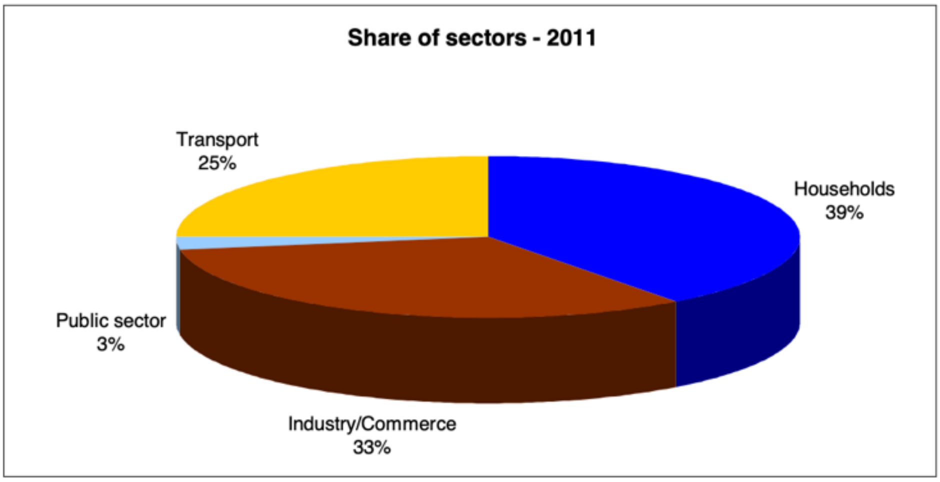
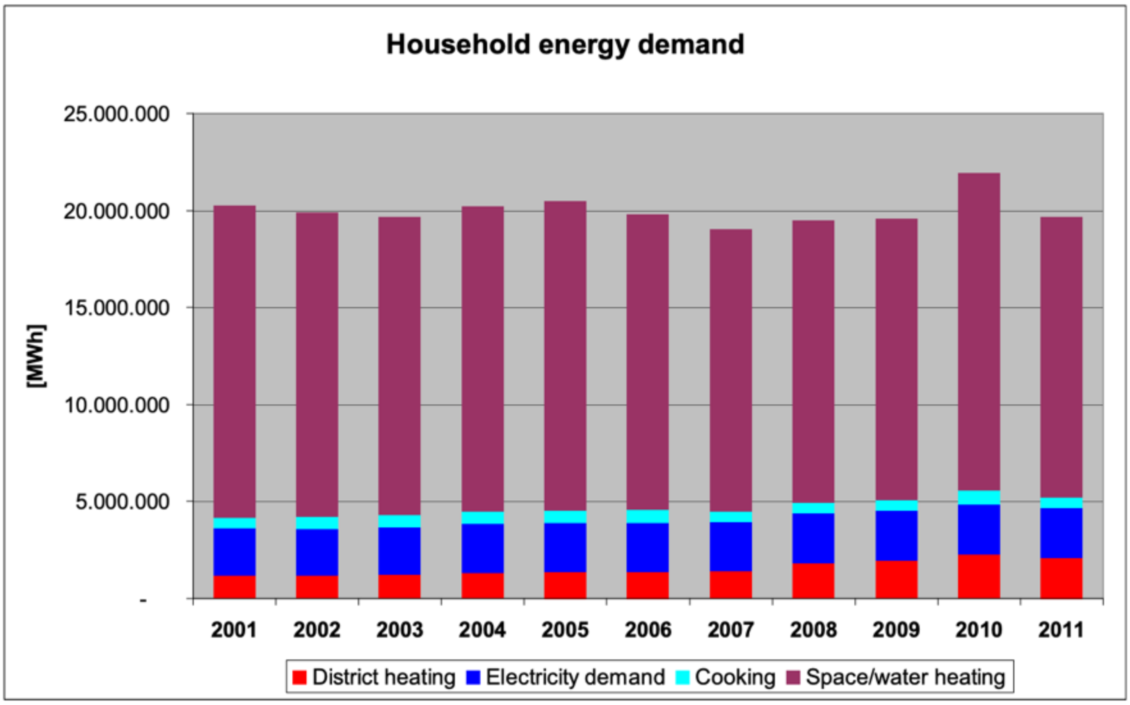



*Figure 14: Energy demand in Turin (de Nigris and Fraire 2013)*

#### 3.2.1. Household

Private households are the largest segment of final energy users, accounting for over 40% of total energy consumption. Setting up an action plan to increase the use of renewable energy sources, reduce primary energy consumption, or reduce greenhouse gas emissions requires careful consideration of the energy performance of the building portfolio. This industry consumed 19.7 TWh of energy in 2011, which is 2,8% less than it did in 2001. As a result, the sector trend over the reference decade under study is rather constant, and the annual fluctuations are primarily brought on by climatic changes. If we merely take into account thermal consumptions (heating plus the generation of hot domestic water), it is important to note that such energy use declined by 4%, mostly in the last five years.

More than 84% of overall consumptions are related to heating and producing hot water for home use, 13% are related to electric lighting and appliances, and 3% are related to cooking.(de Nigris and Fraire 2013)




| Type of demand | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| District heating | 1.154.323 | 1.160.958 | 1.235.970 | 1.306.002 | 1.351.894 | 1.352.229 |
| Cooking | 577.112 | 598.122 | 598.420 | 622.519 | 629.970 | 612.143 |
| Electricity demand | 2.459.649 | 2.444.341 | 2.458.689 | 2.557.797 | 2.553.503 | 2.592.000 |
| Space/water heating | 16.054.504 | 15.684.749 | 15.366.909 | 15.712.422 | 15.955.421 | 15.233.994 |
| **Total** | **20.245.587** | **19.888.170** | **19.659.988** | **20.198.740** | **20.490.788** | **19.790.366** |

*Figure 15: ousehold energy demand (de Nigris and Fraire 2013)*

Natural gas accounts for more than 59% of the overall energy consumption in private households, followed by electricity (13%) and renewable wood (12%). Since the expansion of the gas grid was pushed in previous decades and the capacity for its spread out is already exhausted, the consumption of natural gas has been fairly consistent across all decades. The data from 2010, which was an exceptionally cold year, is extraordinary and should not be considered. On the other hand, annual increases in biomass and electric usage both exceed 3 percent (by an average value of 1.7 percent per year). Between 2001 and 2011, the heating recovered by CHP (combined heat and power) and distributed through district heating systems nearly doubled, accounting for 11% of the total sector demand. Since the district heating system of the City of Turin and the surrounding municipalities is expanding significantly, forecasts for this carrier indicate that its share will increase in the near future. The CO2 emissions of private households will decrease as a result of this circumstance, which will be favorable. The need for natural gas may decline in the near future; in reality, district heating can only be spread out in this manner at the moment because diesel has no effect on private households' energy needs. Nevertheless, from 2.300 GWh in 2001 to 270 GWh in 2011, diesel consumption decreased. The only fossil liquid that is still increasing is liquid petroleum gas, which in 2011 was more than 2.5 times greater than diesel, reversing the trend from ten years earlier. The municipalities or regions not serviced by the natural gas grid are where such a carrier saw the most frequent use. The usage of oil is extremely limited and will end within the next few years since boilers that use this resource will no longer be available because they don't meet regional laws' environmental standards.

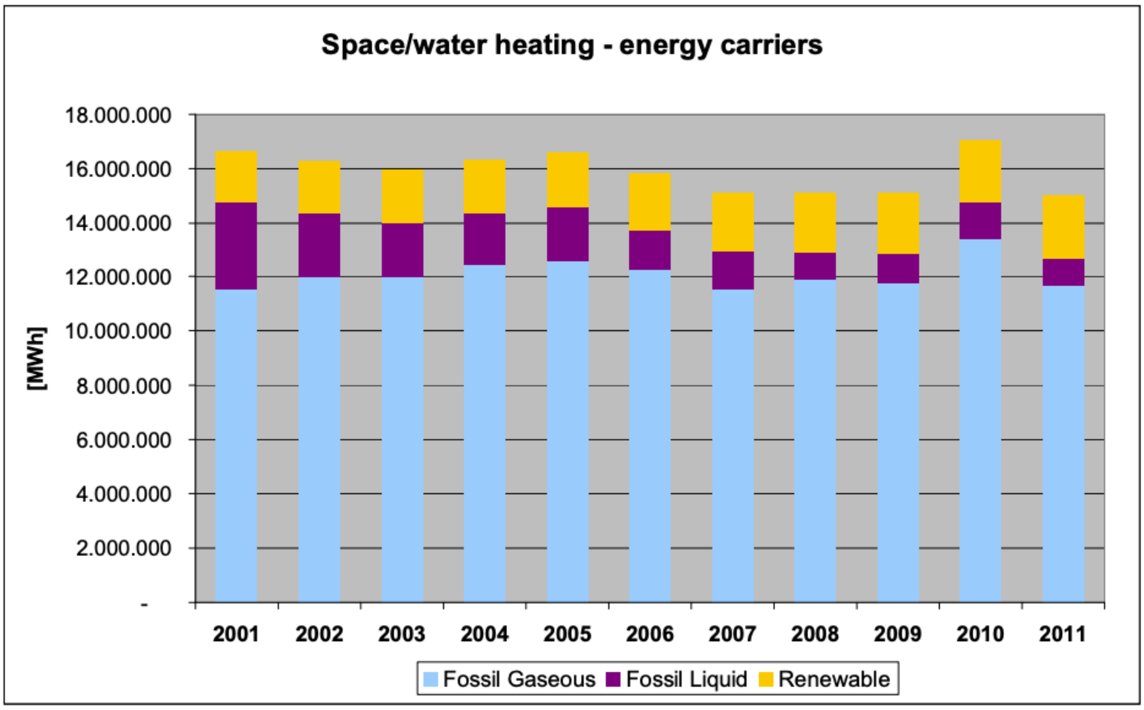



*Figure 16: Share of energy carriers (de Nigris and Fraire 2013)*

Aside from biomass, whose usage is historically significant, solar thermal energy shows a significant growth pattern even though its contribution to global demand is currently insignificant (0,2 percent). The contribution of geothermal energy is much more limited. With a widespread grid, fifteen utilities provide gas distribution service in the province of Torino. Only a few municipalities in the mountains, or about 1% of the population, are not served. Since an optimum basin for the administration of the gas grid will be introduced, the current chaotic and irrational condition of the gas distributors will change during the next three to five years. As a result, the service will only be run by 5 gas distributors. Although per capita consumptions show a different situation, with several mountain municipalities having top peak consumptions due to climatic conditions and their tourist attractions, the total consumption of natural gas is primarily concentrated in the City of Turin and the surrounding Municipalities. Aside from a few towns that are directly operating the service with their own utilities, the Province of Torino has two major utilities that cover practically the entire region in terms of the local electric grid.

As it is depicted in the graph above, 59 percent of total energy carriers is natural gas followed by 13% electricity. Natural gas is the main source of space and water heating in residential sector. This amount is easily redactable by reducing energy demands during winter months and replacing the source by passive and active solar energy

### 3.2.2. Commercial and industry

The economy accounted for 32.5% of all energy demand in 2011, and its weight in the Province of Torino's energy balance is falling. Its energy demand was 35% higher ten years ago, which was a significant increase. This industry lost up to 4.500 GWh in ten years,

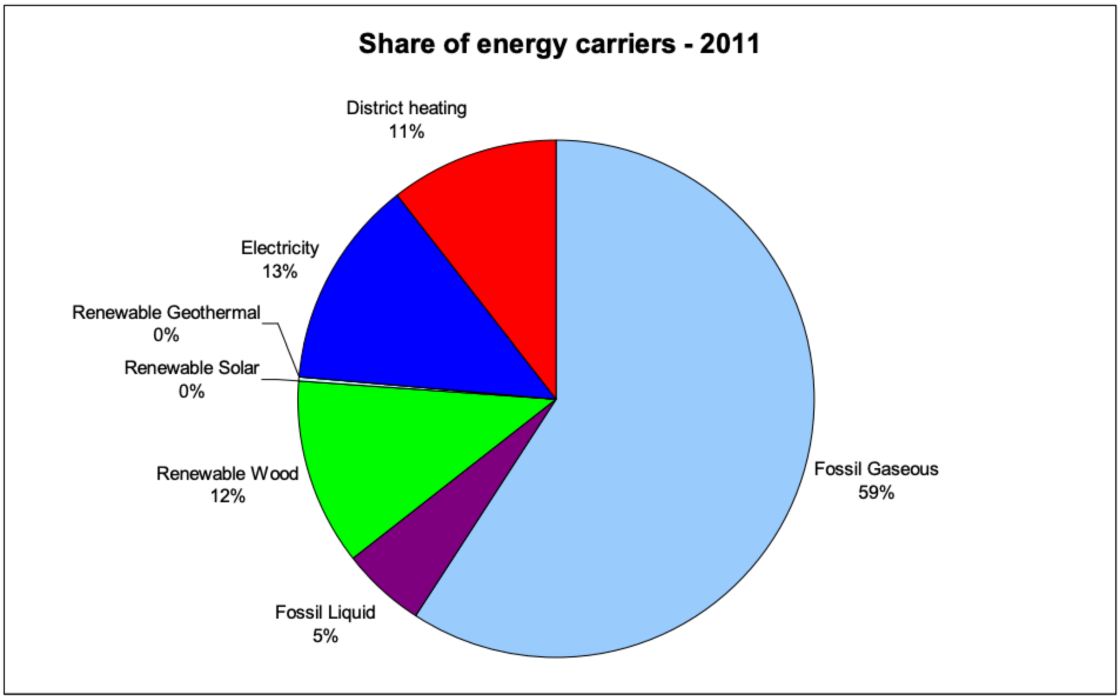



*Figure 17: Share of energy carriers (de Nigris and Fraire 2013)*

primarily due to natural gas usage. This sector's decline was most noticeable in the last five years under review, when industry required 3.600 GWh less. The economic crisis that impacted the entire region and, in addition, the automobile sector, which has historically been the main source of employment in Turin, are to account for this decline. The economics and employment of the region, which is currently considerably more focused on trade and services than industry, were impacted by FIAT Company's delocalization policy. The energy demand was directly impacted by the economic crisis that occurred at the close of the previous decade, accelerating a natural tendency. Even the heating recovered by combined heat and power plants, which in prior years had been the only energy source to keep rising, saw a decrease in the last two years

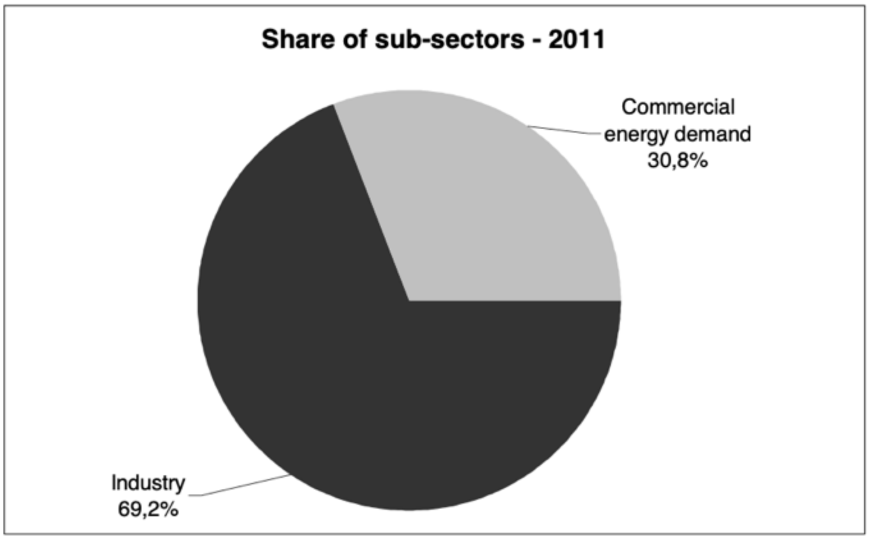



*Figure 18:Share of sub-sectors (de Nigris and Fraire 2013)*

The role of trade and commerce in the Province of Torino's energy balance is becoming more and more crucial. While a general observation, the only industry that has seen demand increase over the past few years, even as the economic crisis has severely impacted the region's productive activity, is trade and commerce. Since 2001, this sub-energy sector's usage has grown by 23% in 2011. An average annual growth rate of 2% is being recorded for the decade under review. Electric consumptions are unquestionably driving the rise, whilst thermal consumptions (heating + the production of hot domestic water) are largely stable and are following the same trajectory as private houses.(de Nigris and Fraire 2013) The primary energy source for trade and commerce is electricity, which is followed by natural gas (38&) and heating from CHP (6%). The demand for heating recovered by CHP and delivered through district heating systems, which has doubled since 2001, has benefited greatly from the growth. Forecasts for this carrier are consistent with those made for the sector of private households. Even in this industry, the importance of fossil fuels has declined, and only liquid petroleum gas has continued to expand for the same reasons as for private households.

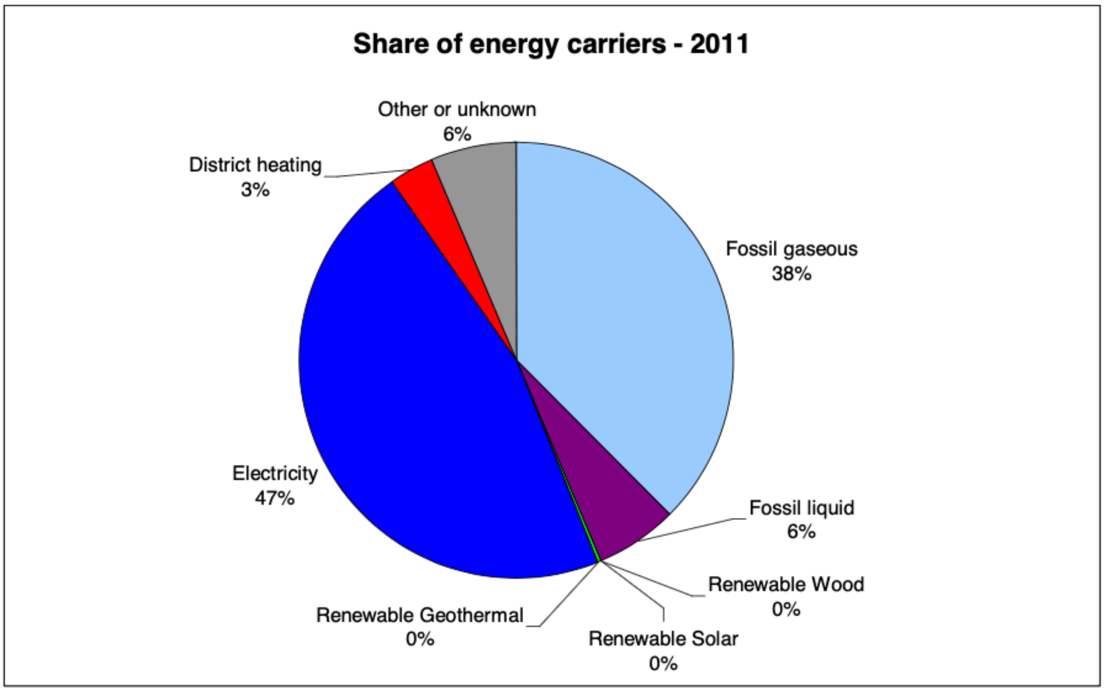



*Figure 19: Share of energy carrier (de Nigris and Fraire 2013)*

When it comes to renewable energy sources, renewable biomass is not used, but geotherm's contribution is seeing an exciting rise, particularly in open loop systems that use both groundwater and soil heat pumps. New initiatives are being developed for these platforms.

Even while solar energy's share of the entire demand is currently small, it has a significant growth trend.

It is fascinating to evaluate the added value's energy intensity because trade and commerce, which accounts for more than 70% of the province of Torino's total added value, is its most significant economic sector. Due to the widespread use of electric appliances and office air conditioning over the past ten years, the ratio of energy consumption to added value grew by over 20 percent.(de Nigris and Fraire 2013)

### 3.2.3. Public sector

The public sector accounts for 2.5% of the total energy demand. Its energy demand has increased consistently over the past four decades (+12%), regardless of what is happening in other sectors. However, the rate of growth is half that of private Trade & Commerce. Electricity (+15%), natural gas (+20%), and heating from local districts all have significant price increases. On the other hand, usage of fossil liquids is drastically declining, especially for diesel, which has mostly been replaced by liquid petroleum gas, natural gas, and wood. Only one large hospital uses fuel oil, and due to technological issues, its replacement is not being planned.

Regarding renewable energy sources, biomass is used in a number of wood-chip boilers that serve public structures like schools. Since 2006, the price of solar plants, the only means of self-producing electricity available in the public sector, has increased significantly.

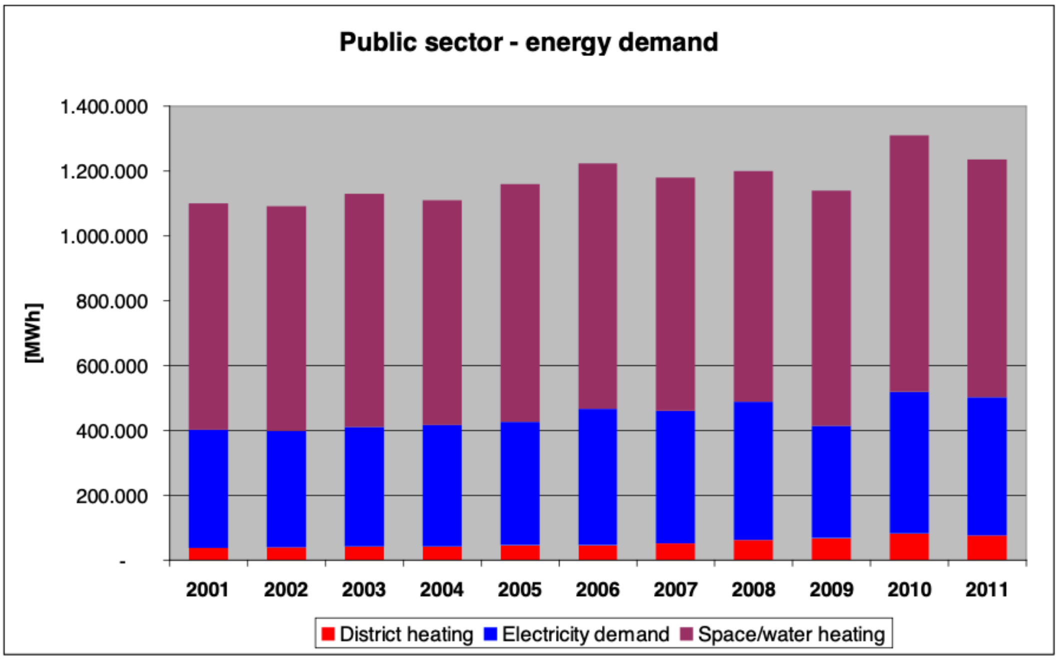



*Figure 20: Public sector energy demand (de Nigris and Fraire 2013)*

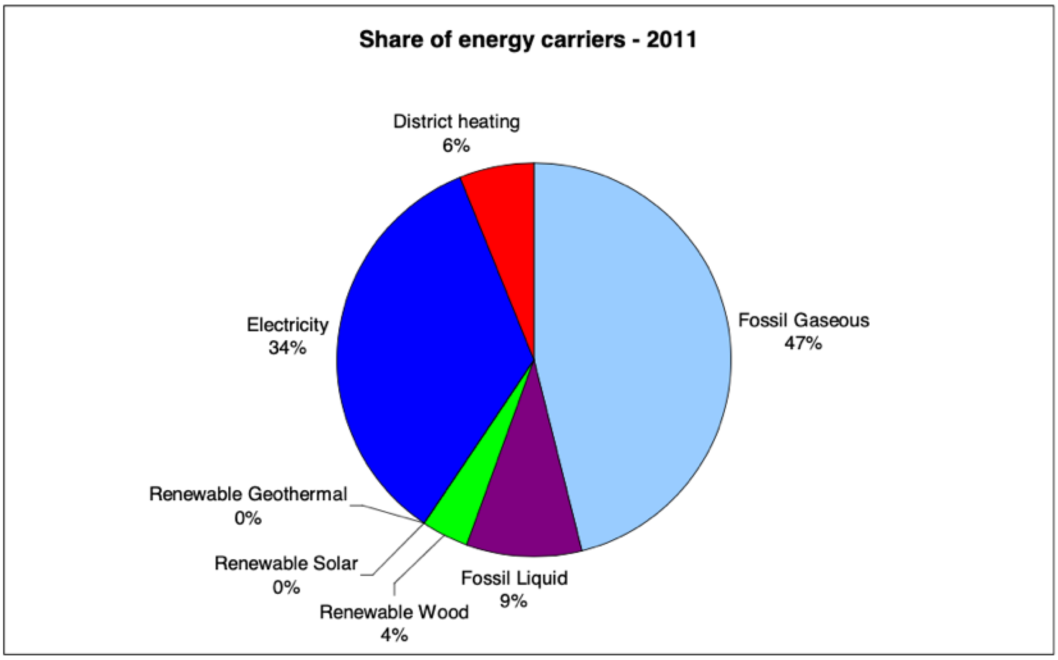



*Figure 21: Share of energy carriers (de Nigris and Fraire 2013)*

### 3.3. Case studies in Turin

The Department of House and City at the Polytechnic University of Turin, which is now the Department of Architecture and Design, created 40 cadastral Micro zones in Turin. In accordance with DPR 138/98 and the Ministry of Finance's Regulation, the Municipal Council approved the Micro zones in June 1999. The Regulation states that a micro zone is often a portion of the municipal territory that must be uniform in terms of town planning and at the same time be a market for real estate. This region is indicated in the land registry by one or more map sheets. (“OICT - Microzones Definition” n.d.)

Focusing on the “building construction period” variable, underlying the historical territorial segmentation of the Micro zones, the building construction periods for each microzne are represented in the map below: (Barreca, Curto, and Rolando, n.d.)

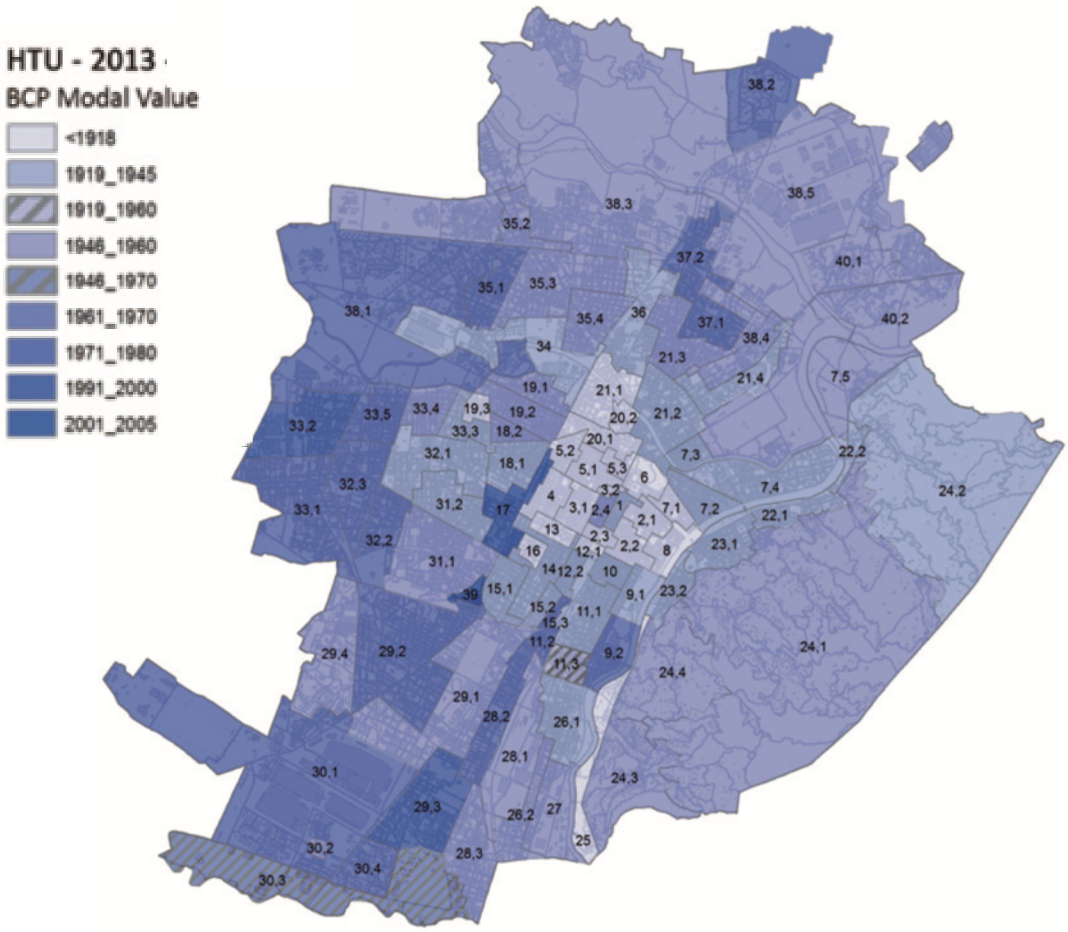



*Figure 22: Microzones in Turin based on construction period (Barreca, Curto, and Rolando, n.d.)*

### 3.3.1. San Salvario (Micro-zone 10)

The city center of Turin consists of grid plan pattern, the buildings are mostly rectangular shaped having a central courtyard which all the existing residential units face and take advantage of the sunlight through that courtyard. This repetitive pattern in the city of Turin gives us the advantage to demonstrate how one block in the urban tissue can be transformed and refurbished towards and energy efficient building. This urban tissue however changes in newer neighborhoods.

1. Roma
2. Carlo Emanuelle II
3. Solferino
4. Vinzaglio
5. Garibaldi
6. Castello
7. Vanchiglia
8. Rocca
9. Valentino
10. San Salvario
11. Dante
12. San secondo
13. Stati uniti
14. Galileo Ferraris
15. De gasperi
16. Duca d'aosta
17. Spina 2-Politecnico
18. Duchessa Jolanda
19. San donato
20. Porta palazzo
21. Palermo
22. Michelotti
23. Crimea
24. Collina
25. Zara
26. Carducci
27. Unita' d'italia
28. Lingotto
29. Santa rita-Mirafiori
30. Mirafiori sud
31. San paolo
32. Pozzo strada
33. Parella
34. Spina 3- Eurotorino
35. Madonna di campagna
36. Spina 4 – Docks dora
37. Rebaudengo
38. Corona nord ovest
39. Spina 1- Marmolada
40. Barca Bertola

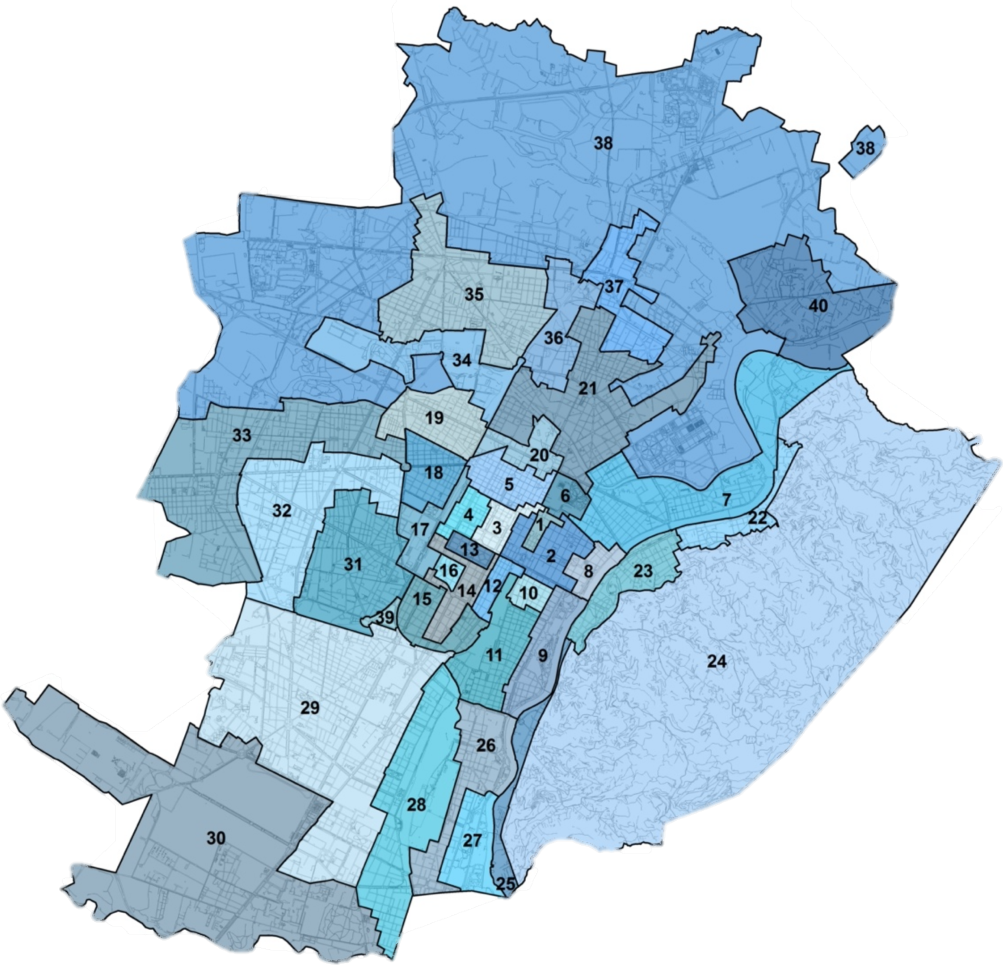


*Figure 23: Name of microzones in Turin (Barreca, Curto, and Rolando, n.d.)*

The map above depicts different Micro zones as defined above in the City of Turin as well as buildings construction period. For this research a portion of Micro zone 10 was chosen and analyzed with approximately and area of **9 hectares**, due to its location in the city center, being close to the Porta Nuova train station and being positioned in a relatively crowded area, it is considered to be a challenging Micro zone. Another reason for choosing this Micro zone is its density.

**Microzone 10:**

- **Area:** 0.4 $km^2$
- **Population:** 10,761
- **CO2 emissions:** 88,603 t
  ("Torino - Population - CityFacts" n.d.)


*Figure 24: A portion of San Salvario (Provided by the author)*

### 3.3.2. Lingotto (Micro-zone 28)

A documentary-style urban area, its placement was impacted by the presence of the General Markets, Customs, and the railway. It features a heterogeneous type of building fabric that is typically of low quality and in a poor condition of preservation, especially for residential structures. The Fiat Lingotto industrial complex, which is now a shopping and exhibition center, served as the area's defining feature. A number of projects that are redeveloping the area have been sparked by the conversion of the industrial complex, the 2006 Olympic Games projects, and broad redefinition of city areas. Corso Sebastopoli, via Giordano Bruno, via Tunisi, corso Traiano, route Onorato Vigliani, and via Nizza are the principal streets. This area was constructed between 1971 and 1980.

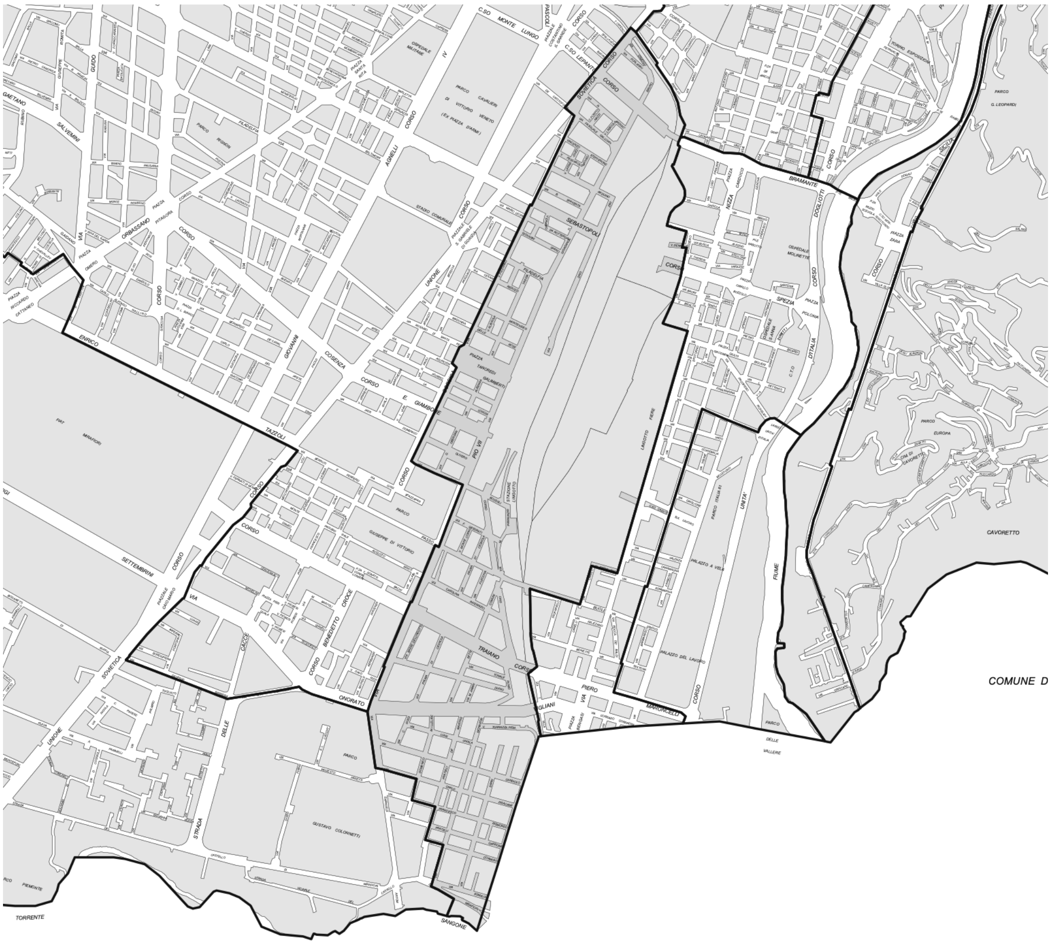



*Figure 25: Microzone 28 (Barreca, Curto, and Rolando, n.d.)*

Similar to San Salvario a portion of buildings in this microzone were chosen with approximately an area of **14.5 hectares**, out of which around **3 hectares** is an area of a park and separates the neighborhood into two groups. This portion of the neighborhood is demonstrated in the map below. Residential buildings among other functions surrounding Piazza Galimberti which is located opposite of the Olympic Village. This neighborhood is connected to Lingotto shopping center through a pedestrian bridge. This collective of buildings is a good representative of newly constructed districts in Turin.

**Microzone 28:**

- **Area:** 3,367 $km^2$
- **Population:** 38,304
- **CO2 emissions:** 315,384 t
  (“Torino - Population - CityFacts” n.d.)

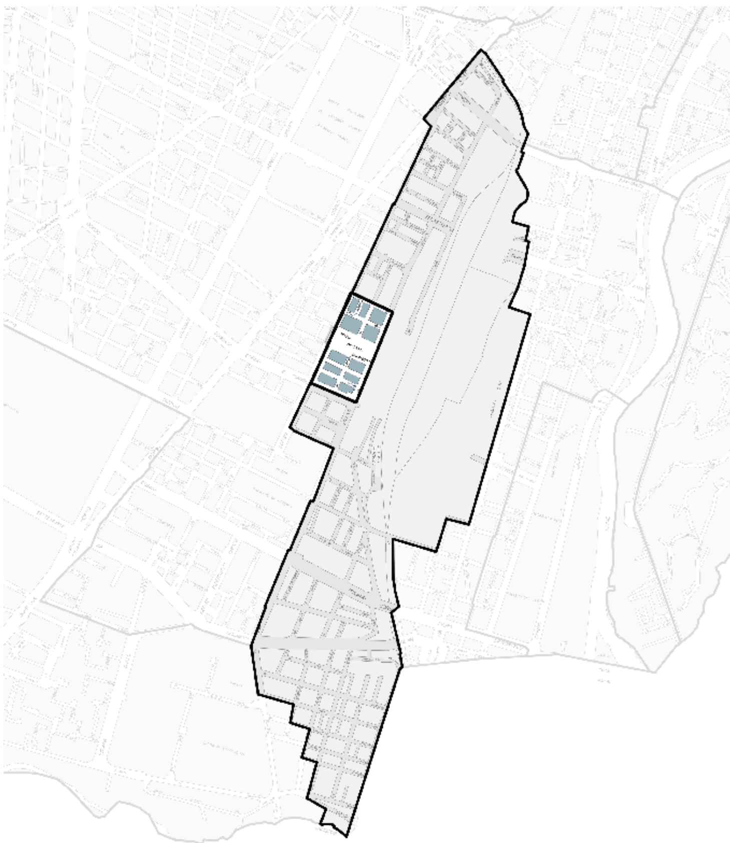


*Figure 26: A portion of Lingotto (Provided by the author)*

# Chapter 4: Identifying the issues in case study in Turin

## 4.1. Shape and orientation

Lingotto is a very heterogenous neighborhood with different building fabrics as it is observable in the photo below. Buildings have different heights, shapes, and colors and not well preserved. The diversity in height have causes some apartments to be overshadowed and not have the possibility to utilize daylight let alone passive solar gain. During the survey it was observed that some of these apartments were shadowed at midday on a summer day, this overshadowing means that even during the winter months they won't be able to receive any sunlight in indoor spaces, therefore zero passive solar gain. Despite it causing having cooler interior spaces during summer, in winter these apartments require higher levels of energy in order to heat up the space and consequently more green gas emissions will be released into the space.

*Figure 27: Buildings in Lingotto (Provided by the author)*

*Figure 28: Buildings in Lingotto (Provided by the author)*

Regarding the size, shape, and orientation of the buildings, the second issue to be brought up is that some of the structures were oriented east-west. Receiving low angle direct sunlight from the east and west, which can lead to overheating on hot summer days and insufficient solar gain for passive solar heating in wintertime. Numerous straightforward techniques in the design of the building's shape, the windows, and the balconies might have reduced the structure's current energy requirements because the building plot was east west. The biggest challenge for these windows is controlling sunlight and solar heat gain because the sun's angle with relation to them changes throughout the day. East-facing windows are most vulnerable to heat buildup because of how shallowly the morning sun reaches them. West-facing windows' similar exposure at the end of the day can easily lead a home to get hot when combined with the high afternoon air temperatures.

*Figure 29: Buildings in Lingotto (Provided by the author)*

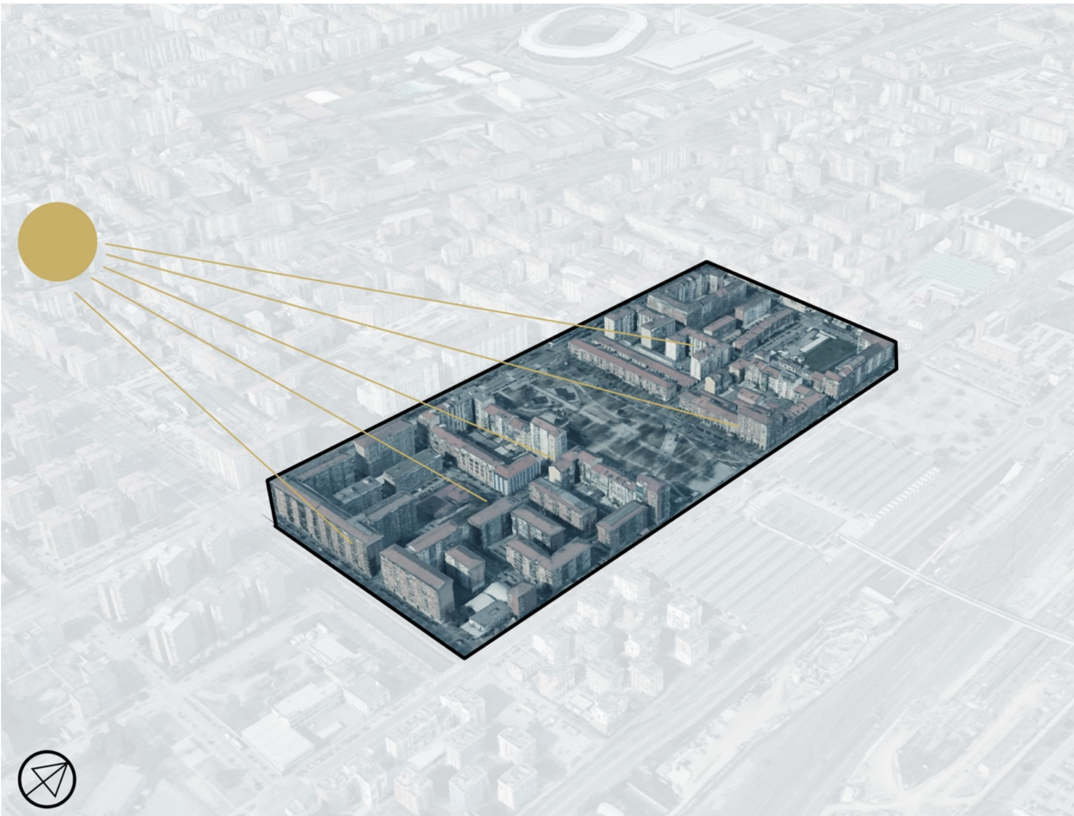


*Figure 30: Sunlight on buildings in Lingotto (Provided by the author)*

In San salvario, the buildings are rectangular shaped consisting of a central courtyard. This means there is a combination of different shapes of dwellings which receive unequal amount of sunlight and therefore have different energy demands. However, having a central courtyard and a void in the center of the rectangle creates the opportunity for all the dwellings to take advantage of the daylight and having cross ventilation. Most buildings like other buildings in the center of Turin have a double height ground floor which are used for commercial purposes. This simple strategy increases the level of dwellings on the lowest floor and gives them the advantage of direct sunlight.

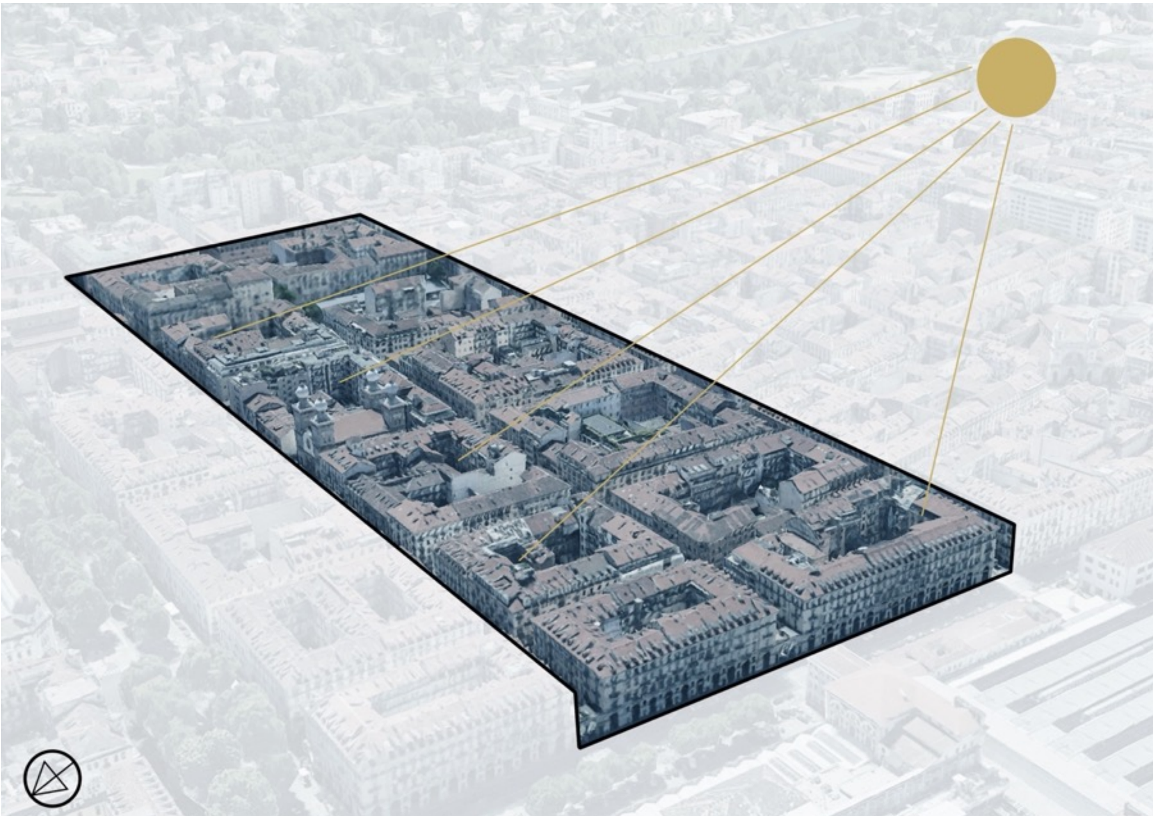


*Figure 31: Sunlight on buildings in San Salvario (Provided by the author)*

Due to the shape of the building in this zone, building blocks have windows on all the four facades. Each building block consists of multiple apartment flats that receive sunlight from different angles. However, looking at the map, since the building blocks are slightly angled from the south-north axis; the main façade is facing south-west and south-east. This means that all the dwellings are able to take advantage of south sunlight during a portion of the day.

The drawing below demonstrates that both the exterior windows (windows that are facing the street), and the windows that are facing the courtyard (on the right); receive south sunlight, especially considering the higher angle of the sun when it is on the south. This causes the apartments on the lower floors to receive more south sunlight and less of east and west sunlight knowing that the sun has a lower angle.

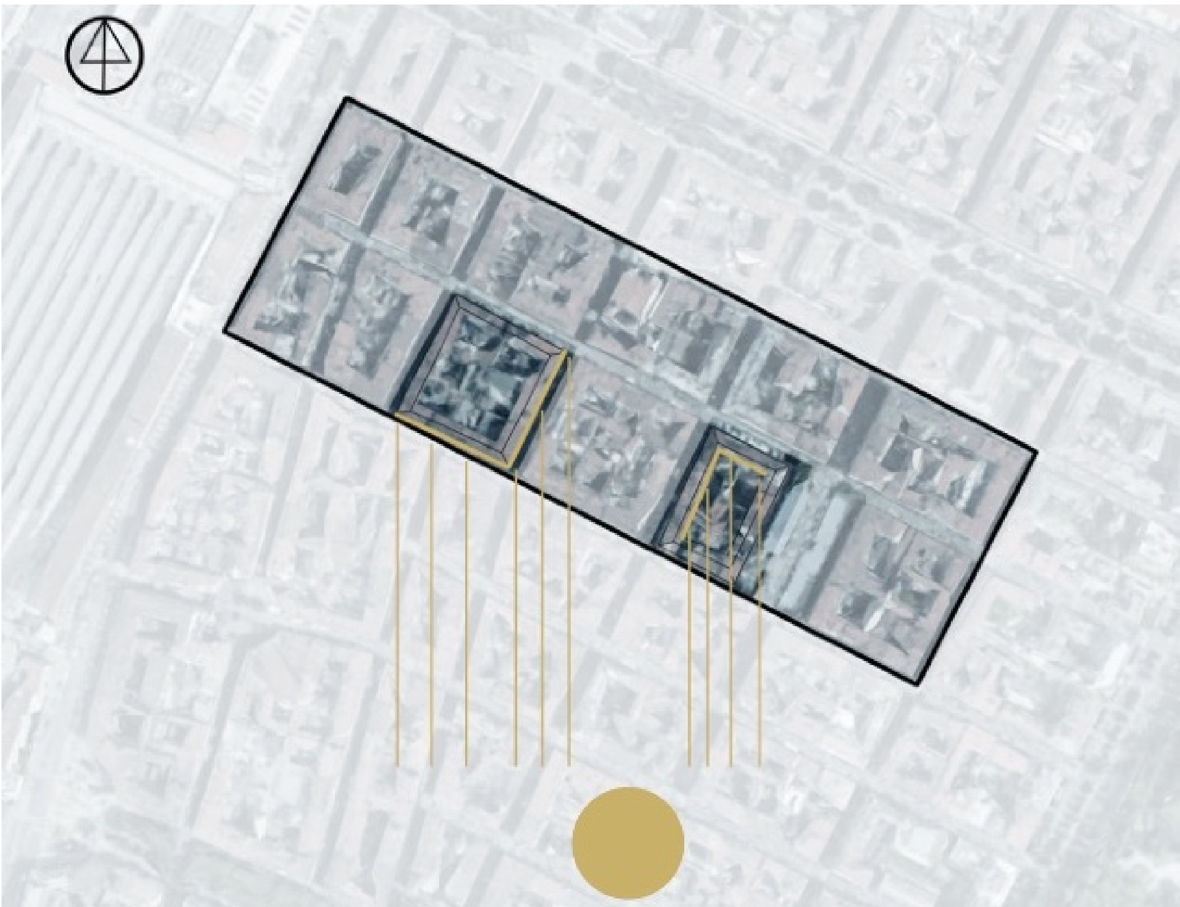


*Figure 32: Sunlight on buildings in San Salvario (Provided by the author)*

### 4.2. Sun and wind

Considering sun and wind and their impact on the district goes hand in hand with their shape and orientation. In order to design an inviting, upbeat building, access to daylight is crucial. Through views, references to the time of day, the present weather, and other means, it establishes a connection to the outside world. Along with the subconscious advantages, exposure to the daily cycles of light can be used to design interesting textures and flowing patterns in the home that change throughout the day, not to mention the vital effects of sunlight on mental health.

*Figure 33: Sunlight n buildings in Lingotto (Provided by the author)*

As it was explained previously, in Lingotto some buildings were overshadowed by others and had less access to direct sunlight whereas some have more than it is required. In San Salvario, how it was described the apartment flats receive sunlight although unequally.

To avoid overheating in warm weather, heat must be removed from the house. Utilizing windows, doors, and the ventilation system will allow surplus heat to be expelled when the outside temperature is lower than the interior. Even during the warm season, these conditions can exist at night. Multiple apertures are needed for the home to have efficient airflow. In a house, a single open window or door will only allow for local air exchange and minimal heat dissipation. Installing a variety of openings in strategic places to encourage the building's use of prevailing winds as a source of ventilation. Giving apertures near interior heat sources, like the ovens and stoves, some thought is advised. Apertures towards hot prevailing winds should be avoided to prevent any discomfort. The best orientations face mild winds with a comfortable temperature, such as a sea breeze or

*Figure 34: Lack of sunlight in the apartments (Provided by the author)*

summer breezes that pass over a cool garden or in case of this district, piazza Galimberti, or marsh before reaching the house.

It was well observed that neither of these buildings were lacking a proper number of openings. There was a big number of windows having overhangs or balconies observed which create the opportunity of expelling exhaust air and creating natural air ventilation in each individual dwelling. One in one case the building design caused both lack of sunlight and proper ventilation.

### 4.3. Heating

As it was mentioned earlier, most of the energy demand in building sector is towards space and water heating and the 64% (59% natural gas and 5% fossil liquid) of primary source of that energy is provided through fossil fuels. This is the primary source of CO2 emissions from the building sector. In both of the chosen districts it was observed that some of the buildings are still using natural gas and fossil fuel in order to heat the indoor space.

The main source of heating in a Passive House can be the controlled capture of solar heat through windows. Any solar heat gain in a traditional home during the winter is normally welcomed because heat is rapidly lost across the envelope, lowering the risk of overheating.

It is important to remember that the district of Lingotto with an area of **3.367km$^2$** is responsible for **315,384 t** CO2 emissions while San Salvario with the area of **2,306km$^2$** is responsible for **265,809 t** CO2 emissions.

*Figure 35: Chimney of a building (Provided by the author)*

#### 4.3.1. District heating in Turin

One of the cities in Europe with the highest prevalence of district heating is Turin. Almost more that 50% of the area is equipped by this system. In the research ‘A feasibility study on the potential expansion of the district heating network of Turin’ (Andrić et al. 2017) published in 2017 by department of energy of Polytechnic University of Turin the researchers carried out a study on technical analysis of potential district heating network additions in Turin. An illustration provided by them demonstrated the districts in Turin which are equipped by district heating. In which it is observed that chosen number of buildings in Lingotto have up to 25% individual heating system. This number shows that the majority of the district is benefiting from district heating and already is equipped by the necessary infrastructure which can provide heating recycling in the district and different zones. This percentage in San Salvario can go up to 90%, however unfortunately provided by the same research, providing a district heating system is not feasible.

By the end of 2018, the district heating network was connected to 60,650,000 m3 of city structures and according to Gruppoiren this area is increases to 73,2 million m3 by 2022. The covenant of majors is aiming to reduce the $CO_2$ emissions of the city by 60% within 2030 and district heating plays a big role in that. (“District Heating” n.d.; “200612_EGCA_2022_singola_def,” n.d.)

This is a huge advantage for the city because it may further increase the benefits of energy conservation and **heating reuse** in each district. The next chapter describes and analyzes energy recycling, which goes one step beyond district heating, in the designated district of Lingotto.

The area of district heating and the locations of the cogeneration facilities are shown in the following illustration from another study on district heating in Turin. (L. Teso et al. 2019)

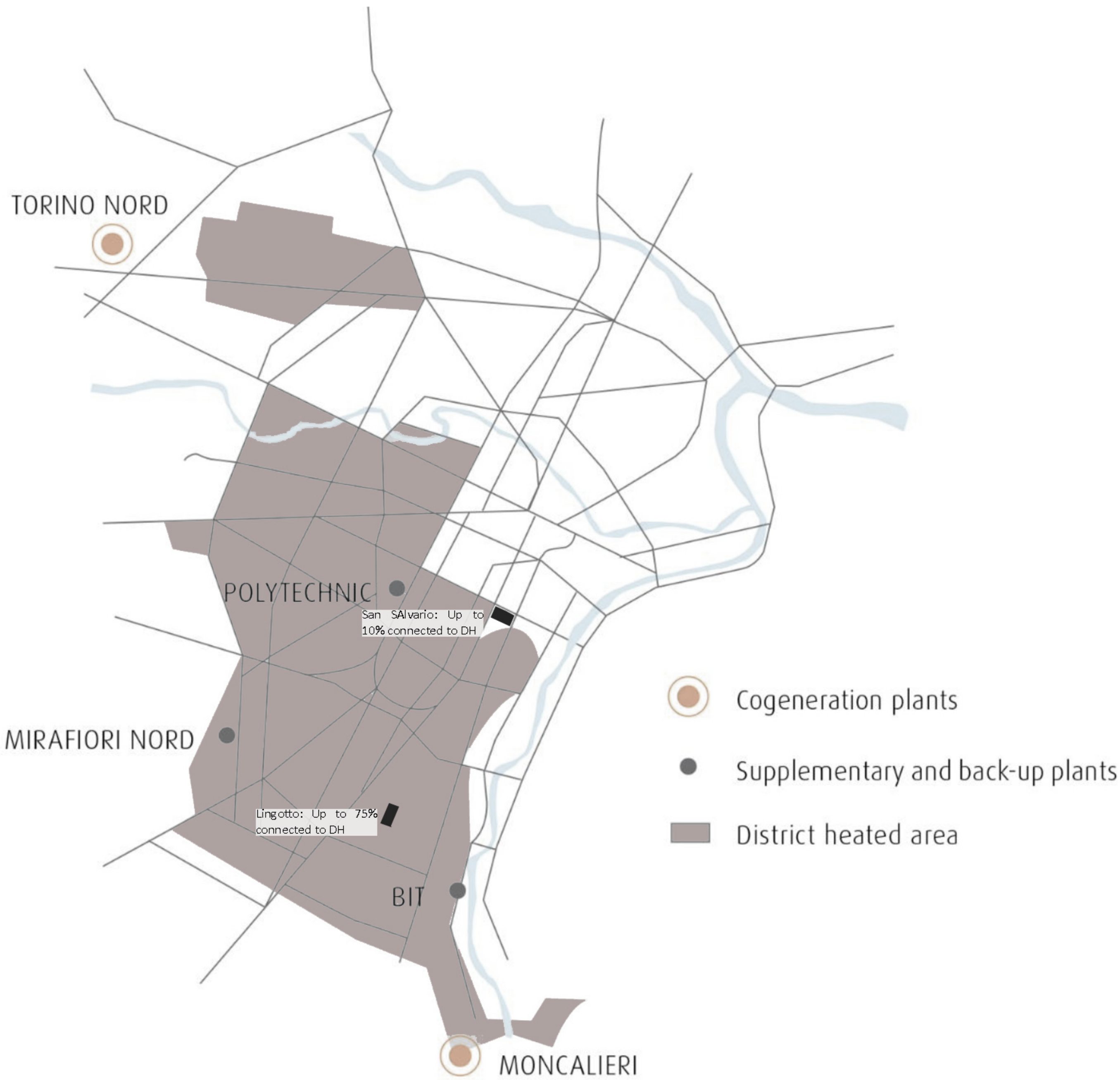



*Figure 36: District heating distribution in Turin* (L. Teso et al. 2019)

# Chapter 5: Suggestions and methodology for district analysis

## 5.1. Strategies overview

Although a district might function as a system rather than as a collection of buildings, each building's effectiveness plays a significant role. This is why the technique was divided into scales for districts and buildings.

### 5.1.1. In urban scale

Attention to the urban tissue and positioning of the buildings in relation to each other is one of the first steps towards an energy conscious district. A building could be well insulated and meet the passive house criteria but if it's overshadowed by neighboring buildings the solar energy gains of that building are compromised and limited. In urban planning the orientation of the buildings, positioning and the distance between the buildings as well as the number of floors, compactness and depth of the building and vegetation all have a great impact on the energy demand of a residential block.

Based on these parameters, it is possible to establish a model strategy towards a solar urban design. The most important principles that can be mentioned are (Gonzalo and Vallentin 2014): A south orientation of buildings; limiting overshadowing of solar aperture through topography, vegetation, neighboring buildings and constructional elements and making use of climate advantages (e.g. wind protected zones, but avoiding foggy areas)

These principles are easily applicable in case of construction of a new building, however in transforming an existing building they can guide us in any possible required modifications. The aim of the above mentioned contents is to bring the two perspectives (urban and building energy efficiency) together in such a way that the energy-related issues become an essential component of the urban design without dominating the process in a one-sided manner.

### 5.1.2. In building scale: Approaching a zero-energy building

This stepped strategy introduced by Andy van den Dobbelsteen consists of following steps.

0) Research: which includes studying bioclimatic design strategies of the Piedmont region as well as studying the climate conditions, the orientation of the building, solar gains, energy consumption and losses of the designated structure.
1) Reduce: in this step the energy demands of the building will be reduced by implementing the bioclimatic strategies on the existing building as well as passive strategies and use of efficient appliances.
2) Reuse: waste flows in the building can be reused to further reduce the energy demands.
3) Produce: generating renewable energy is considered the last step which meets the reduced energy demands of the building.

Furthermore, the location and positioning alongside the density of the buildings in the district has to be considered since there is a big impact of sunlight situation and heat gain.

The goal of this research is to minimize the energy demands significantly to reach or get close to passive house criteria using the first three steps on this strategy alongside passive house principles. Passive house standard is an optimal foundation for creating a net-zero energy building. In this way the passive use of solar energy is maximized and the remaining energy demand for heating, cooling and ventilation, if needed, can be met by photovoltaic panels or alternative renewable energy sources.

- Research: Bioclimatic design in Turin

To summarize chapter 3, the first step of this strategy, research, is to understand the passive strategies used in the past in order to achieve the comfort levels. These strategies in some cases have been completely ignored due to appearance of technology and active cooling and heating systems. Vernacular and bioclimatic architecture in the city of Turin in Piedmont region in northern Italy includes various strategies. Italy is located in temperate climate zone which is one of the most comfortable climates. City of Turin has an average temperature of 12 degrees Celsius, a temperature higher than -5 during autumn and winter months and all year around precipitation. The sky coverage of the city of Turin is approximately 45% throughout the year and around 40% during the summer months July and August. This means solar heat gains are available during winter months 60% of the time and during summer months use of overhangs and shading systems is required.("Climate Consultant 6.0" 2018)

- High mass walls and slabs are the building first elements that can be mentioned. The absorb and store daytime solar heat in winter to release at night. Heat gain from solar radiation and lights greatly reduces heating needs.
- Followed by that overhangs and shading systems are used to prevent overheating during summer months.
- Pitched roofs increase the solar gains as well as shedding the precipitation.
- Shaded outdoor buffer zones are created in urban context which maximizes the level of comfort in summer months for the pedestrians.

- Reduce & Reuse: Strategies for energy reduction and Reuse of waste flow

Whenever a building's functions has to be adapted to new requirements, the whole layout of the building has to be reviewed and possibly transformed. For these steps in order to minimize the energy demands and losses, the introduced passive house principles will be applied to the buildings.

An aquifer thermal energy storage is another way to restore and reuse the energy and reduce the energy demands. In an ATES cold water that is stored during winter months in a cold well and is extracted in summer time and hot water from summer months is extracted from the warm well to be used in the underfloor heating system in winter.

- Produce: Integrated renewable energy system

The most common approach to produce energy is using Photovoltaic Panels. Since most of the building envelope is exposed to solar radiation it is considered to be the most beneficial. Solar systems can be integrated on roofs, facades, shading systems, balconies and even in windows.

Solar heat collectors are also a way to provide DHW (Domestic hot water) or even be used for floor heating systems or simply be stored underground in a BTES (borehole thermal energy storage) for further usage.(Andy van den Dobbelsteen et al., n.d.)

Our protection from damage is the main goal of housing. The goal of positive energy living is to establish a comfortable, well-ventilated, and welcoming atmosphere in which to live. Our homes ought to be a shelter of safety where we can thrive. While we enjoy being outside, we also long for the comfort of our homes. As a result, we are drawn to homes that allow for both inside and outdoor living. But usually, this porosity is only a thrill when the surrounding environment is favorable. In contrast, a positive energy home gives us year-round shelter while allowing us to enjoy the light and airy we love.

The indoor-outdoor flow must be manageable in order to do this. When the elements of the outdoors are not wanted, leaky dwellings cannot keep them out. Homes that include mechanisms to control the entry and departure of weather, pollutants, allergies, noise, scents, and critters are much more pleasant to live in, much as a tap is a much better way to manage water use in the kitchen sink than a persistent leak is! To regulate indoor comfort and air quality, the thermal envelope -a distinct perimeter- must be present around the areas where we reside. This border must not be crossed for it to be effective.

## 5.2. Turin case study: introduction to proposals towards reduction of energy

### 5.2.1. Strategies in urban context

Energy reduction strategies in urban context has been divided in to three main categories. Mainly shape and orientation of the building, followed by sun and wind intake and approaches that can maximize that and finally the heating system and an introduction to district heating.

#### 5.2.1.1. Building orientation and shape

Shape and orientation of the building plays an important role and mostly it depends on the district layout. Each of these factors are explained as follows.

##### 5.2.1.1.1. Shape

Passive solar energy may be used to its full potential thanks to the decision for a south facing facade. However, the building's design must take advantage of this by including as many windows on the south façade as feasible and positioning rooms with a disproportionately high need for heat there in the winter. The probable heat of the summer should also be taken into account, particularly whether passive cooling from underground and shade are needed to reduce high interior temperatures and discourage inhabitants from purchasing air conditioners with a disproportionately high energy usage. (Andy van den Dobbelsteen et al., n.d.)

Building geometry that encloses the largest volumes in the lowest surface area is of utmost importance because heat transfer across the thermal envelope is directly proportional to the surface area of the heated or cooled space. Building sphere-shaped homes or placing furniture on sphere-shaped floors is obviously impractical and trying to stack spheres causes them to lose their geometric advantage. A cube is the second-best shape. Buildings made of cubes are far more adaptable and much simpler to furnish.

It is important to keep in mind that usable floor area is what we are really wanting in our homes, even though the size and geometry of the thermal envelope have a significant impact on the amount of heat loss conveyed through the fabric. A helpful indicator for evaluating various building shapes and geometries is the ratio of surface to treated floor space.

There are various benefits to keeping the thermal envelope's shape simple. Buildings that are smaller lose less heat to the environment. Additionally, because they are simpler, they are often cheaper to create. With less complexity, they are also better able to adapt to shifting demands and fashions while maintaining their high performance over the course of the house.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The transmission losses will be smaller the more "compact" the home is. The term "compact" refers to the buildings outside surface to volume ratio. The shape's complexity is important because it leads to a more compact design and fewer structural connections in the building envelope with fewer extensions and more volume. There will be less transmission and infiltration losses as a result of thermal bridges and air leaks as there are fewer connections.

Compact structure became crucial for efficiently burning wood or coal. With the central kitchen fireplace, which other rooms were arranged around, this trend had already begun. It was soon found that, due to the simple fact that hot air rises, lofty rooms are more challenging to heat than low ones. The contrast between castles and country houses in cold regions and those in Mediterranean countries can be attributed to the fact that compact constructions can be maintained warmer.

Of course, efficient utilities and daylight should not be sacrificed for small buildings. For instance, a terraced house can be made more compact by reducing its width while maintaining its floor area but doing so limits the floor plan's design options. As a result, the building is receiving less sun and daylight.(Andy van den Dobbelsteen et al., n.d.)

To complete this topic, the concept of energy cascading and energetic programming will be opened and explained specifically for the designated district.

**5.2.1.1.2. Orientation**

Solar collectors and photovoltaic (PV) panels work well on roofs. The design must take into consideration the systems' spatial needs, ideal placement, and angle of inclination.

• For both systems, facing south is ideal.

• When utilized primarily for space heating, hot water collectors should be positioned at an angle of around 40°. The optimal angle is between the two, which is about 50° (for mid-Europe) for collectors used for both.

• Around 40° is the ideal angle for PV (for mid-Europe).

• Variation is feasible, but it reduces the output produced by a PV panel or collector per square meter.

As PV systems are highly sensitive to this, shade that is produced by, for example, nearby buildings, roofs, dormers, flues, and plants; needs to be avoided.

As windows are positioned in façades to allow sunshine to enter the house, the placement of walls is crucial for passive solar energy generation. To ensure that this sunlight effectively contributes to energy generation, the direction does not necessarily need to be south. Positioning can be changed by around 20°.(Andy van den Dobbelsteen et al., n.d.)

According to calculations, a south-facing home receives the most sunlight. The effectiveness of solar windows has been demonstrated to decrease by the equivalent of 10m3 of natural gas per year, per dwelling, with deviations of about 20° to the east or west.

Energy consumption rises relatively quickly when the deviation is even greater. This relies on a number of factors, including the façade's glass surface, its orientation, and how well-insulated the buildings are. The following uses a sample semi-detached home:

• The sample home's glass partition is split equally (50 percent south, 50 percent north) between the north and south façades. A save of roughly $50m^3$ of natural gas per year can be achieved by moving 25% of the glass from north to south (i.e., 75% south, 25% north).

• If the property were to be rotated 180 degrees, the distribution would be 25% south and 75% north, and the amount of natural gas consumed would rise by about $95m^3$ year.

• If the house's distribution of 50/50 south and north is rotated by a quarter such that it is 50/50 east and west, the annual energy consumption changes as follows:

Natural gas consumption increased by almost 50 $m^3$ for the front façade facing the north and by almost 10 $m^3$ for the front façade facing the south due to the front façade's window.(Andy van den Dobbelsteen et al., n.d.)

The following section explains the benefits and issues of different angle of the sunlight.

#### 5.2.1.2. Sun and wind in the district

All year round, sunshine and wind protection are beneficial for outdoor areas including gardens, playgrounds, and slow-moving traffic routes. Both may interfere with how well homes utilize sunshine, although neither directly affects how much energy a household uses. When it comes to optimal sunlight for homes, the sun's position is different in outside areas. For instance, in the Netherlands, a south-facing structure would need to be shifted slightly to the east if the blockage angle was between 16 and 20 degrees. This offers both low-rise and stacked houses in an outside area superior solar placement. An east and west façade position should be taken into consideration for obstacle angles greater than 24°. In these situations, passive solar energy is already modest, but it still results in some noon sunshine reaching outdoor regions.(Andy van den Dobbelsteen et al., n.d.)

Equator-facing windows often have the best chance of achieving a balance between solar heat gain and daylighting. Simple awnings or light shelves can be used to block direct sunlight in the summer when the sun is high in the sky because the angle of the sun with respect to the window is constant throughout the day. As a result, there is no need to shut the exterior blinds during the summer, allowing an abundance of indirect light and views to enter the house. When the sun is low in the sky during the winter, it might shine through the shading structure and provide useful heat gain. In most regions, an exterior blind or shutter is still necessary, depending on the window's size and height, to limit excess heat gain during the middle of the year or on extremely sunny winter days. However, a straightforward horizontal overhang can greatly eliminate the requirement for external shades or shutters, enhancing the enjoyment of the window.

Windows that face away from the equator receive little direct sunlight outside of tropical regions, making them great sources of diffuse light that require little in the way of external solar management. But because these windows don't get any winter sun, passive solar heating can't be done with them. They can also be a substantial source of heat loss because they are on the chilly side of the house. In order to balance heat loss with light harvesting, their size and insulating performance must be adjusted. To maximize light collecting, these windows should be smaller than equator-facing windows and positioned high on the wall with exposure to the sky. This type of window is best suited for bedrooms or other spaces that don't require a lot of light. This orientation is also beneficial for high-level windows like clerestory, which may illuminate wide floor plans comfortably with no need for solar management.

Because the sun's angle with respect to these windows fluctuates during each day, regulating daylight and solar heat intake presents the most problem for these windows. East-facing windows have the greatest potential for heat accumulation since the early morning sun hits them at such a shallow angle. When combined with the warm afternoon air temperatures, west-facing windows' similar exposure at the end of the day can easily cause a home to become overheated. Overall, it can be challenging and therefore not always worthwhile to try to balance the possibility for glare and heat absorption from east- and west-facing windows versus maximizing the harvesting of useful light. **The simplest solution** to this problem is to reduce the number of east- and west-facing windows in a building in favor of the more manageable north and south windows. There are various ways to handle this problem with exterior shading and blinds, which is obviously not always desirable or practicable. Use a wide, short window at eye level as one solution to decrease the amount of time the window needs to be shaded while still allowing views out of the house and light inside. Retractable external venetians or shutters with horizontal louvres are the ideal shading option from a performance and comfort perspective. In addition to permitting views and daylight harvesting during the controlled times of the day when the window is not in direct sunlight, this enables the management of low angle sun for glare and heat gain. (Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

Light tunnels or tubes can be used to efficiently direct light into the home as an alternative to skylights or as a way to bring light into areas that are not immediately close to the building envelope. A dome collector on the roof directs light into a reflective tunnel or tube that is attached to a diffuser on the ceiling or wall. Typically, these work in a similar manner. Although they cannot offer views of the outside, these can nevertheless offer many of the advantages of natural light and can be highly effective. This is especially useful for areas like bathrooms and storage rooms that don't need to have a direct view of the outside world.

The thermal and airtight qualities of these elements must be taken into account because they cross the building envelope and receive solar heat gain. Light tunnels, like skylights, provide difficulties for managing solar heat gain as well as the thermal and airtight envelope, hence they can only be used with caution.

Larger or multi-level constructions frequently use voids between floors to let light enter the center of the structure. Such voids can be an attractive design element in a structure but managing direct sunlight as well as controlling air and heat distribution inside the void needs to be carefully taken into account. In multistory buildings, warm air that is buoyant can accumulate at the top of the void while cool air pools at the bottom, resulting in temperature differences between levels that can be uncomfortable for occupants and disturb the ventilation system. As a result, proper shading and air control are crucial design factors for these elements. (Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The World Health Organization (WHO) declared clean indoor air to be a human right in the year 2000. (WHO Regional Office for Europe 2000). There are, however, few legal regulations that outline safe levels of indoor pollutants in residential buildings, notwithstanding this pronouncement and the significance of air quality in our homes. Most laws either pertain to businesses or the open air. However, regardless of where we are exposed, the effects of air pollution concentrations on our wellness will be the same. The wide range of potential contaminants and analytical equipment to test them that can be rather intrusive, which is often less of a concern for outdoor or occupational air monitoring, could be the cause of the lack of binding standards for home environments.

A human need about 30 m3 of fresh air every hour to keep pollutant concentrations under control. Additionally, it is important to make sure that this fresh air is effectively circulated throughout the interior space. For instance, having a bathroom with excellent ventilation does not guarantee that the other rooms in the house would have high indoor air quality.

(“Indoor air quality management - ubol.eb-sgh.de”) Every hour, there must be a driver who constantly provides each passenger with enough fresh air. For areas with stronger polluting sources, more fresh air is required. For instance, when someone smokes, a significant increase in fresh airflow rate is required to sufficiently dilute dangerous chemicals.

CO2 levels are likely to rise in bedrooms overnight if a window is closed or an awning window is left open. In such a bedroom, you have the option of keeping the windows closed to create warm, stuffy conditions or opening the windows to create cool, fresh conditions on a winter night. In other words, having a headache or a stiff neck when you wake up.

Taking advantage of prevailing wind, we can create natural ventilation in indoor spaces. This ventilation can be provided by cross ventilation which is a possibility due the shape of the buildings in both districts. Stack ventilation in another option which will only be possible by using ventilation ducts that can provide fresh air. Stack ventilation is considered to be a more effective form of natural ventilation that can bring the apartments to comfort level without the need of air conditioning during summer months.

#### 5.2.1.3. Heating

Rich Romans were familiar with passive solar energy since they possessed greenhouses for exotic plants. A Roman Heliocaminus was a sun-heated bathing room with the north side closed and the south side open. A sauna with an entrance in the top and a bronze dome below it was created by the Roman architect Vitruvius. This dome heated up from the solar heat. The temperature in the chamber could be adjusted by raising and lowering the dome. Later on, Man may regulate the fire to keep himself warm in chilly environments or on chilly nights. A fire has an efficiency of 10 to 15 percent. In addition to the aforementioned caverns, our ancestors also used tents and shelters to make fire.

For millennia, not much has changed: fire still serves as the primary source of warmth for buildings. But over time, there have been significant changes in how heat is produced by fire and transferred to indoor spaces.

The first thermostat controls, which worked on the theory that materials expand or contract as a result of temperature changes, were developed in 1890 and were the first piece of control equipment for central heating systems. The electric heater was invented in 1892.

Only in the early 20th century was the Roman hypocaust revived with more contemporary wall or floor heating. This was employed, among other places, in the renowned Johannes Duiker Open Air School in Amsterdam.

Later, steam heating became even more concentrated. A steam power station for a city or district became possible as a result of the high temperature steam's ability to travel farther than hot water. Later, electricity was also produced using this steam. Ultimately, the production of electricity took over as the main purpose, and it wasn't until the second half of the 20th century that the residual heat was rediscovered as a source for district heating.

Collective heating refers to the provision of heat from a single central facility to multiple houses. This could apply to a small number of residences in a residential structure or a big number in a residential neighborhood. Energy can be saved by using collective heating methods like block heating and heat distribution. Whether this occurs is influenced by a variety of factors, including the energy efficiency of the heat generation, the system's ability to regulate temperature, the quality and length of the pipes making up the distribution system, and the energy requirements per hectare.

- Benefits:

• Efficient energy generators: waste heat and/or storage techniques can be used, such as cogeneration, industrial waste heat, heat pumps, biomass, seasonal solar energy storage, and deep geothermal heat.

Due to the larger scale of a collective system, capacity and power investment reductions are possible. A boiler may produce 10 to 20 kW on its own, while a collective system only needs 3 to 6 kW per residence. Since most of the time there is just a small base load demand and peak demand capacity can be distributed across several residences, the lack of synchronicity in a communal system can be addressed.

• Use of more affordable, effective parts in a cascade arrangement of smaller units

• Less environmental contamination from collective facilities as a result of better maintenance or more effective power or heat generation.

• There is no need for a heat source to heat a room. The benefits include safety; easier maintenance because individual maintenance is not necessary; and needing less space in the dwelling.

- Issues:

• Significant distribution investment

• Significant heat loss during the distribution process: when big systems with landlines are used, up to 30% of the total heat production can be lost. The level of temperature and the insulation's quality have a significant impact on the loss. The loss rises proportionately as the heat is reduced (for example, by greater home-level energy-saving measures).

• Because there is no gas network, inhabitants cook with electricity, which increases electricity use (100 $m^3$ gas equivalents against 65 $m^3$ of gas) and prices.

Connecting Both networks are therefore in open communication with one another when the heat from the communal distribution is applied directly to the piping of the house or transmitted to the piping of the house via a heat exchanger.

The benefit of the first of the aforementioned points is that there are no additional expenses for a heat exchanger and no additional room is needed. The temperature in the distribution system is roughly 4°C lower without a heat exchanger than it would be with one. As a result, the generator is more effective and there are less losses. However, if a safety valve isn't installed, a leak in one residence could cause the entire system to run dry.(Andy van den Dobbelsteen et al., n.d.)

Domestic hot water:

The warm tap water in homes with a communal heating system is typically heated using one of the following methods:

• Central heating water: To create warm tap water that is around 60°C inside the house, the distribution supply temperature should be at least about 70°C in both the summer and the winter. Significant energy is lost as a result.

• A separate hot water distribution network: Its diameter is smaller, its temperature is lower, and it suffers less losses as a result. It is best to independently meter the hot water.

• Each home has a small boiler that receives heat twice daily from the distribution system. The network runs on the low temperature needed for space heating the remainder of the time. This technology for block heating is quite practical.

• Each home has a heat pump boiler, which utilizes the home's central heating system's return. This functions as a standalone system in the summer and helps to moderately chill the house. In the winter, heat is drawn from the public grid and the communal network preheats the water for drinking. This is controlled according to the summer and winter weather, resulting in a relatively small loss.

• Each home's electric boiler. As it is likely to reduce any savings from the communal system, this sort of boiler is strongly discouraged.(Andy van den Dobbelsteen et al., n.d.)

The size of the two distribution systems is the primary distinction between block heating and heat delivery. Block heating is a compact collective system that can be utilized in one block or several. Thousands of households are served by the heat supply system, historically known as municipal heating. There are more distribution networks that fall in this range of sizes; these are frequently referred to as "district heating."

Depending on the system's size, it may resemble block heating or a heat supply in appearance. For the delivery of heat to 1000 or more dwellings, CHP (combined heat and power), industrial waste or geothermal heat, and analogous technologies, are virtually always used. 75 to 90 percent of the annual heat demand is met by the primary source. Assisting boilers installed at substations built to better utilize the network provide additional heat. To sustain the total return, HR-boilers are required. The following methods are employed for producing heat in smaller communal systems: Cogeneration, heat pumps, solar power, biomass boilers, combined heat and power, or a combination of the options.

To go one step further energy recycling in the district depending on the buildings can be taken int consideration.

### 5.2.2. Strategies in Building context

In building scale thermal envelope is the most important factor on the buildings efficiency. That can be followed by passive use of solar energy and appropriate floor plan design.

#### 5.2.2.1. The thermal envelope

To enable us to survive in the spaces that require temperature regulation, the thermal envelope must firmly encircle them. The best weather protection is not possible with a thermal envelope that fits too loosely. The thermal envelope should also be as compact as feasible because the amount of heat transmission loss is directly inversely related to the surface area of the envelope. A "fabric first" strategy for creating energy-efficient structures is Passive House. It tries to maximize the fundamental, durable fabric of a building—components that cannot readily be upgraded later. To achieve the Passive House standard as the first step to a Positive Energy Home, getting the thermal envelope properly should therefore be a top priority.

Three functional layers must appear at the interface between thermally controlled and uncontrolled sectors. In a heating climate, an airtightness layer (green in the top image) must be internal to the insulating layer (yellow in the diagram). A wind- and weathertightness layer (blue in the diagram) must be positioned the farthest from the exterior. To function at their best, all three functional layers must remain uninterrupted, but the airtightness and wind/weather-tightness layers are most vulnerable to perforations.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

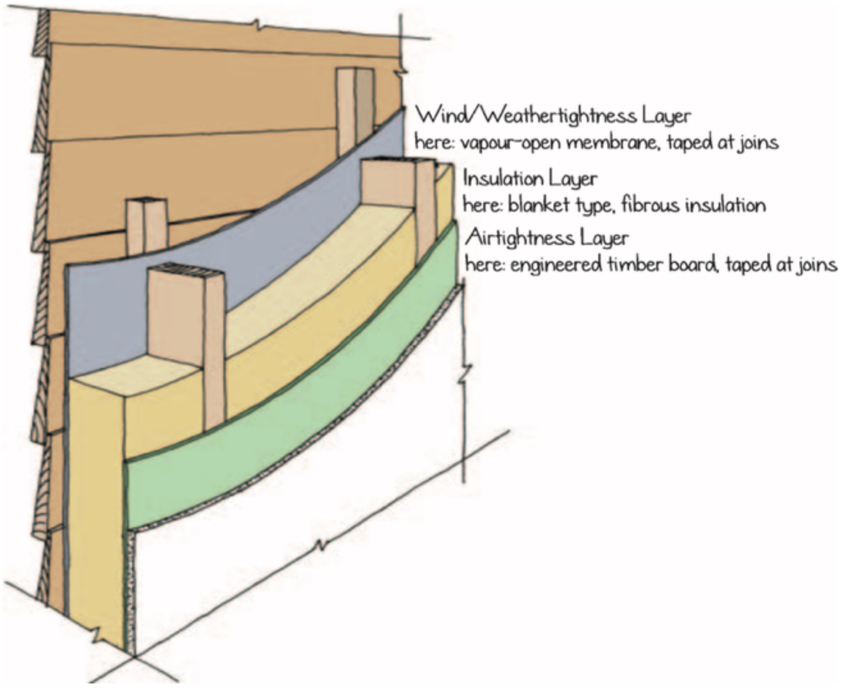



*Figure 37: The layers of thermal envelope in passive house .(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)*

There must be clarity regarding which layer of the thermal envelope is present at each surface. In the diagram depicted in the previous page, the wind- and weathertightness layer is made up of a vapor open membrane with taped joints, and the airtightness layer is made up of engineered timber boards that are taped at the joints. Between the studs is a blanket-type insulation made of mineral wool.

It is not a problem if the materials used for each functional layer vary from one location to another. For instance, the airtightness layer of the thermal envelope's lowest boundary might be a concrete floor, and the airtightness layer of a lightweight wall might be a taped, engineered timber board, as shown in the diagram. However, when these layers are out of alignment, detailing for continuity becomes very challenging, and for successful results joining joints with misaligned layers demands attention and skill equivalent to watchmaking. On a construction site, it is doubtful that you will find people with the necessary skills and abilities or want to pay for their time. Off-site construction increases the possibility of handling challenging issues, yet the ideal choice is to design them out.

#### 5.2.2.1.1. Airtightness layer

A layer that is airtight prevents uncontrolled airflow through the thermal envelope and the accompanying sound and moisture transfer. For this performance, airtight materials, sealing, and blower-door testing are crucial. The airtightness layers' primary responsibility is to prevent the accumulation of moisture in gaps. As we walk from the warm inside surface outwards in a heated structure during the winter, the temperature decreases progressively throughout the thermal envelope. As a result, if damp air is let to enter the fabric of the structure, it may encounter cold surfaces on its way outside and condense there. Damage may result, such as fungus growing on wood components. Therefore, to hold the moisture where it is easily absorbed in air, the airtightness layer should form an uninterrupted barrier to air movement at the warm side of the thermal envelope, often the interior of the insulation layer. Diffusion through solid materials is another way that moisture can reach a cold surface, but this method is less problematic than moisture delivered by air. However, in a cold area, the airtightness layer might be used to help retain vapor if its composition is suitable. For both uses, engineered timber boards, for instance, might be an excellent fit. Another choice for combining airtightness and vapor control is polymer sheets. The vapor pressure profile may be reversed in warm climates, especially when active cooling is used, necessitating the same layering. The exterior of the building envelope contains warm air that may readily absorb large amounts of moisture, whereas the interior contains a cool surface.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The home should be as airtight as feasible to accommodate mechanical ventilation. Balanced ventilation, a highly energy-efficient design element that depends on an exceptional level of airtightness, is typically included in passive homes. Class 3 air density is applied to achieve this.(Andy van den Dobbelsteen et al., n.d.)

In chapter 4 the definition of the airtightness layer was explained. What and airtightness layer needs and what it needs to prevent. The following paragraphs explain how we can design and create an airtightness layer and what kind of materials we can use.

*Creating an airtightness layer:*

Designing out penetrations is the initial step in developing an airtightness layer. For instance, all ducts emanating from the manifold that distributes air ducts must pass through the airtight membrane if the insulation layer is to be used instead of the airtightness layer. Hours are spent sealing. One duct only needs to be sealed to the membrane if the ducts are shifted to run within the airtightness layer as well.

Another typical technique to avoid penetrations is to include an installation layer that rebates the airtightness layer into the wall. The inside surface of the studs is covered with the airtightness layer, and an additional 45–50 mm of insulation is added to the cavity for services. The plasterboard can subsequently be applied in the conventional manner because the airtightness layer, which is a few centimeters behind, is not penetrated by power boxes, light switches, cables, or pipes. Even if the installation layer's materials are more expensive, the measure may result in labor savings because all installations can be finished more rapidly. Additionally, it enables testing of the airtightness layer at a point when any problems can be fixed reasonably cheaply. The airtightness layer must be in a warm enough area, which means it must have adequate insulation on its exterior.

*Airtightness material:*

The next phase in the airtightness plan is to choose an airtight material to line the heated surface of the house. Wet plaster and renders, as well as precast concrete slabs, are common building materials that offer adequate airtightness. However, some materials that you might assume to be airtight, like solid wood or masonry, may not be at all.

An airtightness layer can be made of the following materials:

- **Cast concrete** is sufficiently airtight, but premade concrete blocks and other items need to be wet plastered in order to be airtight.
- To form an airtight membrane over a solid structure, such as blockwork, use **wet plaster**.
- If there are no knots or other flaws, the **most of engineered timber boards**. Certain oriented strand boards could be overly permeable.
- **Plasterboard**
- **appropriate polymer membranes**

The challenge with employing boards to create the airtightness layer is that their joints must be taped. With boards like plasterboard that are still visible, this is especially difficult.

Jointing compound can be used to fill the gaps created by the sheet edges, but this does not ensure long-lasting airtight performance because the fill is vulnerable to breaking due to structural movement or settlement. Simply said, it is too inflexible for this job. Although they might not yet be an aesthetic problem, enough microcracks already pose a threat to airtightness. The integration of the plasterboards with nearby structures, such as window frames or timber construction, is another issue because a filler made of gypsum will not stick to these surfaces. Plasterboard is becoming more difficult to use as the airtightness layer when problems with penetrations such power boxes, beams, ducts, and pipes are added. Plasterboard also fails to effectively stop water vapor from spreading through it. Therefore, the capabilities of the plasterboard are exceeded when the climate calls for both an airtightness layer and a vapor retarder. (Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

*Airtight design:*

As is always the case, the details are the most important. To link the primarily airtight materials in a way that will ensure uninterrupted performance over the course of the building's lifetime, extreme care must be taken during the design and construction phases. Joints in particular need to be precisely crafted, and solutions that call for highly developed origami abilities are probably not appropriate for use on a construction site. Additionally, careful construction sequencing is required to prevent effective connections from being broken by succeeding trades. In order to maintain its sealing effectiveness, silicone sealer may need to take routine maintenance. When exposed to light, expanding foam may eventually peel away from surfaces or become brittle. Few sealants have a chance to endure the entire life of the structure. You want a substance that quickly tacks well, has strong adhesion and cohesiveness, and won't dry out over time. Solid acrylic polymers, either placed on tapes or utilized as a liquid in a cartridge with membranes, are successfully used as a long-lasting adhesive for many connections. All sealed joints must be capable of withstanding the pressures caused by building movement. Many tapes, for instance, feature fibers reinforcement to aid in this, but on occasion, mechanical repairs are also required.

The following restrictions must be taken into account while designing an airtight joint:

- All components, including adhesives, tapes, and grommets, as well as any necessary mechanical fasteners, primers, and treatments, must be specified.
- There must be enough room for the assembly of the parts.

- Without applying tension to the connectors, joints must be joined.
- To prevent creep fatigue, no forces should strain on membranes or adhesives. (Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

One building component's airtightness layer must interface with another airtightness layer. Although it seems obvious, we must specifically determine the airtightness layer of each component of the thermal envelope. Examples of frequently disregarded components are chimneys. A brick-built chimney will lose air through fractures in the brick and holes in the mortar if it is not plastered. There is absolutely no benefit to connecting an airtight membrane to a screen.

An airtight building envelope's "natural enemy" is an electrician. If they are not given clear instructions to preserve the airtightness layer and are not well informed about its function and location, they will cut holes in it for power boxes and pull cables through it. This results in what blower-door testers refer to as a "power box typhoon" where, under test conditions, extremely high air velocities can be measured.

It can be impossible to create a thermally acceptable interior environment if there are multiple of them and the additional heat loss and comfort consequences were not taken into account while sizing the heating system.

Wet plaster is the most dependable and economical method of adding an airtightness layer to durable building. However, for this purpose, the plaster must penetrate even locations where it has no functional or aesthetic purpose, including hidden spaces such as those found behind kitchen cabinets, bathtubs, floor voids, dropped soffits, and stairwells. Since foils cannot usually just be plastered over, specialized tapes are provided to enable an airtight connection between plaster and foils. Connector tapes offer a mesh for the plaster to key in on one side and an adhesive for the foil on the other. To achieve a successful seal for the duration of the building, careful consideration of the longevity of the items being used is essential in all situations. The loads a connection tape must withstand are quite heavy:

- shearing force caused by movement along the adhesive layer
- peeling load, such as when an attached membrane overhead declines and its load tries to pull the tape off.
- When two connected pieces are loaded at an angle, such as perpendicular to the glue layer, they move differentially.

Because the connector must be able to support the ensuing loads continuously, these loads should be reduced as much as feasible. Both the cohesiveness within the glue layer and the adhesion of the glue to the tape's fabric must be guaranteed. If cohesion failed, glue traces on connected surfaces and a loss of seal on the tape fabric would occur.


*Figure 38 Airtightness layer sealing for pipes and ducts (Photo: pro clima Moll bauökologische Produkte GmbH). [5]*

Penetrations produced for services like plumbing, electrical, and ducting that cross the airtightness layer are also very important aspects. Specialty gaskets are available for pipes, cables, and ducts; these gaskets can be taped or plastered into the airtightness layer to provide an airtight seal around the penetrating service.

Another crucial element is organizing construction projects with airtightness in mind. For instance, to obtain a continuous airtightness layer later, a membrane flap must be in place before the upper story structure is erected in a platform wood frame building.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

As it was mentioned above, the details are the most important when it comes to an airtightness layer. Even the smallest crack can cause air movement and energy loss. This step is especially important to be considered since the chosen building are already constructed and in order to achieve an optimal thermal envelope only the above-mentioned layers need to be added to the existing masonry walls.

*Passive house pressure testing:*

One of the main criteria of a passive house is the airtightness measurement which is measured through a pressure test.

The n50-value, also known as the air pressure test, "measures the overall leakage through the building envelope." (“Blower Calculation”) The n50-value (in h-1) describes the air changes at a differential pressure of 50 Pa. A differential pressure of 50 Pa (equivalent to 5 mm water column) is created between the inside of the building and the outside by means of a blower door test. (“Airtightness Test [Passipedia EN]” n.d.)

Blower-door testing is a useful technique for identifying remaining leaks inside the envelope after careful joint design and meticulous construction. The blower-door is a frame that fits into a typical entrance and has a fan and pressure gauge. The entrance door is not usually the optimal location because doing so prevents inspection of the door, which is frequently air leaky. The blower-door frame should ideally be inserted into a big window if at all possible. The structure can be inflated or deflated using a nylon tarpaulin or movable panels in the frame.

It is possible to measure the exchanged volume required to keep the pressure difference. After a while, no additional air would be required to maintain the pressure differential if the building was totally airtight. Therefore, the volume that is leaking through the envelope must match the volume that the fan adds to or subtracts from the building volume.

The leakage rate is typically assessed at a pressure differential of 50 Pa. (Pa). To account for all plausible scenarios, measurements are made at a variety of pressure differentials, from which the result at 50 Pa is derived.

The volume exchanged at a pressure differential of 50 Pa may then be distributed over the thermal envelope's area (the result is then known as q50), the volume within the house (n50), or the treated floor area to determine the leakage rate per m2 or surface area (w50). Building rules might demand adherence to q50 or w50 values, but for passive houses, the n50 result is what we're targeting. For instance: The n50 is 3.0/h if the internal volume of the home is 500 m3, 1500 m3/h were exchanged, and there is a 50 Pa pressure differential. This home would not meet the criteria for a Passive House, where the n50 must be 0.6 h or less. This means that a maximum of 300 m3/h at a pressure difference of 50 Pa can pass through the building envelope of a house with an internal capacity of 500 m3. (Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The reason that there needs to be a 50pa difference is that the 50 Pa pressure differential is helpful for finding leaks, but it will only approximate the house's usual leakage rate on windy days, when this significant pressure differential may naturally occur. However, the average leakage rate will probably be much lower. Since wind and weather have less of an impact on test results at higher pressure, this pressure differential was selected for testing. Nevertheless, since strong winds would affect the results, measuring on a windy day is still not permitted by the measurement standard.

**5.2.2.1.2. Insulation layer**

Insulation protects us from the elements outside, as the name says. It provides comfort for the entire house. Your budget is the only thing that can prevent you from increasing the insulation layer's thickness. Otherwise, it is impossible to apply too much insulation because, when done correctly, adding more insulation will always have a good impact. The insulating layer is there to stop noise from entering the structure, unwanted heat loss, and exterior temperature conditions determining internal climate.

Insulating materials come in all shapes and sizes and are made from a wide range of different basic materials. They must be continuous, have a low thermal conductivity, and be covered in an airtight, wind-, and weather-tight layer in order to function properly. Because it conforms firmly to all structural components and liners, loose fill insulation is especially well suited to create a gapless blanket in a cavity. When used under slabs or as insulation for exterior walls, where they do not need to fit between structural elements, rigid materials are more suited.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The thermal resistance (R-value m2K/W) of the building envelope—excluding windows and doors—indicates the construction's level of insulation. Less transmission losses occur when the R-value increases with increasing heat resistance.(Andy van den Dobbelsteen et al., n.d.)

It depends much on the situation whether an insulation material works well or not. To identify the greatest fit for the situation at hand, additional performance requirements, such as structural, moisture-proof, fire-proof, and acoustical, must be defined and compared to material properties. This elimination procedure must be done carefully because it is often difficult and expensive to repair an inadequate insulation layer after the fact. This is specifically more important since for the refurbishment projects and an additional care and attention to details needs to be taken into the account.

A building's hygrothermal state improves when insulation is retrofitted. Surfaces that were previously indirectly heated by the fabric and consequently relatively warm will become chilly surfaces as a result of being insulated from interior conditions, increasing the danger of high-water activity or even condensation.

Direct energy transfer between molecules or atoms within a substance causes heat to be conducted. Heat transfer through dense, highly organized materials, like metals, is dominated by conduction. Because insulation and other fluffier materials often have lower thermal conductivities, heat transmission is mostly mediated by air flow. This characteristic is utilized by vacuum insulation panels because, in the absence of air, the vacuum prevents convective heat transmission. As a result, their thermal conductivity is decreased to a tiny fraction of that of conventional insulation, with air movement still present. The indoor-outdoor temperature gradient affects heat transfer rates for conduction and convection processes correspondingly. The third component of heat exchange, radiation, is an exception to this norm. Temperature differences to a power of four affect the rate of radiation heat transfer. Radiative heat exchange is significantly influenced by even slight variations in the temperature differential. Physical contact or the movement of air between surfaces are not necessary for the transfer of heat by radiation. Any line of sight will do.(Claudia Bouwens et al. 2020)

Therefore, every effort should be made to construct a functional airtightness layer throughout the entire warm surface when insulation is added retroactively. Without relining the warm surface of the building, this is very challenging to accomplish for the majority of structures. Use insulating materials with the ability to wick any moisture that reached the cold side of it back to the warm side again in situations when an adequate impermeable layer cannot be reliably produced. There is a significant possibility of keeping the water vapor suspended in the air on the heated side. These substances are referred to as "capillary active." For instance, calcium silicate and specific wood fiber boards exhibit this behavior. Of course, any render or liner placed inside of them must not block the movement of moisture, and in particular, there must be no space between the inside liner and the insulating material, as this would disrupt the wick. In general, adding insulation to existing dwellings without also applying a gapless airtightness layer should only be done with the assistance of a qualified professional and hygroscopic analysis. However, for this project it is not recommended to apply the insulation layer without the airtightness layer.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

#### 5.2.2.1.3. Wind and weather tightness layer

The thermal envelope's third and last control layer ensures wind- and weathertightness. The goal of airtightness is to keep outside air from entering the thermal envelope, whereas the goal of wind tightness is to keep inside air from entering the thermal envelope. The purpose of keeping out wind and water is generally combined, although it should be noted that while overlapping membranes may be adequate to keep out water, joints will need to be taped to keep out wind.

This layer's goals are to prevent:

- the entry of water into building cavities
- preventing wind from blowing around the insulation's layers or along its edges (this would greatly reduce insulating properties)
- the varied pressure zones that are created in building cavities (which could amplify pump- effects, as already discussed with airtightness).

Sometimes, the wind- and weather-tightness layer may not be in the same location. For instance, the roofing and underlay on a roof may offer the service of weathertightness. However, a second windtightness layer can be required if the insulation is above the ceiling and not directly under the roofing. The insulation could wind-wash if the roof cavity is vented and consequently occasionally windy. However, in most cases, the weathertightness and windproofing layers are either the same (for example, external render on an outside insulation finishing system) or quite close to one another, cladding as primary weathertightness layer with breather membrane as a combined wind- and weathertightness layer and second line of defence behind.

To be safe, the wind- and weathertightness layer should let the passage of water vapour even while it is impervious to liquids, at least in a climate with a heating season when the gradient of water vapour pressure will mostly decrease from inside to outside. Any remaining moisture that manages to enter building cavities due to flaws in the airtightness layer or diffusion processes has a chance to escape to the outside rather than being trapped within. The use of non-porous (monolithic) copolyester materials, which are water-repellent but permeable to moisture and gases, or micro-pores on foils can accomplish this.

#### 5.2.2.1.4. Glazing

The transparent portions of the building envelope are the hardest to get right in terms of thermal performance. Windows are a genuine two-edged sword because the thermal protection chain usually includes them as the weakest link. Even windows with triple glazing leak more energy than a typical wall does. However, they also permit the entry of sunlight, making them helpful in a hot region where they can contribute to the thermal envelope's net energy gain. Of course, there is also summer when big windows can cause serious overheating.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The orientation, size, geometry, optical, and thermal characteristics of a given window, as well as the level of shade, all play a role in determining whether losses or benefits prevail for that window. The structure itself may shade a portion of the window or external elements may be to blame (e.g., the window reveals or any overhangs). Since only the glass-covered area of a window may gather solar benefits, the proportion of frame to glass has an impact on the energy balance.

The edge spacer, which separates the glass panes, is a frequently disregarded component of an insulated glazing unit that affects how well it performs. Aluminum is a very effective heat conductor and has historically been employed as an edge spacer due to its form stability and diffusion resistance. Therefore, if you increase the glazing's thermal efficiency while maintaining a strip of aluminum around the perimeter of the glass, this will be sufficient to encourage warmth to pass through to the other side. As a result, even when there are numerous layers of glass, condensation forms on these surfaces because the perimeter of the glazing unit becomes chilly on the inside.

Finally, the way a window is integrated into a wall or roof can have a significant impact on how well it performs. The usual issues are airtightness, insulation, and wind- and weathertightness, and windows must be connected to all three functional thermal envelope layers. The finest insulation results are obtained when the window is fitted so that it aligns with the center of the insulation layer and when portions of the frame are additionally covered in insulation. A solution for airtightness or compression seals is specialized tape (careful, though, because the latter are only airtight up to a certain expansion rate). It must be attached to the adjacent airtightness layer without unduly stressing it, regardless of the shape that the seal between the window and surrounds acquires.

**Heat loss:**

The area weighted performance of the frame and glazing, as well as the length and caliber of the edge spacer, all contribute to a window's U-value. The best double glazing can achieve a window U-value of 1.20 W/(m2K) when it is supported in a frame that is effectively insulated. Triple glazing is required for lower values. Heat can find new ways to escape if a window unit is installed in a wall or roof. For instance, extra support may be required, or insulation may be impeded by flashing. As a result, the installed U-value is usually more than the U-value of the window unit.

When they relate to a medium-sized window, these values are also included in the requirements for the certification of windows. Because the impact of the frame is more noticeable on smaller windows, the U-value is likely to vary with window size.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

To become a certified Passive House, windows do not need to be certified. However, using them is simpler because all the information you require for optimizing your design is consistently offered by certified windows and is simple to select from a drop-down option in PHPP.

Different types of coatings can be used to alter the thermal insulation of double and triple windows.

filling cavities with inert gas or air.
the cavity's depth. The widest values, between 15 and 22 mm.
Spacers are often constructed of stainless steel or aluminum. Between the inner and exterior glass panes, this causes a sizeable thermal leakage.

An inert gas, typically argon, or, for higher insulation values, occasionally krypton, is utilized in HR++ and triple glazing. Although neither gas poses a risk to human health or the environment, it is predicted that the inert gas content of the cavity will decrease by a few percent annually. Adding PVB (A) film to the inner pane (residential side) of laminated glass will increase sound insulation.
If shutters can be controlled from inside the living area, the heat transmission coefficient of the windows may be reduced. Based on an operating system, this assumes that during the heating season, between dusk and seven in the morning, the shutters are closed for 80% of the time.
You can temporarily improve the window's insulation by putting a temporary fix, like insulating panels. However, the resident is solely responsible for using and benefiting from the improved insulation. Shutters can be left "open" for sunlight and views for extended periods of time thanks to the improved insulation. Insulation shutters might be useful in specific situations, like with facades that change seasonally. A wide glass surface in the heating season on the north facade can be partially closed with shutters.
A window's insulation is improved by blinds, especially if they feature a layer that reflects heat. They are much more important in conservatories since they can provide insulation and nighttime shading, especially if they have single glass. For instance, the U-value of a single-glazed window assembly in a wooden frame that includes a roller blind is 3.1

W/m2K as opposed to roughly 5.1 W/m2K without blinds.(Andy van den Dobbelsteen et al., n.d.)

**Solar gain:**

The link between the amount of solar radiation received and the overall amount, including direct and diffuse radiation, is shown by the absolute sun access factor (ASA). The relationship between incoming and visible solar energy at a perpendicular angle is shown by the absolute light access factor (ALA).(Andy van den Dobbelsteen et al., n.d.)

A triple-glazed window might not be the greatest option in a milder region if gains and losses are balanced. More heat is retained, but more sunlight is also kept out, which is unpleasant in the winter but might be advantageous in the summer. For each window, a balance must be struck, and many configurations must be tested to see which is best in light of the aforementioned considerations. With the Passive House Planning Package, this is simple to do.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

By employing glass that is either sun reflecting (by using coatings) or sun absorbing, the glazing's sun protection capabilities can be improved. Modern glass varieties are typically reflecting because they may create greater shade than glass that absorbs sunlight. Solar HR++ glass is available with an ASA of 0.41 and an ALA of 0.70, while reflective glazing for residential buildings has ASA-values of 0.40 to 0.50. The ASA and ALA values of the most recent bright, non-reflective HR++ glass varieties are roughly 0.60 to 0.65 and 0.80, respectively.

When solar radiation is accumulated on the glass's outside, the best sun protection is provided. The best solar protection is consequently provided by outdoor sunshades. The blinds can be raised in the winter when the warmth of the sun is appreciated.

Fixed architectural elements: these comprise components that are incorporated into the architectural design, such as cantilevers and fixed awnings. The glass surface is slightly darkened by these components. The sun's location with regard to the wall will determine the shade, hence the ASA-value is unstable. Like solar protection glass, another benefit of this shading technique is that it is constantly present, even in the winter when the heat is really beneficial.

Awnings are primarily relevant for façades that are located between the southeast and southwest, practically speaking. While the low sun in the winter can get through, the high sun in the summer is obstructed. Even in summer, the solar position for other façade orientations is too low to be achieve a reasonable degree of shading with fixed elements.(Andy van den Dobbelsteen et al., n.d.)

To assess an overhang's fitness for this purpose, a four-dimensional (including time) model must be created. Many permanent shading structures only block the midday sun during the hottest part of the day; they do nothing to block the morning or afternoon heat. As the seasons change, they increasingly do less to block the midday sun. Shutters are a far better solution for letting sun in when desired and keeping it out when overheating is a problem than fixed, exterior shading devices. With a small photovoltaic motor and a photosensor, they can even be automated. In this manner, even if the sun shines while you are at work, you will still arrive home to a comfortable temperature because the photo-sensor detected light on the relevant façade.

Casement or top tilt opening windows are preferable to awning windows for ventilation purposes because they perform the worst in terms of an efficient air exchange. Remember that a window should be able to be opened for nighttime ventilation in the summer without posing a security risk.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

**Daylight:**

One of the elements that contributes to a room's effectiveness is the amount of daylight that enters the space. A poor sense of space can result from a lack of natural light and views, as well as from using more electricity for lights. The illuminating capabilities of a window or skylight are necessary for daylighting. Coatings that act as thermal and solar barriers lower the ALA value. Comparing triple glazing to double glazing (HR++ glass), the third layer of glass lowers the ALA-value. For instance, unless a reduction factor is determined, the daylight factor (ALA) of the glass should not be less than 0.6 to determine the minimal glass surface needed.

Strong contrasts in daylight are advised to be minimized as much as possible for visual comfort. The reduction of artificial lighting use is a benefit of this. Apply frames, such as those in a light color, to the façades to divide the daylight openings (windows and doors with glazing). Use skylights or "tubes" or "roof light spots" if at all practicable. The quantity and kind (direct or diffuse) of light that enters a house mostly depends on the orientation, placement, and size of the windows as well as the glass's composition. Light transmittance varies depending on the type of glass. The amount of daylight entering a space can also be affected by the colors and materials used outside. For instance, since light is better reflected in areas that are densely populated or in courtyards, utilize light colors for the façades and paving.(Andy van den Dobbelsteen et al., n.d.)

#### 5.2.2.1.5. Thermal bridges

Cold bridges are another name for thermal bridges that refers to their impact on interior surfaces. However, strictly speaking, heat, not cold, is what bothers them. Geometrical thermal bridges, which are difficult to avoid, and material-related thermal bridges, which are often brought on by structural elements piercing the insulation layer, are the two main forms of thermal bridging.

A relatively small region of a structure whose insulation is inadequate compared to nearby faces is known as a thermal bridge. Thermal bridges, also known as linear thermal bridges, are frequently seen in transitions between various components (façade-floor, façade-roof, window frame-façade, etc.). Additionally, thermal bridges may form inside of buildings. Examples include hardwood framing in façade elements, steel structural elements, and rafter roof framing. At exterior corners, where the inside's heat-absorbing surface area is significantly smaller than the outside's heat-emitting surface area, geometric thermal bridging occurs. Since the surface temperatures are lower in corners, the heat transfer is increased as a result, which explains why mold is more prevalent there.

The only thing you can really do to prevent geometric thermal bridges on your property is to reduce the number of outside corners. Oblique angles are somewhat preferable to sharp angles in this situation. Corners are often covered twice when the heat loss at the thermal envelope is calculated using external dimensions, which is what you must do for a Certified Passive House. As a result, the additional heat loss is typically covered, if not exaggerated.(Andy van den Dobbelsteen et al., n.d.; Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The thermal conductivity of structural components, such as concrete columns or steel beams, is significantly higher than that of a nearby insulation layer. The lines of equal temperature are disrupted as a result. Both the area that is bridged and the layers in contact with the bridge are affected by the disturbance. Results obtained by purely area-weighting the influence of thermal bridges are very imprecise. The footings of walls, where they join a concrete foundation, are another location to search for thermal bridges. There, obtaining a gapless insulating layer is challenging but not impossible.

In order to deal with them, the first step is to design thermal bridges out. Can balconies be built in front of the thermal envelope as a distinct structure rather than being made by cantilevering concrete slabs? The separate structure would still need to be fastened to the wall's framework with bolts or brackets, but these punctiform thermal bridges have a far gentler impact than the linear thermal bridge created by a ceiling joists slab. Therefore, consider other approaches before considering strategies to mitigate thermal bridges.

Any remaining bridging materials must have the lowest heat conductivity practical for the task if this premise is exhausted or not viable. Think about using steel instead of aluminum, or aerated concrete or lighter concrete in place of heavy concrete. However, it's likely that this is just the beginning of mitigating effects. You might also need to enclose the bridging material with insulation. If the outcomes for interior surface temperatures and a minimal additional heat loss are obtained, modeling in a thermal bridging software will demonstrate this.

Our goal is to lower the excess heat loss across thermal bridges to less than 0.01 W/m2 for a Certified Passive House (mK). If it is 0°C outdoors, a thermal bridge of 50 m length with this thermal bridge coefficient would increase the size of a required heater by 10 W. An example of this would be around the perimeter of a 150 m2 house. Not much for a regular home, but in a Passive House, 10 W are sufficient to warm 1 m2 of the building even in bitterly cold weather. The 0.01 W/(mK) number may, if necessary, be surpassed in some places, but only if it can be demonstrated that doing so will not have a negative impact on the interior surface temperatures and that the increased heat loss will be made up for.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

#### 5.2.2.2. Passive use of solar energy

Utilizing solar radiation to help heat a home during the winter is known as passive solar energy (or the heating season). For homes with an EPC of 0,4 (Energy performance certificate), the amount of heat supplied by solar energy, internal heat sources (people, lighting, and household appliances), and heating installations is each equal to about one-third of the home's total heat supply.(Andy van den Dobbelsteen et al., n.d.)

High solar heat gains are usually always a factor in passive homes, although this does not imply that they always have a lot of glass. It all comes down to how heat gain and heat loss are related, as is always the case with energy balance.

First and foremost, it's crucial to decrease heat loss because failing to do so would signify that the saying "easy come, easy go" had been adopted. The goal of the following phase is to guarantee the feasible and useable solar heat gain based on its availability. This in turn is influenced by the building's design and the urban environment with reference to solar radiation.(Gonzalo and Vallentin 2014)

**Impact of orientation:**

South-facing windows have a far higher potential for solar heat gain in the winter than windows with an east, west, or northward orientation. On the other hand, windows facing east and west experience significantly more unwanted solar heat gain in the summer than windows facing south. The best results are obtained when thermal solar collectors and photovoltaics are south-facing and installed at an angle between 15 and 60 degrees.

Thus, from an energy perspective, windows that face south and active solar systems should be preferred. Simulations demonstrate that compared to low energy homes or existing structures, Passive Houses are more responsive to this design element. Important choices about the orientation and distribution of windows are already established at a very early design stage through the positioning and shaping of the structure.

Every Passive House construction should have a creative and iterative process to choose the location and size of the solar apertures (windows, solar facades, transparent thermal insulation systems, solar collectors, and photovoltaic modules). In this situation, the climatic and urban factors are always crucial. They decide, among other things, whether the solar notion should be centered on a winter or summer environment.

It is typically preferable not to significantly increase the window area due to the high expenses of transparent or translucent materials as well as the cost and work involved with sun shading devices and cooling systems. From a tactical standpoint, it's crucial to comprehend that in the case of suitably compact Passive House buildings, unfavorable solar radiation conditions can be overcome by a deft window placement and/or a slight increase in thermal insulation.(Gonzalo and Vallentin 2014)

#### 5.2.2.3. Floor plan dwelling

The use of solar heat is enhanced by partitioning and zoning of houses, which also reduce transmission and ventilation losses. Certain rooms can prevent needless heating and/or ventilation by being divided into separate parts. For instance:

- A closed kitchen can save heat by reducing transmission and ventilation losses when compared to an open kitchen.
- • Air portals at the front and back doors
- A vapor screen between the kitchen and living room improves the air quality in the latter.
- • Loft and upper floor insulation (for an unheated loft)
- • Insulating the walls and floors that separate houses reduces the reliance of energy consumption on the actions of neighbors. This is especially significant in homes with excellent insulation.

Zoning is the practice of placing spaces with about the same target temperature next to one another. The typical advice is to place the "cooler" areas, like as the entrance, separate kitchen, and storage room, on the more shady side of the house and the "warmer" spaces, like the living room and children's rooms, on the sunny side of the house wherever possible.

Considering placing the living room on a higher floor in areas with a significant concentration of low-rise structures that have severely occluded angles. The amount of light in the space will significantly enhance as a result. It is necessary to have a decent adjustable heating installation in each room or zone if you want to profit the most from zoning and partitioning.

Avoiding relatively narrow widths for terraced homes located on a street's north side. Unless the living room is on a higher floor, there isn't enough room for both the entry and the living room to be on the south side. Design the homes on the north side to provide the north gardens with the most sunlight possible. Pick an asymmetrical cross section, for instance.(Andy van den Dobbelsteen et al., n.d.)

## 5.3. Turin case study: introduction to proposals towards reuse of energy

### 5.3.1. Strategies in urban context

When every building inside a district is cooperating, it is said to have a zero-energy district. As a result of their communication, the community as a whole experiences optimal energy performance. It is significantly easier to achieve greater energy efficiency by maximizing the performance of a group of buildings as opposed to a single structure.

#### 5.3.1.1. Building functions in San Salvario (micro-zone 10)

The building's ground floor operations are shown on the map that is provided below.


*Figure 39: Building functions on ground floor in San Salvario (Provided by the author)*

The commercial district depicted below includes some offices along with stores, restaurants, pubs, supermarkets, and other commercial services.
Hotels and other forms of temporary housing are additional first-category building types that are located in areas in this neighborhood. These are not just ground-floor parts of the blocks.

The second category displays a bank that faces the outdoor market. On weekends and in the mornings, this farmers market serves as the center of the community.
San Salvario is a popular destination for nightlife, which explains the abundance of bars and restaurants there. The underground parking garage located below this outdoor market will have the lowest energy requirements of all the services mentioned.

In the area, there is also a synagogue that is connected to a Jewish school and takes up nearly an entire building block.

### 5.3.1.2. Energy re-cycling in San Salvario (micro-zone 10)

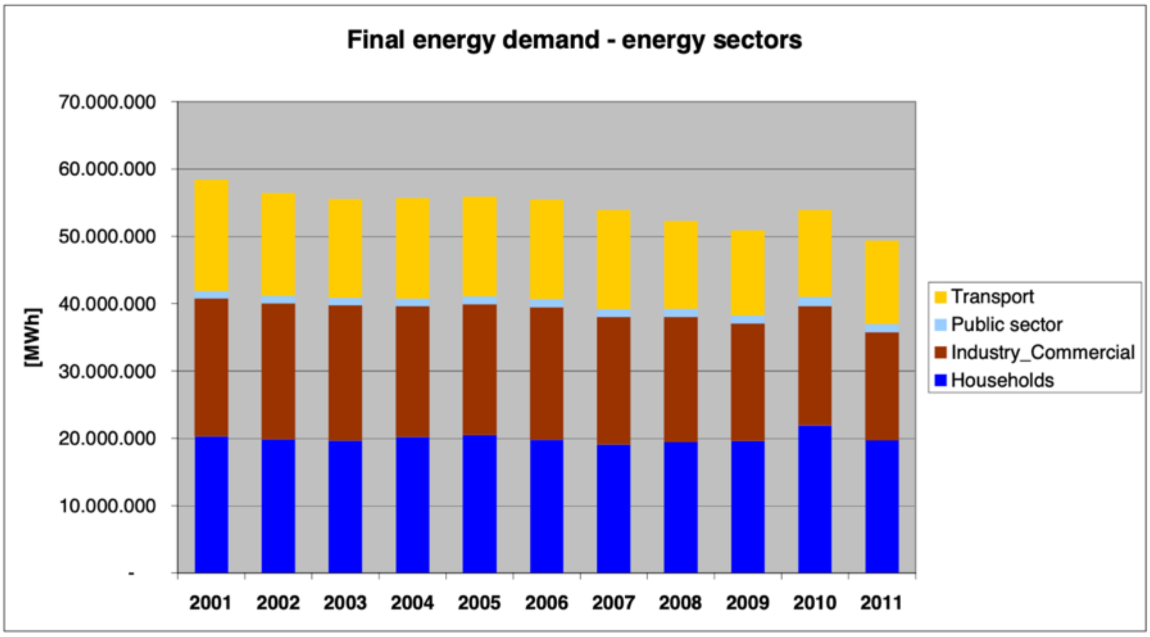



*Figure 40: Final energy demand (de Nigris and Fraire 2013)*

The residential sector has the highest need for energy, as shown in the graph above. The majority of the buildings in the selected area are apartment complexes with ground-floor shops. Numerous hotels that are also present in the area are seen as being a part of the residential sector. The second sector in terms of commercial and industrial activity comes after this. The ground level of each building block is home to a number of bars and restaurants, or in certain cases, offices, and public services.

By reusing energy, energy recycling, which was inspired by the idea of district heating, helps to lower energy needs. The way it would work is through the underground district heating infrastructure; heated water or liquid that has been used for heating purposes in residential apartments; will then have a lower temperature, say from 60 C to 45 C; that temperature of liquid will be sufficient to heat up better insulated households or the commercial sections located in the area on the ground floor. Following that, the temperature will drop by about 30 C and be supplied to the outdoor market and the underground parking.

### 5.3.1.3. Building functions in Lingotto (micro-zone 28)

The building's ground floor operations are shown on the map that is provided below.


*Figure 41: Building functions on ground floor in Lingotto (Provided by the author)*

These number of buildings, surrounding piazza Galimberti, neighboring the Olympics village consist of different functions dominated by residential buildings. As it was the case in San Salvario, the ground floor is dedicated to commercial uses specifically for buildings facing busier streets. There are two hotels in the neighborhood as well as offices and public services which more or less have the same energy demands as the residential. However, the highlighted functions that were observed which can contribute to their surrounding functions were, a school in the south portion and an electronics manufacturer. On the north, the is less diversity when it comes to building use. However, there are some car dealer shops that are located next to an auto repair shop. That shop considering the size of it can only contribute its own building block.

#### 5.3.1.4. Energy recycling in Lingotto (micro-zone 28)

A transfer of energy from vast scales of motion to tiny scales (referred to as a direct energy cascade) or from small scales to big sizes is referred to as an energy cascade (called an inverse energy cascade). That is how energy cascading is defined in continuum mechanics. The various varied building uses around the city require varying amounts of energy for heating and cooling. For instance, compared to a hospital, a sports facility or gym needs less energy to heat during the winter due to the high level of mobility activities. Therefore, it can be advantageous to swap energy across buildings and use the wasted energy for another purpose. The illustration below is a general example that represents a part of the city of Turin and demonstrates the concept of energy cascading.

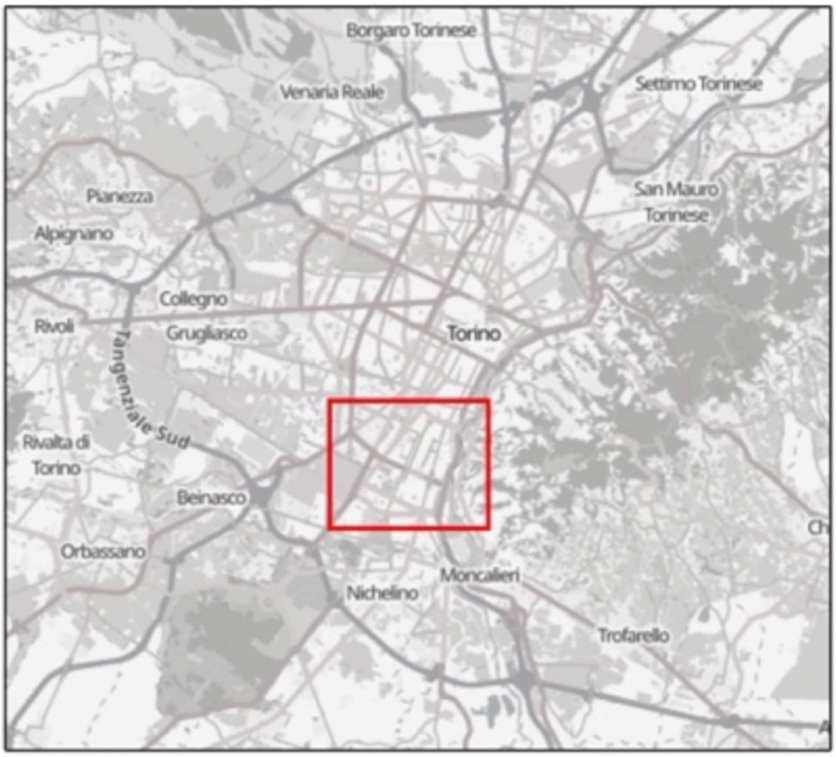



*Figure 42: Map of Turin (open street map)*

This part of the city consists of different functions with different levels of energy demands. There are a number of residential areas as well as an area with sport facilities. The fiat car factory is also located in this area. Although it is not entirely active as it used to be decades ago, a portion of it is still in production line which still requires high levels of energy. That active portion of the factory is highlighted in the illustration below.

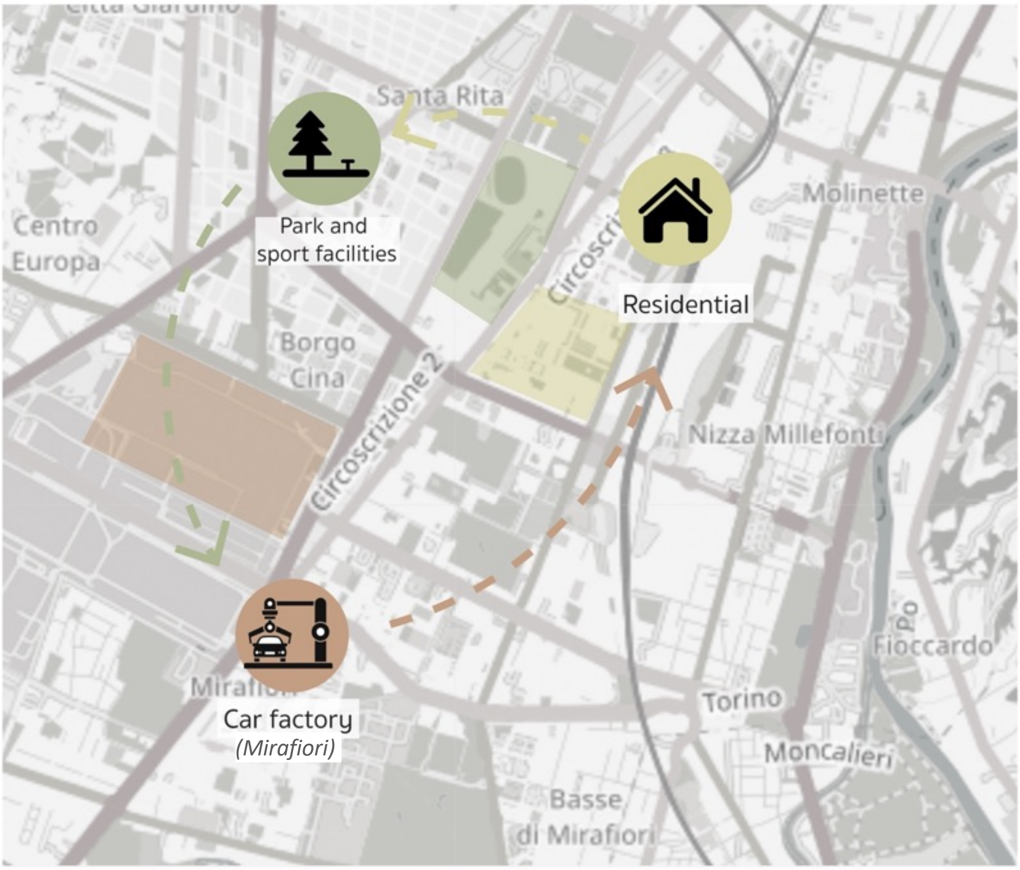



*Figure 43: Energy recycle in bigger scale (Provided by the author)*

Different kinds of machinery are used in a factory that require high levels of energy. As a result of production and energy use of the machinery, the factory is heated up that needs to cool down. This waste heat due to higher demands of heating in residential area, can be fed to these number of zones. A way to do this is through heat exchangers. Heat exchangers can function using fluids, either gas or liquid. Later on the decreased temperature will transform to sport facilities in comparison to all have the lowest heating needs since high mobility activities are taking place in indoor spaces. The cooled down fluid then will go back to the car factory and the cycle continues.

Coming down to the smaller scale of urban tissue as it was demonstrated earlier, I am going to focus on a portion of the residential section of this area and how energy coming from the car factory can be distributed among these buildings with different functions. Each building block or a number of building blocks can work together to reduce the energy demands, depending on their functions. Since the functions are in small scales, therefore small cycles work well in the neighborhood. For example, a number of shops can only use the remaining energy that has been used in the same residential building only.

### 5.4. Energy production

Collecting more energy than the home needs through on-site renewable energy flows is the last step in building a Positive Energy Home. Again, it's important to emphasize that this action makes sense only after the preceding ones have been carried out. By including a rainwater tank, the issue of leaking pipes is not resolved. Similar to this, we must stop the energy leaks in our homes before we even think about producing the energy we need. The two energy sources that are often accessible in metropolitan areas are wind and solar.

The generation from solar photovoltaic (electric) systems, is only accessible during the day but is more predictable and reliable even in built-up regions. Because heat can be captured from indirect solar radiation, such as in solar hot water systems, the generation of heat is even more dependable. This enables these systems to capture valuable energy even on cloudy days. Solar energy collection is the most practical and affordable way to generate positive energy for the majority of homes due to the difficulties and limitations of wind power, its accessibility in urban areas, the relative scarcity of micro-hydro compatible watercourses, lowering costs, and diversity.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

#### 5.4.1. Implemented PV panels

Electricity is produced from solar energy using a photovoltaic (PV) system. The phrase is derived from the requirement for light (photo) in order to produce electricity. A physical process in a PV cell that produces direct current allows solar energy to be generated. A PV panel consists of a series of connected cells. A PV system is made up of these panels as well as other necessary elements including inverters, cables, and installation requirements. The majority of PV-equipped homes are plugged into the grid; thus, batteries are not needed to power the systems. Batteries are required to store power in autonomous structures like parking meters, ships, and buoys for navigation. Energy for grid-connected systems is often used as much as feasible within a home or other residential structure. The grid only receives the surplus. PV cells are coated to lessen sunlight reflection. The amount of reflection reduction depends on its color; a dark blue or black coating reduces reflection the most. Other color alternatives include yellow, green, brown, grey, and purple; however, these ones are less effective than dark cells by 10% to 30%. The development of plastic and organic material-based PV cells is under development.

The inverter is one of a PV system's crucial components. This changes the direct current (DC) generated by the PV panels into the alternating current (AC) of the grid. Inverters that are connected to the public grid make sure that the generated electricity is just as powerful as that from the grid. No unwanted currents or voltages will be allowed to enter the circuit thanks to security and control equipment. Only when they are linked to the grid do grid connected inverters operate. Electricity losses of 2–8% arise from the inverter's conversion of direct power to alternating current. Conversion losses are doubled since some devices, such batteries, LED lights, and USB ports, operate on direct current. The quantity of energy that needs to be converted to the alternating current of the power grid can be reduced by using a portion of the generated electricity directly with this equipment.

In the middle of Europe, a horizontal roof receives about 1000 kWh of solar energy per m2 each year. A PV system using crystalline PV cells has a maximum annual yield of 160 kWh of electricity per m2 of PV panel with a 16 percent efficiency. The maximum for 6 percent amorphous PV cells is roughly 60 kWh. This employs the most advantageous orientation and inclination in both situations. When a PV panel is partially shaded, its yield drops down significantly. This is due to the fact that the PV cells are often connected in series, with a number of them per panel. The entire sequence will be powerless if one cell gets shaded. The same result can be obtained with entire panels because panels are likewise put in sequence. We need to make sure that the roof installation, roof structure, ventilation systems, trees, or solar panels don't shade the area.(Andy van den Dobbelsteen et al., n.d.)

Individual solar panels are connected in a "string" with a common connection to the inverter when a central inverter is employed. The inverter then utilizes a process known as maximum power point tracking to control the voltage and current of that line of panels to maximize power output (MPPT). The output of all the panels on the same string can be hampered by shading that alters the performance of a single solar cell or panel within the string. This can also happen when panels on the same string are oriented differently, producing a range of output. As a result, strings should be constructed of panels with the same orientation and coupled to an inverter specifically equipped to handle that orientation or numerous strings of inverters with different outputs.(Brimblecombe, Rosemeier, and CSIRO (Australia) 2017)

The top of the house is where PV is most frequently used in residential applications because it is least likely to be shaded by nearby structures and vegetation. Additionally, it is typically the largest continuous surface that is available. There are several possibilities:

• Common PV panels installed in the roof profile: Typically, there is a water-protective coating under the panels on pitched roofs.

• PV panels mounted on a typical (metal) support structure that is perched over the roof for flat and pitched roofs only.

• Roof tiles with built-in photovoltaic cells.

• Glass roofs with integrated PV cells (see below).

• PV foil applied with glue to metal roofs.

• PV systems fitted into plastic roofing sheets.

• PV that was deposited on a glass inner tube.

PV modules can also be connected to a façade. It could take the shape of "loose" PV panels or PV built into glass and/or windows.

However, only 70% of the maximum quantity of sunshine can enter a vertical arrangement without significant risk of shadowing. Display panels, which are glass that is partially covered with PV cells, should provide some architectural alternatives because they filter sunlight.(Andy van den Dobbelsteen et al., n.d.)

### 5.4.2. Solar hot water collectors

Flat plate and evacuated tubes make up the two main types of solar hot water/thermal collectors that are readily accessible. Vacated tube collectors are constructed of an inner heat tube that has been carefully treated to maximize solar absorption and an exterior borosilicate glass tube. The heat-collecting tube is insulated by a vacuum created when the space between the inner and outer tubes is emptied.

Heat that has been absorbed is collected in a heat tube and sent to an insulated header at the collector's top. Many evacuated tubes utilize a fluid that absorbs heat and evaporates when heated. Vapor then ascends to the tube's top where it indirectly warms a fluid (in this case, water) in the header. In order to restart the cycle, the vapor condenses once more into a liquid and drains back into the tube. Other systems use copper U-shaped pipes instead of U-shaped copper pipes to circulate cold water directly through the tube. Only places free of frost should use these systems. The performance of these panels is not unduly susceptible to the ambient temperature because of the extremely insulating qualities of the evacuated tube, which enables them to provide excellent efficiency even in cold areas. They may provide useful heat even on cool, overcast days thanks to this excellent gathering of indirect solar light.

With a low absorption/reflectivity glass layer covering the collector surface, flat plate collectors are more comparable to solar PV panels. A metal plate (usually made of copper or aluminum) that has been carefully treated to maximize sunlight absorption serves as the collector. To collect the heat, a number of pipes are adhered to the metal plate. The entire system is then put inside an insulated box. Normally, fluid enters the panel from the bottom, allowing heated liquid or water to rise or flow to the panel's top for collection. Flat plate collectors are able to provide good performance at a reasonable cost in warm locations with an equator-facing roof.

### 5.4.3. PV Thermal panels

There are also hybrid PV-thermal (PV-T) panels that combine electricity generation and water heating into a single panel by sandwiching a PV layer between the glass and the metal plate. Theoretically, the chilly water influx also aids in increasing the PV solar panel's efficiency and lowering the number of materials and space needed to produce hot water and power. This technology hasn't developed to the same level or reached the same market penetration as conventional PV and solar thermal in the majority of places. Where roof space is at a premium, hybrid PV-hot water systems which are normally either optimized for PV or for hot water might be worth exploring.

### 5.4.4. Storage

#### 5.4.4.1. Heat storage

In a hot water tank, where hot water is kept ready in a super insulated tank for later use, there is a common approach to store energy in the home. It has the ability to store extra energy created during periods of peak generation for a number of days if necessary. When solar PV is used to power a heat pump, hot water can be produced during the solar panels' peak output during the warm afternoon, increasing the heat pump's efficiency, and then stored for later usage. Installing a larger hot water storage tank may be advantageous in situations where the hot water system is used to satisfy home hot water and heating needs. This will enable for enough heat to be stored to cover nightly hot water and heating needs. However, in a perfect world, hot water creation and storage should be managed against usage on a daily basis to avoid energy being squandered as heat loss. If a tiny amount of excess hot water is generated, it can be used the following day with little tank loss.

#### 5.4.4.2. Electricity storage

Batteries are the most common type of electrical storage in homes. Electricity is stored in batteries as chemical energy that can be quickly released as needed. Pumping water to a high point and storing the energy there as potential energy in the water, which may then be converted back to electricity via a micro-turbine, when necessary, is an alternate technique of storing power. This might be feasible for a rural property with dams or when residential water pressure is provided by a header tank. Electricity to gas (hydrogen or methane) and capacitor banks are two other ways to store electricity, however as of this writing, neither of these technologies is feasible or widespread in homes. Due to conversion inefficiencies when converting between electrical and chemical energy, battery storage devices ostensibly increase costs and annual usage. Battery storage is crucial for balancing generation and demand in remote places that are not connected to the grid and for providing electricity when there is none during periods of low generation. The advantages of battery storage for grid-connected devices include smoothing and controlling grid interaction; allowing more of the generated electricity to be used in the home; the possibility of supply security during grid outages; and the possibility of being grid-independent.

An integral part of a grid powered entirely by renewable energy, from the perspective of the energy community, integrated home energy storage aids in balancing demand and the variable output of residential renewables.

### 5.5. Reference projects

#### 5.5.1. Prinz Eugen Kaserne in Munich

The urban tissue in San Salvario has a grid layout can be described as dense with mixed-used functions, specifically the city center of Turin. Therefore, this specific case study was used as a reference project. Prinz Eugen Kaserne in located in Munich Germany with relatively a similar climate to northern Italy.

The goal of this reference project is to show how climate protection methods can be implemented to a specific urban development scheme. Transformation into a new urban district with 1800 apartments, a school and childcare center, office buildings, and a central square with local services for 5000 residents is represented. (Gonzalo and Vallentin 2014)


*Figure 44: Refurbished district plan (Gonzalo and Vallentin 2014)*

*Figure 45: Refurbished district plan (Gonzalo and Vallentin 2014)*

Specific interventions on this referenced project are mentioned below:

The proposal is based on the concept of establishing a densely built, mixed-use quarter with a number of development blocks or pockets that can act as separate neighborhoods. This is specifically relevant to the designated zone in Lingotto.

Clear urban characteristics with differentiated parts characterize the public space and residential courtyards. This basic structural concept is a pattern that is widely observed in Turin. The Passive House criterion is met by all of the structures. However, depending on the form factor, orientation, and overshadowing of the various structures, the constructional and technical input required to achieve the energy criteria varies.

The majority of the structures face south. All principal facades are oriented south, especially in less crowded arrangements with semi-detached and terrace houses.

Photovoltaic panels can be installed on south-facing roofs.

A district heating system with a low-temperature network provides heat . By adding only one substation each block and then employing so-called small networks, the main network is limited to a bare minimum. Waste water heat pumps are used to achieve the higher temperature required for domestic hot water.

The mobility idea is centered on good public transportation (tram, bus) with stops at the central square, car sharing services, and good electric vehicle (bicycles, city cars) facilities in each neighborhood

**Related issues:**

- Density of a portion of this neighborhood is comparable to the designated Micro zone in City of Turin. This density brings out some specific issues such as availability of natural light to the lower floors.
- Mixed-used functions; different functions have different energy demands and this can be problematic if the functions are in the same building, however, looking at it from a different perspective, the diverse energy requirements can work in our favor as the concept of energy cascading will be explained later on.
- Residential courtyards are an iconic feature in the urban tissue, specifically in the grid pattern that we have in Turin.

**Related solutions:**

- South facing facades have increased solar heat gain which can not only work in the favor of the apartments receiving the direct sunlight, but also in future steps of energy production for other apartments with shorter time frame of direct sunlight.
- Use of PV panels on south facing roofs
- District heating system as a result of energetic programming. The district would work as a system with each function dependent on another for heating. This approach can significantly reduce the energy demands during the winter months.

### 5.5.2. A refurbished passive house in Mixed-humid and cold climate

An example of a refurbished passive house in mixed-humid climate, a row house in New York City can be mentioned. Brooklyn row houses are classic New York City buildings that are often dated from late 1800s. Jane Sanders, an architect, and a PH designer, purchased one of these brick rows houses and it was retrofitted and transformed to a passive house. New York City located on east coast of United States of America, has a mixed climate. Really hot and humid during summer months and cold and snowy in winter months. The house purchased by Sanders' is a street facing house with a brick façade, three floors with regularly spaced and sized doors and windows. The total area of the house is 250 m$^2$ that was remained unmodified.

*Figure 46: Photo of a refurbished house* (James and Bill 2016)

For the refurbishment of this house, the interior walls were demolished, and arrangement of the interior space was modified. They found out that replacing the joists in a row house is the most cost effective. With all the new joists spanning the whole house, the structural connections were transformed to party walls and therefore eliminating the thermal bridges on the exterior façade. The existing slab was dug out 2.4 m so that the insulation could be installed below.

A variety of insulation products were used mostly to adapt to tight spaces around the windows. She started by the insulation of four unbroken brick walls and the airtight layer was added as the next layer. At the shared party walls, a coat of cement and a fluid applied air barrier made the existing walls airtight. The trickiest part to be airtight in this project were the cellar corners.

For ventilation Sanders had an ERV (Energy Recovery Ventilator) installed to help with controlling the moisture; to be conserved in winter and excluded in summer. This system can provide required heating and cooling through separate ducts. A humidifier was added to the mini split system, so no damages were caused to the interior woods by low indoor humidity during winter. During milder seasons a skylight would help with ventilation and cooling since use of the split unit would not be a necessity. This ERV system helps getting rid any cooking odors in the kitchen and if any more ventilation is required opening windows can help with an additional airflow.

On this specific house, installing roof solar panels was not possible due to the city regulations and lack of space. However, a solar thermal system was installed to provide domestic hot water to this household. (James and Bill 2016)

**Related issues:**

- Age of the building; is relatively similar to the chosen area and therefore they might suffer from the same kinds of issues and corrosion.
- Relatively similar climate. New York has a mixed-humid and cold climate. Hot and humid summers and cold and snowy winters. The climate in New York features a humid subtropical variety (cfb) similar to Turin.
- Elimination of thermal bridges is another issue that would be faced.

**Related solutions:**

- Moving the structural connections to neighboring shared walls which eliminates the thermal bridges

### 5.6. Implementation of proposed technologies to district

The detailed strategies that were introduced and explained in section 4.1 are important strategies that have big impact on energy demands of each individual building. However, in this section the focus is mostly on the district level and different functions contributing to each other. There are 2 steps of the implementation of strategies, firstly reduction and recycling of energy and followed by energy production depending on the building location, orientation, and shape.


*Figure 47: Zone in Lingotto, divided zones by the author (Provided by the author)*

### 5.6.1. Implementing of energy reduction and recycling proposals

As it was demonstrated and explained in section 4.2, heated water coming from the use of different machinery in the car factory can be fed to the residential sector nearby. This heat then will be distributed differently in each zone depending on their different functions.

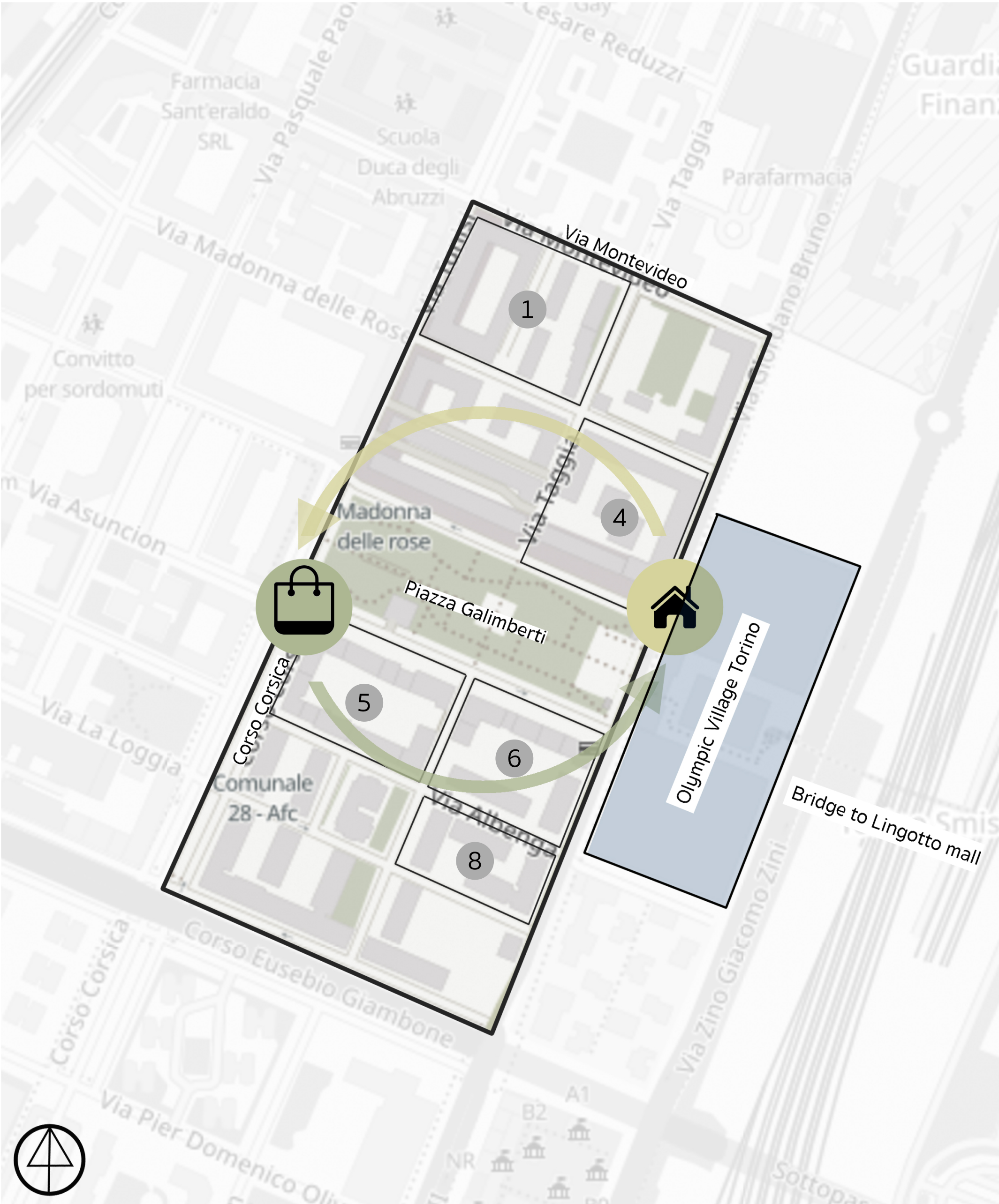



*Figure 48: Energy recycle- Zones 1,4,5,6,8*

The first step of implementing energy recycling was to divide the district in different zones. Each zone consists of different functions that can work together in order to reduce the primary energy needs by reuse of energy through heating system. However, some zones only consist of residential and commercial on the ground floor and some only residential, in which case the energy recycling can be implemented to individual buildings or a number of residentials that are located next to each other and heat flowing from one residential to a another which happens to be more insulated and therefore has less needs of heating. only and heat will be flowing from residential with higher needs of heating due having less mobility, towards commercial with fewer number of rooms, having higher mobility and being more in contact with the outdoor space. The illustration below demonstrates the zones that consist of buildings that are able to take advantage of this technology individually or a number of residential together.

In **zone 2**, there are 5 residential buildings located next to each other. Except for one located on the south, they relatively have the same height. The majority of them are east-west facing, therefore use of shadings is essential where overhangs will not be enough due to low angle of sunlight from east. On the ground floor of these residentials, several shops including car dealer shops are located. Which is followed by an Auto repair shop on the ground floor of northern building. Considering the low mobility in the residential, they are first in demand for heating and need more than the car shops and finally the mechanic shop which is more in contact with the outdoor and can also take advantage of the heat emitted from the cars.

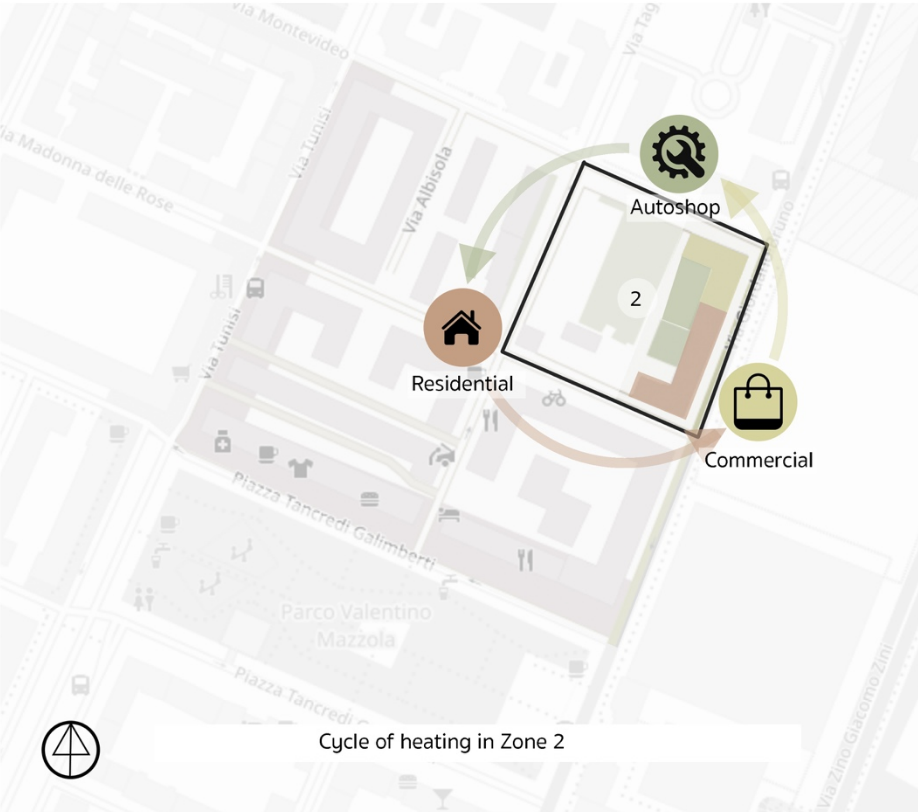



*Figure 49: Energy recycle- Zone 2 (Provided by the author)*

**Zone 3** is consisting of a residential building on the south facing the park and having different shops on the south facade. In the center of this zone there is building which provides car services. The difference of this building and the care repair shop in zone 2 is that firstly this is an individual building only functioning as a car service and secondly the use of machinery in this shop is much higher that the shop in zone 2. Therefore, higher demands of energy due to the use of different machinery. The heat produced through the use of heat exchangers can be fed to residential buildings. This can either operate separately as the heat coming from the car factory or be added to that in contribution to the zone. And lastly shops and the cycle continues.

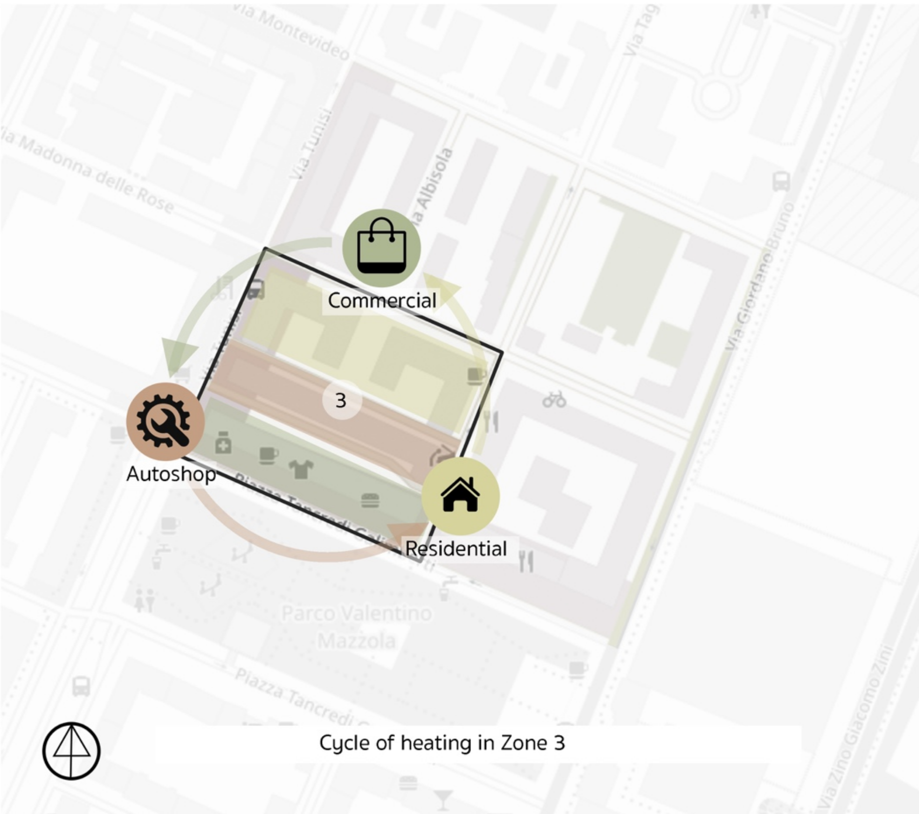



*Figure 50: Energy recycling-Zone 3 (Provided by the author)*

**Zone 7** is one of the most important zones having a school for children which consists of only one floor. There are 3 main buildings in this zone, first one, the building on the west being a residential building having a number of commercials on the ground floor. Second builidng, the one on the centre which is a shorter building in height and is completely residential and thirdly the primary school which is one floor and is not overshadowed by any surrounding buildings. The highest demand for heating again is known to be for the residential due to having less activities. Second in line would be the primary school for 2 main reasons. Firstly the school is for children and there are high levels of physical activities from big numbers of people in room or area. And secondly the building is only consisted of one floor, the roof is not overshadowed by other buildings which creates the opportunity of using passive solar energy and as a result less heating would be required. The third function with less demands for heating are the shops and commercials facing the main road. They are more in contact with the outdoor spaces and have higher levels of activity in comparison to residentials.

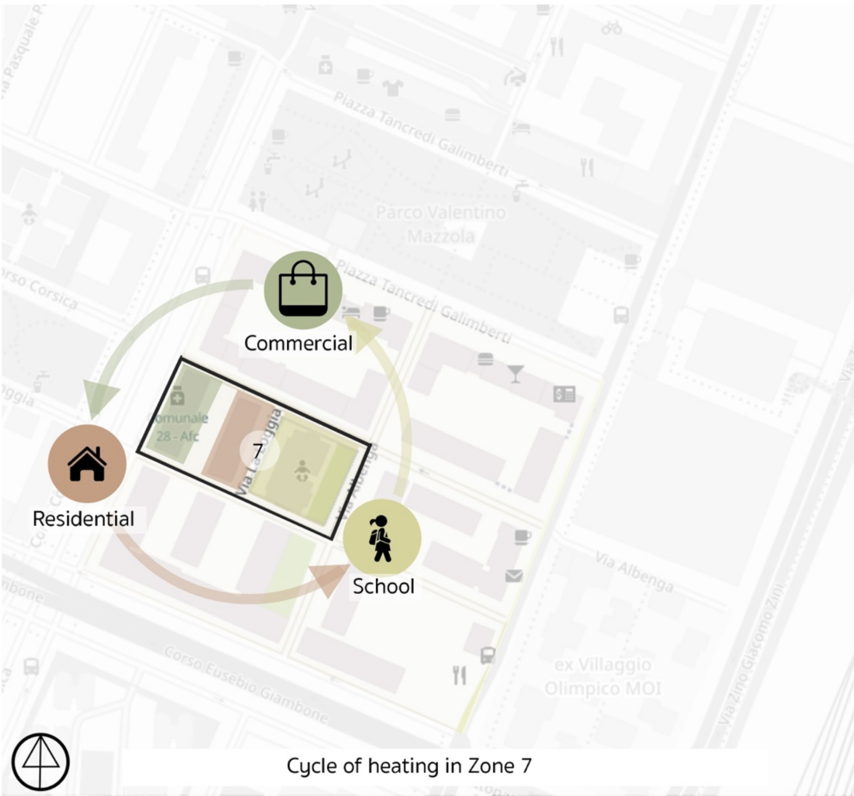



*Figure 51: Energy recycle-Zone 7 (Provided by the author)*

**Zone 9** consists of 2 bigger building complexes with a combination of residential and office and a smaller building located in the centre. The bigger buindings facing the south consist of 10 levels whereas the smaller building located on north side of these buildings has 6 levels and is completely a residential building. This difference in height has caused to the smaller building to be overshadowed by the south facing complex and therefore having more need of heating during winter months. It also needs to be pointed out that this building is east-west facing and can not take advantage of passive solar energy throughout different seasons. One of the main functions to be mentioned in this zone is the electronic manufactures. Manufacturers have highest levels of energy demand which can be recycled and reused in the dwellings in upper floors. The energy comsumed in the manufacturing portion of the building though the use of air-water to water-water heat exchangers and be transformed into heating and fed to the residential seactor, and from there on the cycle continues and it was explained before to the commercials.

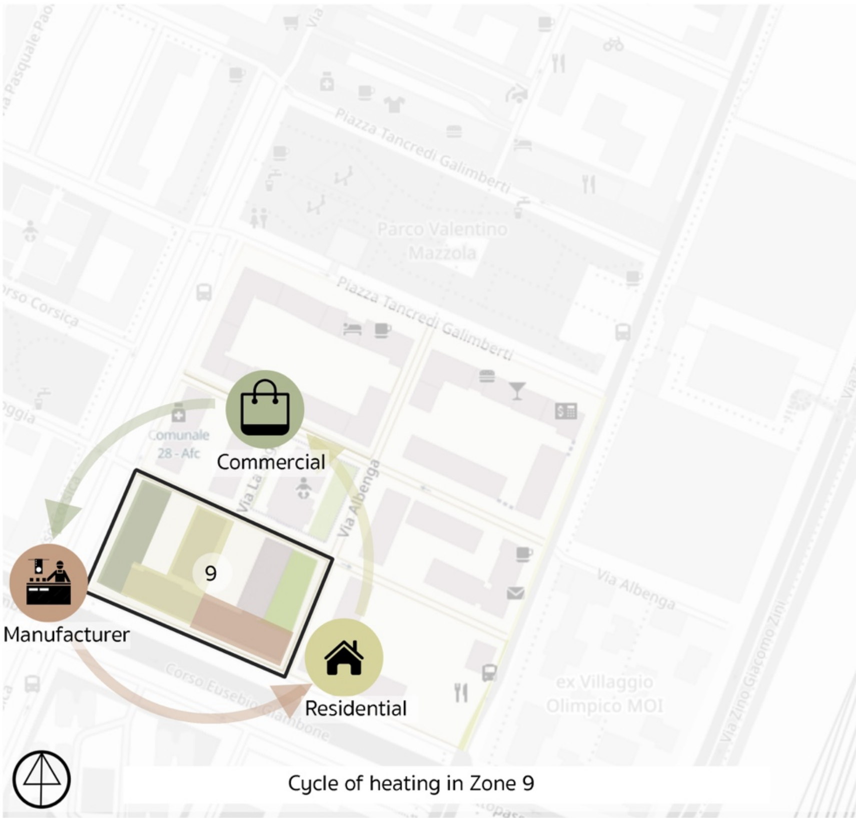



*Figure 52: Energy recycle-Zone 9 (Provided by the author)*

The final zone and the most interesting combination of functions which is a very common combination, are located in **zone 10**. Half of this zone is only residential and the other half is a combination of a hotel located next to gas station, a residential building and a gym which is covering almost a quarter of this zone. It needs to be mentioned that a number of public services and offices were also located in this zone which are second in demand in terms of energy requirements. First being the residentials and the cycle ends on the gym which has higher demand for cooling rather than heating due to higher level of physical activity. The residential and offices on the west side and have their own different cycle. And on the east the residential will have the primary needs of heating (the hotel is also considered to have the same level of heating demand due to the similarity of the function), followed by the offices and shops in this sector and finally as mentioned before the gym will have the least heating demand and from there on the cycle continues.

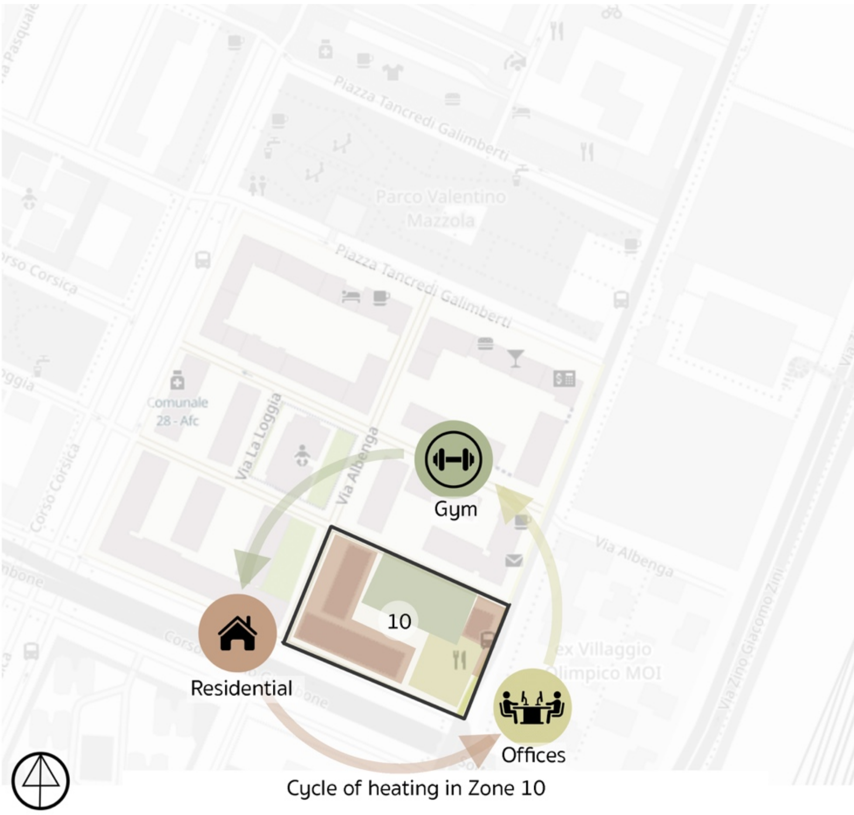



*Figure 53: Energy recycle-Zone 10 (Provided by the author)*

This approach of energy recycling can help reducing the primary needs of energy for heating in different districts and zones depending on their functions. We will have the opportunity to reuse the energy that was already used in another function. The water transforming from one function to another can also be considered pre-heated water if the temperature is not high enough to heat the building because of different climatic reasons. However, even a preheated water can help in significantly reduce of energy needs to have hot water in comparison to heating up cold water in winter months.

### 5.6.2. Implementing energy production proposals to the districts

The first step towards understanding appropriate buildings for energy production and using PV-Thermals is understanding the orientation of the buildings and how they are able to utilize the direct sunlight. The illustration below demonstrates the buildings facing east in red and south-facing buildings in yellow.


*Figure 54: Buildings orientation (Provided by the author)*

East-facing buildings which are dominant in this district; receive sunlight at lower angles both from east and west facades, therefore overhangs are not very practical in terms of blocking the sunlight. Shaders however can prevent overheating and help to manage the solar intake in the dwellings during summer months. Implemented PV shaders for east facing facades are a way to produce energy, which will be specifically useful during the summer months. However, since they will be mostly shadowed during the day, it will not be recommended. The best way to implement the PV-Thermals to their placement on south facing to cover the energy demands of all neighboring buildings as well.

The issue with these buildings' easterly orientations is that they receive too much direct sunshine in the summer and too little direct sunlight in the winter. Because of the increased energy demand during both the cold and hot seasons due to overheating in the summer and a lack of sunlight in the winter, east-west facing buildings must produce more energy.

Another number of buildings as highlighted on the illustration above are overshadowed due to their height and orientation. Some rooms were observed to not receive any sunlight on a midday on a summer day, therefore they are only able to take advantage of the morning sunlight. For these building the implementation of the PV-thermals needs to be on southern neighboring buildings which are taller, not overshadowed and are oriented towards south. As a result, the contribution of the individual building blocks compensates for the need for extra energy that could have been saved had the heights been reversed.

To achieve net zero energy for the majority of Positive Energy Homes, an existing roof must be designed or modified for solar generating. In order to maximize annual output and aid in solar panel self-cleaning during rain events, the ideal roof design/selection would include a sizeable area of south-facing, unshaded roof with a pitch of 15°. This would allow panels to be laid directly on the roof without the use of additional frames. With this setup, the panels can also be connected in equal strings and controlled by a single inverter of the right size. Additionally, the roof should be aesthetically pleasing and functional for passive solar energy generation, daylighting, and solar control. In areas farther from the equator like northern Europe, increasing the pitch off the roof can assist balance annual generation, but this must be balanced against reducing the home's overall surface area.

| Country | Representative City | Nearest Meteorological Station | Station Lat. (deg.) | StationLon. (deg.) | Opt tilt |
|---|---|---|---|---|---|
| Germany | Munich | Munich | 48.13 | 11.7 | 33 |
| Ghana | Accra | Accra, Ghana | 5.6 | −0.17 | 6[a] |
| Gibraltar | Catalan Bay | Ceuta, Spain | 35.89 | −5.29 | 31 |
| Greece | Athens | Athens | 37.9 | 23.73 | 29 |
| Guatemala | Guatemala City | Guatemala City | 14.58 | −90.52 | 18 |
| Guinea | Conakry | Dakar, Senegal | 14.73 | −17.5 | 14 |
| Guinea-Bissau | Bissau | Dakar, Senegal | 14.73 | −17.5 | 14 |
| Guyana | Dadanawa | Boa Vista (Civ/Mil) | 2.83 | −60.7 | 6[a] |
| Haiti | Port-Au-Prince | Punta Maisi, Cuba | 20.25 | −74.15 | 19 |
| Honduras | Catacamas | Catacamas | 14.9 | −85.93 | 15 |
| Hong Kong | Hong Kong | Hong Kong | 22.32 | 114.17 | 20 |
| Hungary | Debrecen | Debrecen | 47.48 | 21.63 | 30 |
| India | Rajkot | Rajkot | 22.31 | 70.8 | 24 |
| India | Chennai | Chennai | 13.07 | 80.24 | 13 |
| Indonesia | Balikpapan | Bandar Seri Begawan | 4.93 | 114.93 | 5[a] |
| Iran | Tehran | Tehran | 35.41 | 51.19 | 31 |
| Iran | Yazd | Yazd | 31.88 | 54.28 | 26 |
| Iraq | Baghdad | Tabriz, Iran | 38.05 | 46.17 | 30 |
| Ireland | Kilkenny | Kilkenny | 52.67 | −7.27 | 36 |
| Israel | Be'Er Sheva | Be'Er Sheva | 31.25 | 34.8 | 29 |
| Italy | Catania | Catania | 37.47 | 15.05 | 27 |
| Ivory Coast | Yamoussoukro | Accra, Ghana | 5.6 | −0.17 | 6[a] |
| Jamaica | Kingston | Santiago De Cuba | 19.97 | −75.85 | 20 |
| Japan | Osaka | Osaka | 34.78 | 135.45 | 30 |
| Jordan | Amman | Jerusalem, Israel | 31.87 | 35.22 | 28 |
| Kazakhstan | Zhezqazghan | Tashkent | 41.27 | 69.27 | 32 |

*Figure 55: Optimal PV angle (Jacobson and Jadhav 2018)*

Another observable factor in the shape of the buildings in this neighborhood was buildings with flat roof that are mainly east facing. In order to install PV thermals on flat roof framing is required to achieve the optimal angle for PV panels. This gives us more flexibility to take the most advantage of the sun beside having easier access to the panels for services. Although it needs to be considered that one of these buildings as demonstrated earlier in partially overshadowed by southern buildings, therefore it will not be appropriate to install PV-thermals on. The following plan demonstrates the buildings with flatter rooftops. An alternative way to take advantage of flat rooftops is green roofs and using green rooftops on the roof. Green roofs offer shade, absorb heat from the air, and lower the surface and ambient air temperatures. Cities and other constructed areas with little vegetation can reduce the heat island effect by using green roofs, especially during the day. Another benefit of having green roof on flat rooftops is that he temperature on the roof is lowered by a green roof. The effectiveness of the solar panels is higher because of this cooler roof, which lowers your overall energy bills.


*Figure 56: Flat roofs (Provided by the author)*

The south-facing buildings in the area should be given priority for PV-thermal implementation. In the previous image, it is illustrated in yellow. These are not the more dominant structures in the area but are able to provide the energy needs, and their greater floor counts and superior direct sunshine make them the best candidates for the production of solar energy. Due to the adaptability of implementation, east-facing facades with flat rooftops come next. Finally, very few east-facing buildings have southern facades with even a small percentage of windows that are not under any kind of shadow. The area's final option for producing solar energy is these facades.

## 5.7. District as a system

District energy systems provide residential and business customers with heating and cooling that is produced centrally and delivered (often through underground piping). The heat is frequently produced by a cogeneration facility using fossil fuels. Renewable energy sources including biomass, geothermal heating, and central solar heating are increasingly used as the main energy source in plants.(Dragoon 2017) On the selected district, district heating as a form of energy recycling was explained.

A supply of both hot and cold utilities is necessary to maintain the vital energy balance in structures or building complexes. Local boilers, freezers, and air conditioners can create these utilities. In these circumstances, the Process Integration approach possibilities are constrained to those mentioned in the preceding section. The supply of utilities, such as steam, hot water, or chilled water, can be given through a centralized distribution network in metropolitan regions such as Lingotto when buildings of various types are located close to one another. The most energy-efficient method of distributing utilities in densely populated places today, district energy systems, enable this. There is no need for individual buildings to have their own boilers, furnaces, chillers, or air conditioners when they are served by a DE system. The advantages of DE systems include: (Kapustenko and Arsenyeva 2013)

- Enhanced environmental protection: Less $SO_2$, $CO_2$, and other emissions are released into the environment when less energy is utilized.
- Flexibility in fuel.
- Simple operation and maintenance.
- Convenience and comfort.
- Lower initial construction costs.
- More adaptability in architectural design.

The areas where district energy systems are installed benefit greatly from having them there. The location where these systems are implemented, in particular, gains the most from them in terms of residents, companies, and clients. Customers gain from having a reliable energy supply in addition to the advantages for other members of the community. Due to the variety of subsystems included in district energy systems, numerous industries work with these systems. Depending on the system that will be implemented, several energy sources may be used in these systems. Because of this, industrial businesses can work on various district energy systems in the same area. By implementing numerous cost and performance improvements with various energy sources inside the energy system, these industrial collaborations can make money. In addition, by collecting a source like hydrogen, they can use these energy systems to obtain more sources of energy. Systems with personal heating and cooling require more maintenance and capital investment than systems with district energy. In terms of security, district energy systems hardly ever have issues. District energy systems provide for the affordable provision of additional heating and in some cases cooling to customers.

The popularity of these systems is largely due to their low operating and maintenance expenses. These systems are recommended because they perform better than the individual systems do at the same time. Furthermore, district energy systems free up nearly 80% of the space that would be devoted to individual customer systems. This creates a new space for various applications that may generate cash for users. These systems can also be expanded with additional backup capacity to continually satisfy customer requests. This backup capability makes it possible to accommodate circumstances like seasonal fluctuations and rising need levels. District energy systems provide more reliability since production occurs centrally. These advantages may make district energy systems more appealing than standalone systems. (Dincer and Ozturk 2021)

# Chapter 6: Conclusion

To summarize, the goal of this research was to illustrate methods for energy reduction in an existing area. The investigation began by determining Turin's climate and the bioclimatic methods used before the technological advancement. These techniques aided in our comprehension of the passive techniques employed in the building's design. Then, two Turin neighborhoods were examined and evaluated in terms of their shapes and orientations, exposure to the sun and wind, functions, and most crucially, heating. The bioclimatic methods are demonstrated by one district, which is historically significant (San Salvario). The dominant source of $CO_2$ emissions which is heating in this region from the built environment was identified after an analysis of the existing energy requirements of various industries and their primary energy sources. After comparing the key four previously mentioned elements, the main challenges in the Lingotto district were then determined. The reasons why certain buildings have higher than necessary energy demands. Finally, strategies and the application of suitable technology were discussed.

This study outlined one strategy among many, based on a variety of criteria, for an energy-conscious district. This is a step in the direction of a city with lower energy needs, fewer $CO_2$ emissions from the built environment, and an ultimately more sustainable city. A district is considered to be a zero-energy district when every building within it works together. The community as a whole function at its best in terms of energy efficiency thanks to their communication. By maximizing the performance of several buildings as opposed to just one, it is much simpler to attain greater energy efficiency.

## 6.1. Answer to thesis questions

At the starting point the research began by three main questions which can be referred to by the results acquired from the analysis.

- **What makes a single building part of a system in a district?**

As we discussed before, each building block can have a good or negative impact on the buildings around it based on its size, form, orientation, and function. The district functions as a unit rather than a collection of buildings that are close to one another when each structure contributes to and communicates with the others in the area. A building's contribution to and communication with its neighboring structures is what defines it as part of a district. Based on the function and heating requirements, this was demonstrated in this study, included in a heating cycle.

- **How can buildings communicate and work as a system in a district to reduce the energy demands?**

The first step in addressing this question is to understand how the energy requirements of each building are influenced by those of its nearby structures; it is crucial to comprehend the purposes and heating requirements of various structures. In this study, a method for contributing building blocks to energy recycling was introduced. This method showed how heated water enters a cycle among many buildings based on building functions and heating demands, and as it cools down flows towards the buildings with less heating needs, continuing the cycle. Since the primary energy is used only once among several buildings rather than several times for each individual structure, this strategy can greatly minimize the primary energy requirements for heating in a zone or district. This strategy demonstrates a very effective method of communication between buildings in an area or district and how it might function as a system towards energy recycling.

- **How can we transform an existing district to a more energy conscious district?**

There is no one permanent definition for a net zero energy district as it can be defined in a variety of ways, and several strategies can be used to create one. However, an energy-conscious district is one that is working as a system to reduce energy requirements for a more sustainable urban environment. This study showed how energy reduction in the district might be followed by energy production based on the orientation and design of the buildings. The study was conducted in a neighborhood of existing homes in Turin, next to the Fiat factory, where a large number of machines are in use and ready for energy recycling. This was one technology among many to transform a district to a more energy conscious district.

## 6.2. Future perspective

### 6.2.1. Further design proposals

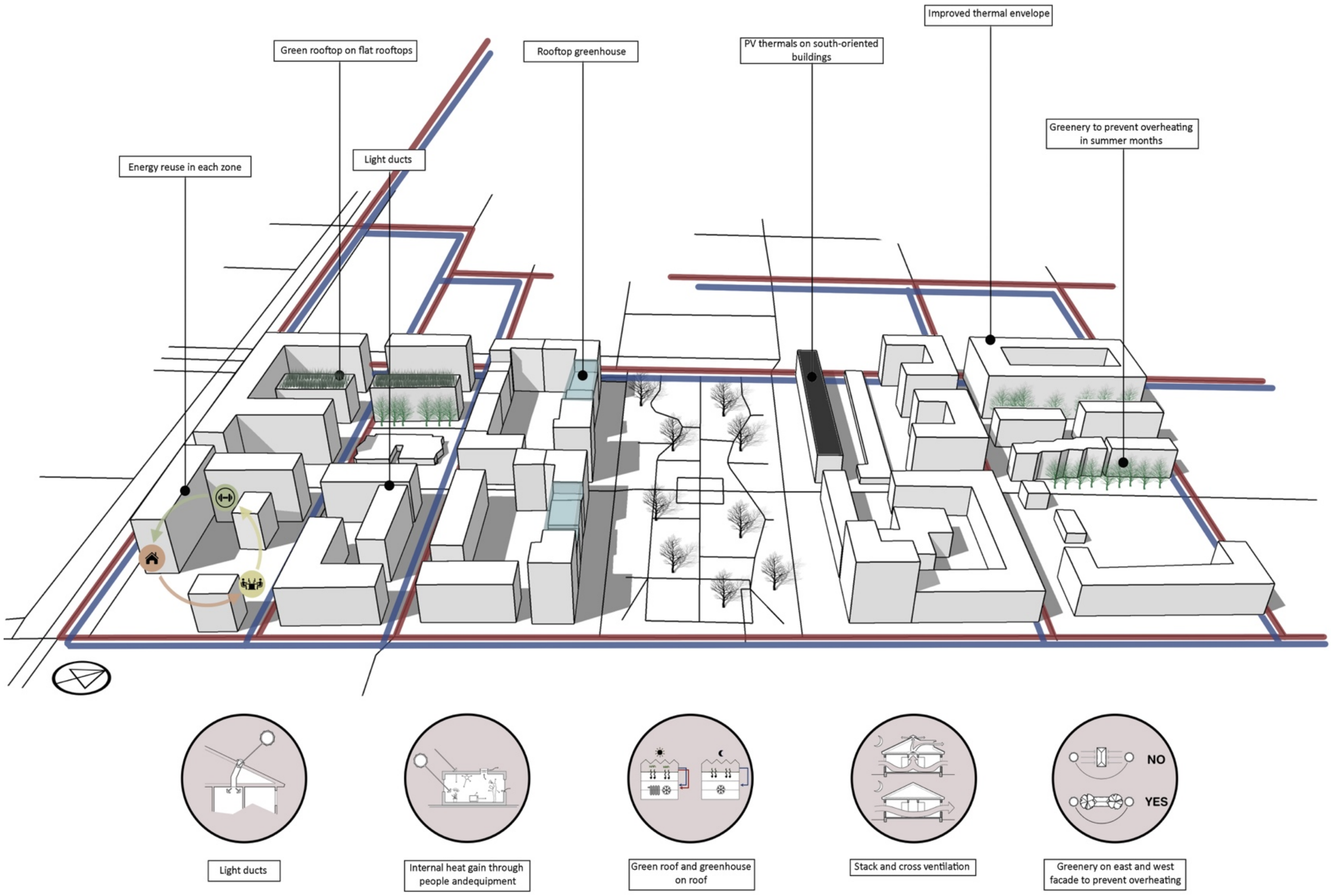



*Figure 57: Overall design elements (provided by the author)*

As it was discussed the heterogeneity of this district can be observed in the illustration above. In response to that, some of other design elements that can be mentioned are demonstrated. The other design elements that are beneficial to the individual buildings based the analyzed problems are as follows:

- **Light ducts**: A number of buildings in the district were overshadowed by taller buildings located on their south. Without demolishing this problem is difficult to be faced. One solution that can provide lighting to those apartments is using light ducts.

- **Internal heat gain**: People and equipment can help reducing the heating needs in the interior spaces if the building is well insulated as it was explained in the section of thermal envelope.

- **Green house rooftop**: This design element is proposed mostly to the heterogenous buildings facing the piazza (fig. 27). This can bring an aesthetically pleasant look and harmony to these buildings. Furthermore, for greater efficiency, greenhouses can be included into HVAC systems of buildings.

- **Natural ventilation**: Due to the density of the district, natural ventilation was not identified as an issue, however using stack ventilation as well as cross ventilation during summer months can increase the level of comfort in indoor spaces.

- **Greenery**: Use of vegetation on the east and west sides of east-facing buildings can help prevent overheating during the summer since the building is receiving sunlight at lower angles, and it is advantageous to have sunshine during the winter because the trees are leafless and make it possible.

### 6.2.2. Future research

The first version of the district energy system, called district heating, was a heat supply system. These types of systems have been utilized in Europe since the thirteenth century, and they may be traced back to the well-known hot water-heated baths and greenhouses of ancient Rome. Instead of just one building in the neighborhood, a district heating system distributes hot water to several of them, returning cold water to the primary power plant in the process. However, there is a hierarchy for energy recycling among the structures that get heating based on their purposes and heating requirements. Further reducing the district's energy requirements is made possible by this type of energy cascading.

This implementation varies in different areas in the city with different functions. The likelihood of implementing of this system must be investigated for the following steps, and the amount of energy loss during the transformation of water or any liquid used for heating between buildings must be taken into account in order to determine the appropriate function that will be receiving the heating after the heat loss. The quantitative research examination of this strategy is recommended for the future. This will make it easier to comprehend how this technology works and determine whether the chosen district will experience a substantial enough energy decrease.

Another future prospect that needs to be taken into account is the future research on the economic aspects of the implementation of this technology on an existing district. The upfront expenses of putting these technologies into place and its place in life cycle costing, should also be taken into account. It will be compared to energy savings in order to establish the long-term energy expenses and the cost-effectiveness of this approach.

Eventually as for a performance indicator, LEED rating system can be taken into account. A framework for eco-friendly, cost-effective, efficient, and healthy buildings is provided by them. The completion of environmental goals and leadership are denoted by LEED certification, which is widely known. This rating system was created to solve environmental issues while meeting commercial demands. Leadership, creativity, environmental stewardship, and social responsibility are all displayed through certification.(“LEED v4: Neighborhood Development Guide | U.S. Green Building Council” n.d.)

Some of LEED certified projects in Turin mentioned in the report published by covenant of mayors in 2018 are as follows:

- Building of the "Intesa-Sanpaolo" tower, an office building that won numerous accolades, including the LEED PLATINUM certification.
- Building "Nuvola Lavazza," an office complex with meeting spaces that was certified LEED PLATINUM for achieving a high energy and environmental performance as specified by the protocol.

### 6.3. Research outcomes

#### 6.3.1. General outcomes

Having a district heating system has many advantages and recycling that heat can help further reduce the demand for primary energy. This system can be upgraded with more backup capacity to consistently suit the customer needs. Systems for district heating offer durability because production takes place centrally. Some of the main outcomes of above-mentioned system could be as follows:

- Having a single heating space spread out among several buildings frees up more room for architectural uses.
- Because the heating was only provided at one location, maintenance and servicing became quicker and simpler.
- More adaptability.
- There will be less spending both immediately and over the long run as a result in decrease of energy demands.
- Lower initial construction costs because only one heating location is required per zone or district.
- Lower energy requirements for heating by at least 50%
- A flexible energy sources
- A healthier environment because there are fewer $CO_2$ and $SO_2$ emissions as a result of using fewer fossil fuels.

### 6.3.1. Outcomes of Turin case study

In the analysis carried out in this research, some of the main design issues that can potentially lead to higher energy requirements were identified. East-west orientation, buildings overshadowing each other are the main ones to mention. The reason that these factors were considered issues were mostly due to the elimination of passive solar gain. Solar energy plays an important factor in passive house or net-zero energy design. It is very important in both the reduction of energy demand and production of electricity and providing domestic hot water, therefore, lack of it was addressed as an issue.

Lingotto district was constructed during the economical peak of Turin where a lot building was being constructed quickly to provide accommodation for workers in the industry. Attention to details were overlooked in this period. Demolishing residential buildings is not an optimal approach, however some technologies can help to make up for the above-mentioned problems.

District heating which covers more than 50% of city of Turin is a great way to reduce the primary energy demands for heating. In this research one step further than that was which is energy recycling was introduced in the district based on the existing functions. This method can help to further reduce the heating energy needs. Furthermore, some elements were proposed to further help the issues some buildings may be facing.

**In conclusion, because renovation may not be the most practical course of action, paying attention to details and design before the construction period, as well as using the proper technology, can enhance the building efficiency in the long run. A district should be thought of as a whole because the nearby buildings have a significant impact on one another and energy needs. This impact can be used to their advantage when the district acts as a system.**

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