Towards Nearly Zero Energy

URBAN SETTINGS IN THE MEDITERRANEAN CLIMATE

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FOREWORD

Annarita Ferrante's book, *Towards Nearly Zero Energy: Urban Settings in the Mediterranean Climate* is a remarkable scientific contribution. It is a complete and scientifically advanced work that successfully investigates the synergies, the relations, and the trade-offs between buildings and the surrounding urban built environment.

The tremendous increase of the urban population, combined with an unprecedented increase of the boundaries of our cities, has created significant energy, environmental, economic, and social problems that mandate an immediate solution. Particularly in Southern Europe, these problems have become very significant and have increased the stress level in our societies.

Through specific case studies, this book identifies problems and presents their major characteristics, but it mainly tries to offer practical solutions for immediate implementation. It presents very well organized studies that identify the mitigation and adaptation potential of major technologies for buildings, and all are presented in a very practical and accessible way.

The idea of zero-energy buildings in zero-energy settlements that Ferrante promotes is a very attractive one and without a doubt her ideas will be a major theme for the future of architecture. Furthermore, very few books and articles of such a practical nature are available in the international literature, which is something that makes this book unique.

Mat Santamouris

CHAPTER 1

The Framework of Urban Built Environments

1.1 INTRODUCTION

In some ways, nowadays the concept of green buildings belongs to the "history of architecture," as the first prototype solar houses and the first attempts to achieve zero heating date back to the 1950s (Hernandez and Kenny, 2010). Over the past several decades, energy-oriented innovations in building technology have emerged in many areas of the building construction sector (Brown and Vergragt, 2008).The latest projects are aimed at setting to zero the energy demand and the carbon emissions of new housing developments and even of a whole city. Working toward this goal is the well-known urban village BedZED, the Beddington Zero Emission Development, winner of the prestigious Energy Awards in Linz, Housing and Building category, Austria, 2002 (Dunster et al., 2009). Another well-known example is the first zero waste/zero carbon emission city designed by Norman Foster, in Abu Dhabi, Masdar City, where the urban development is designed as a huge, positive energy building complex, resulting in a self-sustaining, car-free, urban environment. Finally, a pilot city plan to set to zero the carbon emissions of the entire city of Copenhagen (The Climate Plan, City of Copenhagen, 2009) shows how to make this city the world's first carbon-neutral capital by 2025, by means of using biomass in power stations, erecting windmill parks, increasing reliance on geothermal power, and renovating the district heating network.

We may assume that at present, energy-saving technologies have been successfully developed, that energy-efficient building designs have been experienced and extensively publicized, and that we own a large set of best available technologies (BATs). In other words, we now possess the technical knowledge to design and construct zero-energy buildings and city as well. "Moreover, extensive monitoring of local, national, and international building stocks means we know more than ever before about the precise potential for improved energy performance" (Guy, 2006).

Towards Nearly Zero Energy
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Today, the concept of nearly zero energy building (nZEB) has gained great international attention. It represents the principal target of the next generation of buildings; in fact, building design construction and practices need to respond quickly to the mandatory nearly zero energy requirements for new construction within a few years (EU Directive on Energy Performance of Buildings, 2011; EU Communication, 2011a, 2011b).[1] The increasing interest in nZEBs, the recent European and national directives on energy performance of b (EPB), and more easily accessible BATs and renewable energy sources (RES) all seem to point to further exploitation of BATs and better penetration of RES into new building construction. However, current construction practices in the new housing sector show limited signs of change (Ferrante and Semprini, 2011). Furthermore, despite growing investments in RES technology (Bürer and Wüstenhagen, 2009), feed-in tariffs and, in general, policy incentives (Bulkeley, 2010), additional investments are needed to reduce carbon emissions and fossil fuel consumption.[2] "Needless to say, this is particularly challenging in a context of global economic slowdown such as the one the world is currently experiencing" (Masini and Menichetti, 2010).

This concern is particularly true within the Mediterranean areas, where mild winters and hot summer conditions, together with different – and more critical – social and economic factors determine a chronic resistance to the widespread penetration of nZEB principles in building construction practices. Here the observed growing interest in nZEB usually results in prototype models and experimental pilot studies whose real impact on building practices and construction is very limited. Furthermore, commercial and industrial interests by specific categories of landlords or private owners in green buildings has also caused the production of highly visible, fashion-oriented and contemporary buildings that are often located in the

[1] In the frame of the legislative plane, recently the European Parliament (Directive 2010/31/EU on the EPB), amending the previous 2002 EPB Directive, has approved a recast, proposing that by 31 December, 2020 all new buildings shall be nearly zero-energy consumption and will have to produce as much energy as they consume on-site. See also Task 40/Toward Zero Energy Solar Buildings, IEA SHC /ECBCS Project, Annex 52.

[2] The treaty issued by several NGOs calls for a doubling of market investments by 2012 and quadrupling by 2020 to attain the proposed carbon emission reduction targets (Meyer 2010). As reported by Guy (2006), according to the United Nations Environmental Programme (UNEP) there is still an "urgent need for the incorporation of EE issues to be included in urban planning and construction."

framework of superimposed, universal, and/or incremental master plans and radical urban operations (Charlseworth, 2006), whose real impact on current behavior and smaller building practices is, again, negligible (Brown and Vergragt, 2008).

In general, the majority of pilot models and constructions cited so far refer to newly conceived buildings and new development plans. Although new nZEB concepts and experiments might have been the first priority in the previous decade, in more recent years it has become widely acknowledged that renovating dwellings is the most significant opportunity to reduce global energy consumption and greenhouse emissions. In fact, while there was detailed research on and the implementation of new buildings designed to perform in a zero-energy world, it is important to remember that even if, going forward, we built all new zero-energy buildings, we would only make a very small contribution toward the reduction of energy consumption and emissions due to the energy-consuming tendencies of the existing building stock as a whole (Ravetz, 2008; Kelly, 2009). This is especially true in the European Union (EU), due to three main geo-political, concurrent factors:

First, the consolidated and historical characterization of the EU continent, where refurbishment represents the major need: three-quarters of the buildings standing today, including the residential stock, are expected to remain in use in 2050 and the demolition rate is about 0.1% per year. (Highly energy efficient new-build rates are approximately 1% additional per year [JWG, 2013]).

Second, the EU is facing a challenging economic crisis, with the construction and real estate sectors representing the worst affected market sectors and where energy efficient (EE) refurbishment is often indicated and supported as one of the potential solutions for the real estate/building construction crisis (Kaklauskas et al., 2011).

Finally, the EU faces uncertainties on energy imports. Since buildings represent 30% of the total energy consumption, the consequent gas and oil reduction in this sector could substantially contribute to reducing the EU's dependency on energy imports up to a hypothetical scenario of energy self-sufficiency for all the European countries.

In particular, the need to focus on saving energy in the building sector of the Mediterranean area is illustrated by a vast array of political, economic, and social factors. Globally, governments are called upon to reduce greenhouse gas (GHG) emissions. Worldwide, the Mediterranean region has the third largest growth in carbon emissions, especially in those countries that export oil, which make up 74% of the total emissions of the region.[3]

It is evident that the current challenge is to widen the nZEB technical knowledge in existing built environments, shifting the methodological and technical achievements on energy-efficiency from newly conceived buildings toward the rehabilitation of existing building stock (Ferrante, 2014), since the large amount of existing stock represents the biggest challenge and the larger potential in the reduction of energy demand and carbon emissions. This is urgent, and trial in fragile sectors like the social residential areas of the Mediterranean cities is imperative (Santamouris et al., 2007).

A systematic approach to retrofit buildings has been reported and discussed by Zhenjun et al. (2012) and Ferreira et al. (2013), and a specific set of tools for energy retrofit including economic cost-benefit models have been developed by Rysanek and Choudhary (2013) and by Kumbaroglu and Madlener (2012). Furthermore, studies, design proposals (Ferrante and Semprini, 2011), and measurements (Morelli et al., 2012) on building energy retrofitting have been investigated and discussed to achieve energy-saving tools and techniques toward nZEBs in existing buildings.

Despite the recent attention received by the topic from researchers and building market actors and notwithstanding the stress on the goal of reaching nZEBs within 2020, so far, only about 1.2% of Europe's existing buildings are renovated every year. In fact, buildings and the existing urban compound of modern cities still face a number of hurdles and bottlenecks to retrofit uptake:

First, there are high up-front costs, long payback times of retrofitting interventions, and a lack of access to available and affordable finance

[3] These countries include Algeria, Iran, Iraq, and Saudi Arabia. A growing awareness about the fact that fossil fuel resources are limited is emerging in these countries. In recent years, some of the previously net exporting countries became net importing countries. Also the (still) oil exporting countries will be facing with future problems to maintain high growth rates of energy supply. While in the past long-term power development plans have been focused on supplying more energy from more fossil-fuel burning power plants it is high time to redirect those investments to the supply of Green Energy and, more important, to increasing EE measures, thus increasing energy saving, and in parallel decrease rate of energy consumption. Relocating investments into sustainable energy production and consumption cannot only provide a cleaner and safer future but can actually reduce investments in energy infrastructure (MED-ENEC, 2015).

(economic barriers and financial barriers), all of which represent a major obstacle.[4]

Second, insufficient incentives and rigidity of current regulations, neither of which allow significant improvements in existing buildings nor give priority to deep energy renovation (legislative barriers), is another significant hurdle.[5]

Third, the delay of states and regions in producing strategies for building energy renovation threatens the adoption and application of measures

[4] The economic and financial barrier is indicated as the major obstacle also in MED-ENEC (2015). In this report are listed the following main subcauses in the framework of economics gaps limiting the energy retrofit uptake. They are: energy tariffs subsidized that distort the market and make investments look less attractive/not financially feasible; the absence of Green Finance guideline to incentivize commercial banks to lend to energy efficient investments (in the Mediterranean regions not all recommended technologies and the best available technologies (BAT) seem to be economical and financially feasible); the lack of public funds, public sector funds that very often are not properly targeted at the end-user; Public sector funds that, if and when available, often fail to leverage commercial lending; loans provided with no or little accompanying measures such as technical assistance; reluctant commercial banks in lending to EE because they do not understand the EE savings potential, so they do not assume EE investments considered to be high risks (with the consequent increase of interest rates) resulting in EE investments even less attractive; lack in staff capacity; lack of internal procedures, lack of cash-flow based lending procedures; high transaction costs also connected with the small size of investments; EE investments are considered to have high up-front costs, making pay-back periods long, and increase risk for investor. Finally, the report indicates that generally banks require high collateral, which can limit future investments.

[5] The obstacles in the legislative framework are also considered in the list of major barriers toward retrofit uptake (MED-ENEC, 2015). The following main sub-causes in the framework of legislative gaps limiting the energy retrofit uptake are listed: EE policies that do not formulate clear objectives and the connected weak enforcement of the policies; the policies that do not provide for clear priorities (no benchmarks such as standard labeling programs, EE building codes, certification systems to establish transparency. No standard energy auditing procedure, no standard energy auditor trainings, no certified graduation processes. No reporting standards on EE, no sufficient metering to document savings. Government support programs are developed but information not disseminated, leading to little or no demand); the absence of development of convincing implementing programs; the absence of government budget to kick start identified EE priorities; the absence or scarcity of reporting mechanism deployed; the weak capacity in the relevant authorities. One crucial observation in the MENA region is that the decision-making processes are very centralized, making a swift and locally adapted implementation difficult. The absence of a holistic approach is also indicated, for example there is a clear omission of cooperation between ministries and public authorities, while energy efficiency actions require different Ministries and authorities to cooperate between them and major stakeholders. In this context, the private fund and banking sector stakeholders are left out of consideration of energy efficiency although they are undoubtedly among the major facilitators of EE investments.

for EE as foreseen by article 4 of the Directive 29/2012/EU (Memberstate dependent legislative barrier).

Finally, other major bottlenecks for retrofit uptake are due to a general lack of awareness among final users (urban dwellers, tenants, owners, and house managers) and small enterprises operating in the building sector.[6]

By building on this backdrop, this book aims to contribute to the current debate on nZEB in the retrofitting of the built environment, pointing out the potential for major renovation in existing urban settings that has not been discussed so far. Using in-depth case study investigations in selected representative urban areas, the book seeks to answer the following questions:

- Is it technically feasible to achieve nZEB targets in existing urban buildings and compounds in Mediterranean cities?
- Which are the main barriers and constraints hindering the practical feasibility of retrofitting existing buildings toward nZEBs?
- How might we overcome those barriers?

1.2 URBAN ENVIRONMENTS AND ENERGY RELATED ISSUES

Cities are the "guilty victims" of energy demand pressures and climate change. On the one hand, cities are responsible for around 75% of energy consumption and 80% of greenhouse emissions, despite accounting for only

[6] The deployment of best practices, such as pilot projects or development of champions, is very often missing. Technical understanding of EE and its implication in practice is very limited among population in the Mediterranean regions; in the context of building construction/refurbishment, there are little skills to install, maintain, and monitor EE equipment and materials. There are not or not sufficient local equipment providers or production of EE material; no understanding of traditional (EE) materials and building techniques. Furthermore, in the frame of final users and inhabitants a number of barriers can be numbered. Among these barriers, difficulties are encountered in the quantification and appreciation of energy savings in individual equipment, and these are not easy to measure; lack in consumer awareness is another hurdle since benefits of saving are often not perceived as big, because each of the measures/appliances, when taken singularly, consume only a small amount of energy. This problem is exacerbated, as the information on EE equipment/material and its benefits are not readily available, which makes the information process burdensome and time-consuming. Finally, split incentives in decision-making processes represent a major barrier in the frame of home tenure: developers very often do not want to invest, because they are not directly the ones to save on energy, while tenants are not involved in the construction/renovation processes but are the ones that have to pay the energy bill at the end.

about half of the world's population (While, 2008). Cities have an extremely great impact on the environment, as they concentrate most of the population of the globe and most economic activity in sectors of building, transportation, and industry. Urban areas (especially in the warmer regions) often offer a very low climatic quality and therefore use large amounts of energy for air conditioning in summer. In general urban zones use even more electricity for lighting (Bitan, 1992).

Throughout the world, human beings are moving into cities (EU Report, 2010) and today more than two-thirds of the European population lives in urban areas (EU Report, 2011). With their concentration of population, cities consume resources disproportionately, contributing to the production of climate change (May et al., 2013). Urban growth has reached such a peak that bypasses, reversals, and new ways of development are needed.[7]

Conversely, cities are the victims of climate change. Phenomena such as the urban heat island (UHI) effect and its health consequences on urban dwellers, and the exposure of coastal areas and riverside cities to flooding and natural disasters represents the main threats in the Mediterranean region. Besides their energy and environmental needs, many cities in this specific region are now facing new and persistent problems of unemployment, poverty, and social exclusion. As a combined outcome of the labor market crisis on the one hand, and the functional or "Ford" city of the twentieth century on the other hand, much of the urban space is devalued[8] and an

[7] Some significant and alarming figures: the world population has grown from 2 to 6 billion, and soon will reach 7 billion, while the percentage of human beings living in cities has increased from 3% in 1800 to 14% in 1900 and is estimated to rise from the current 50% to 75% in 2050. The figure for Europe is still higher: 83% of the population are expected to live in cities by 2050 (EU Report, 2010). The average temperature on the Earth's surface has suffered an increase of +0.6% and is estimated to reach 1.5% by 2030. The progressive increase of global warming will specifically raise urban temperatures and heat island effect. Forecasts prepared by the Intergovernmental Panel for Climate Change indicate that, under reasonable assumption about future human activities (its mid-range "business-as-usual scenario"), concentrations of greenhouse gases will rise sufficiently over the next century to cause a world-wide rise in average temperature of between 1.5°C and 4°C.

[8] The urban space of the contemporary cities is often deteriorated, starting, for example, from the street level, where pedestrian paths and accessibility of buildings are often destroyed, either by closing all potential social/public attractiveness on ground level or by the infill of garages, causing a tunnel effect, which makes the streets unattractive and unsafe for pedestrians to pass.

increasing societal need for human recognition within depersonalized urban environments is emerging.[9]

The environmental question, as reflected in the issues of climate change, resource depletion, and loss of biodiversity, is nowadays arguably the foremost worldwide public concern, and urban planning, monitoring, and mitigation are essential parts of environmental and energy policy. The growing urbanization of the world population makes cities central players in the search for new approaches to environmental management.[10]

Thus cities, which use most of the environmental resources, are called upon to adopt programs in accordance with the concept of sustainability. The large, complex series of environmental dysfunctions produced by the urban-related use of resources is multifaceted: it produces effects at the local level, such as high energy consumption in the built environment, and air

[9] Redesigning energy technologies in the urban areas is certainly a major scientific challenge. However, succeeding in this endeavor requires more than getting the engineering right (Webler and Tuler, 2010). Thus, energy efficiency in urban settings is more than a technical problem. Recent studies have suggested that more focus should be placed on the social aspects at community level and that energy users should be engaged in their role of citizens. In fact, developing more sustainable consumption and production systems depend upon consumers' willingness to engage in "greener" and more collective behaviors (Peattie, 2010). In this frame, local urban communities have inimitable advantages in providing infrastructure for more sustainable consumption environment; in fact, different types of low-carbon communities as a context to reduce carbon intensity are emerging at different scales (Heiskanen et al., 2010). Existing literature (Mulugetta et al., 2010; Guy, 2006) stresses the need for a clear transfer from a technical/economically based urban theory to a human based and socio-technical urban vision to achieve a greener behavior in urban environment. Timid attempts in the sustainable "redesign" of urban places by locally based communities are arising in the spatial sphere of the urban street environments. In this context, it is important to recall that some of Europe's leading innovation nations have included user-driven or user-centered innovation as a way of providing innovative products and services that better correspond to user needs and therefore are more competitive. User-driven innovation (EU Communication, 2009) is closely associated with design, and involves tools and methodologies developed and used by designers. The re-designing of existing buildings by engaging final users is also occurring in different contexts of EU and worldwide.

[10] The need for rapid and concerted action on the global scale has been officially recognized by the international community in events like the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992. Agenda XXI, one of the agreements emanating from this conference, addressed the specific issue of climate change. This is a complex and controversial phenomenon related to the increase concentrations of naturally occurring greenhouse gases in the atmosphere due to human activities. These gases, which include carbon dioxide and methane, trap solar heat in the atmosphere, so warming up the surface of the planet. The main source of greenhouse gases is burning of fossil fuels, such as coal, oil, and gas for energy, very often in a rather inefficient way.

and water pollution at the urban microclimate, but it also produces regional and global effects, such as global warming.

1.2.1 Heat Island in Mediterranean Cities

It is largely demonstrated that the progressive increase of global warming will cause urban temperatures to rise, thus producing the heat island effect. This will have a tremendous impact. For example, after the Messina, Italy earthquake of 1908 (which caused about 83,000 deaths), the hot summer of 2003 with ~ 70,000 deaths, mostly in the cities, was the second heaviest natural disaster of the last 100 years in Europe.[11]

As reported by Santamouris (2001), countries in the Mediterranean region have recorded a huge increase in summer cooling demand, especially evident in urban areas. The effects of global warming are of concern for both the environment and for humans in the area.[12] Here, the average yearly air temperatures are expected to increase between 2.2 and 5.1°C

[11] As reported by Santamouris (2006), during the summer period, high ambient temperatures and heat waves cause dramatic problems to vulnerable populations living in overheated households. In France, the estimated death toll of the 2003 heat wave was about 15,000 deaths. According to the EuroSurveillance (2005), an estimated 22,080 excess deaths occurred in England and Wales, France, Italy, and Portugal during and immediately after the heatwaves of the summer of 2003. Additionally 6,595–8,648 excess deaths have been registered in Spain, of which approximately 54% occurred in Aug., and 1,400–2,200 even occurred in the Netherlands, of which an estimated 500 occurred during the heatwave of Jul. 31 to Aug. 13. In parallel, it is reported that approximately 1,250 heat-related deaths occurred in Belgium during the summer of 2003, almost 975 excess deaths during Jun.–Aug. in Switzerland, and 1,410 during the period Aug. 1–24 in Baden-Württemberg, Germany. Studies in Europe and the United States (Michelozzi et al., 1999; Michelozzi et al., 2005), show that the greatest excess in mortality was registered for people in low socioeconomic status, leaving in buildings with improper heat protection and ventilation.

[12] The Mediterranean climate is the less extensive of mesothermal climates, according to the 20th century geographical classification developed by German climatologist Wladimir Köppen (1846–1940), which continues to be the authoritative map of the world climates in use today. Currently, the upgraded version of Köppen classification uses six letters to divide the world into six major climate regions, based on average annual precipitation, average monthly precipitation, and average monthly temperature. As also reported, Köppen defined the Mediterranean climate (or Etesian climate) as the area where: (1) the mean temperature of the coldest month is between 3 and 18°C; (2) the summer season is generally dry and the rainfall amount of the wettest month is at least three times greater than that of the driest month; (3) the mean temperature of the warmest month is above 22°C; and (4) the mean annual rainfall amount (in mm) is higher than 20 times the mean annual temperature (in °Celsius). The first three conditions also refer to semiarid and arid regions adjacent to Mediterranean climate zones. Thus, the crucial difference between the Mediterranean and

(*Continued*)

(in summer between 2.7 and 6.4°C). On the northern side of the Mediterranean basin, the increase (to about 38°C) is likely to be most pronounced in winter. This is forecast to occur by 2100, although more recent research indicates that the time span may be even shorter (Hansen et al., 2007). The overall 2°C air temperature increase represents a critical limit beyond which dangerous climate changes could occur by 2030.[13] All climate forecasts also converge onto similar considerations for extreme events like the increase of the frequency, intensity, and duration of heat waves, and a clear drop in the number of rainfall days with a consequent increase in the length of the longest rainfall-free periods.

As a consequence of the heat balance, air temperatures in densely built urban areas are higher than the temperatures of the surrounding rural zones, which is known as the "heat island" (HI) phenomenon. The HI effect is due to many factors (Santamouris, 2001; Yamashita, 1996; Akbari, and Konopacki, 2005): the canyon geometry of cities, the thermal properties of certain materials that increase storage of sensible heat in the fabric of the city, the anthropogenic heat, and the urban greenhouse. Research studies on this subject usually refer to the "urban HI intensity", which is the maximum temperature difference between the city and the surrounding area (Santamouris, 2001).

Zinzi (2010) reports interesting data about the Mediterranean region, defining it as a "geographical complex entity" which consists of 23 seaside states with about 600 cities, 46,000 km of coastline, and more than 450 million inhabitants. This constitutes 7.2% of the world's population, 9% of

adjacent arid climate zones is the mean annual rainfall. The Mediterranean Sea contributes to the temperate warm climate, retaining heat in summer and releasing it in winter. The majority of the regions with Mediterranean climates have relatively mild winters and hot summers. However, winter and summer temperatures may vary greatly between different regions. In the case of winters, for instance, Lisbon experiences very mild temperatures in the winter, with frost and snow practically unknown, whereas Thessaloniki has colder winters with annual frosts and snowfall. As a further example, inland France is very different from the southern borders of Egypt or Libya. Nonetheless, many similarities can be found for a wide portion of countries bordering the basin: in almost all the coastline cities, the minimum yearly average temperature is within 5–10°C and the maximum is within 27–34°C, with the highest values being recorded in the Turkish coastline and Cyprus.

[13] These climatic conditions in the Mediterranean area would result in one additional month of summer and in a longer duration of tropical nights (namely temperatures always above 20°C). Another consequence is a decrease in rainfall of around 30% with respect to the actual average standards.

total energy supply, 10% of electricity consumption, and 8% of CO_2 emissions. According to Zinzi (2010), in this complex area, a first simple partition can be assessed on a socioeconomic basis: the north rim European states and the south and east rim states, with their transition economies.

The Mediterranean is widely recognized as the area of the world in which the call for sustainable development encompasses all main issues because: (1) it represents a fragile eco-region where development is already set back by environmental damage, and (2) it is an example of a common contrast between the developed northern part and the developing southern part.

The demographic trend in the Mediterranean region is quite alarming: the north rim population increased by 14% from 1975 to 2005, when the maximum expansion occurred and when it reached 190 million inhabitants. The south rim population has almost doubled in the same period, accounting now for more than 258 million people (Zinzi, 2010). The south rim trend appears to be critical in terms of environmental impact because all the issues are strictly related to the massive urban sprawl.

The urban population increased from 42% of the total to 62% in 2005. Another consequence of urban sprawl in several countries is that more than 20% of the population moved into major cities; the percentage increased to 26% in Turkey and more than 35% in countries such as Greece and Portugal. Percentages of more than 60% were recorded in smaller states where the population is concentrated in a few urban areas, such as Israel or Jordan. According to the trend, it is expected that another 70 million people will live in metropolitan areas by 2025, with about 90 million expected to dwell in the coastal urban settlements. Thus, the future of Mediterranean countries relies on the implementation of new development models based on a conscious integration of environmental, social, and economic issues.

As also reported by Zinzi (2010), a strong impact of the urban heat island is on energy use in buildings.[14] According to OECD/IEA (2007), the building sector, including both residential and nonresidential, is experiencing

[14] The outdoor air temperature increase has several implications at the level of energy consumption of buildings: (1) energy consumption increase for cooling the building; (2) increase of peak cooling demand and, as a consequence, chillers' size increase; (3) energy price increase; (4) less "granted" energy supply especially in crucial periods, as in summer heat waves; and (5) reduction in the efficacy of bio-climatic and passive cooling strategies, often based on night natural ventilation techniques, when the outdoor air temperature decreases and shows several degrees lower with respect to the indoor air.

an incremental trend in energy consumption, accounting for one-third of global end uses (the total rises to more than 50% when considering the sole electricity consumption). The relative electricity consumption increase was 2.3% in 2005 with respect to the year before, but the value for the building sector was 3.7%. A decisive role in this context is played by room air conditioners and cooling systems mainly used in dwellings, whose market is under a continuous positive trend (Zinzi, 2010), also considering additional increasing electricity consumption in the next few years, because of the growing energy demand of transition economies.

Global warming and urban heat island increase the ambient temperature and intensify the energy consumption for cooling purposes of buildings (Santamouris et al., 2015). In fact, the major impact of ambient temperature rise is related to the possible increase of the peak electricity demand that obliges power utilities to construct additional power plants and probably increase the cost of electricity supply. Furthermore, as illustrated by Santamouris and colleagues, the potential increase of electric energy consumption puts both the consumers and the electricity networks under stress. The review illustrates the results of 15 studies examining the impact of ambient temperature on total electricity consumption, showing how the penalty of ambient overheating is quite high and depends mainly on the characteristics of the building stock, the climate zone, the urban form, and the type of energy services provided. The potential increase of the electricity demand per degree of temperature rise varies between 0.5% and 8.5%. In particular, for the case study of Athens, a percentage increase of the base electricity load per degree of temperature increase equal to 4.1% was found.[15]

1.2.2 The Case Study of the Athens Metropolitan Area (AMA)

The city of Athens represents a highly significant pilot study, both in the context of energy issues and for the ever-emerging problems of degraded urban environments.

The urban history of Athens in the last 170 years (1830–2000) is marked by expansion – its population grew from 9,000 inhabitants

[15] The potential increase of the peak electricity demand triggered by the ambient warming is also high (Santamouris et al., 2015). Existing studies show that the peak electricity demand increases from 0.45 to 4.6% per degree of ambient temperature rise. This corresponds to a penalty of about 21 (±10.4) W per degree of temperature rise per person.

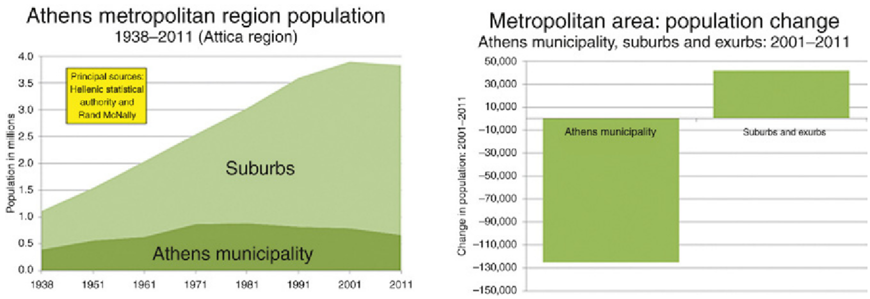

Figure 1.1 ***Athens growth population.*** *(Source: Wendell Cox,* The Evolving Urban Form: Athens; *Principal Source: Hellenic Statistical Authority & Rand McNally).*

in 1824[16] to 3.75 million in 2014 (considering the Athens Metropolitan Area, in the Attica region, with its 58 municipalities).[17]

The Athens city area is a metropolitan area (AMA) located at the south end of the Attica peninsula, on the Aegean Sea. Since 1951, suburban and exurban Athens has accounted for 95% of the growth in the metropolitan region, adding 2.2 million new residents, compared to approximately 100,000 for the Athens municipality (Wendell, 2013). Since 1971, all of the population growth has been in the suburbs and exurbs (Fig. 1.1).

Even with its current slow and (and sometimes negative) growth, the Athens urban area remains among the densest in the developed world (Figs. 1.1 and 1.2). This place, Athens is slightly ahead of London (15,300 per square mile or 5,900 per square kilometer), about double the density of Toronto or Los Angeles, and more than four times that of Portland.

From the administrative and urban point of view, the territory of Athens can be represented by a synergy of conurbations involving the historical town, the central area of the city, and the other 34 municipalities, for a total of 35 municipalities forming the prefecture of Athens. The monumental

[16] During the years of the Greek Revolution, Athens was a small city (in 1824 has 9000 inhabitants and occupies extension 116 hectares) destroyed and depopulated by war events. Nevertheless played an important ideological role in the symbolism of the birthplace of democracy and the source of Greek culture and civilization – values that have been adopted by the European Enlightenment and the Greek Revolution. Therefore, Athens as the capital would have the ideological authority to incarnate the center of the scattered Greek ethnicity.

[17] The 2013 edition of Demographia World Urban Areas indicates that the Athens urban area has a population of 3.5 million, living in a land area of 225 mi^2 (580 km^2), for a density of 15,600 per mi^2 (6000 per km^2).

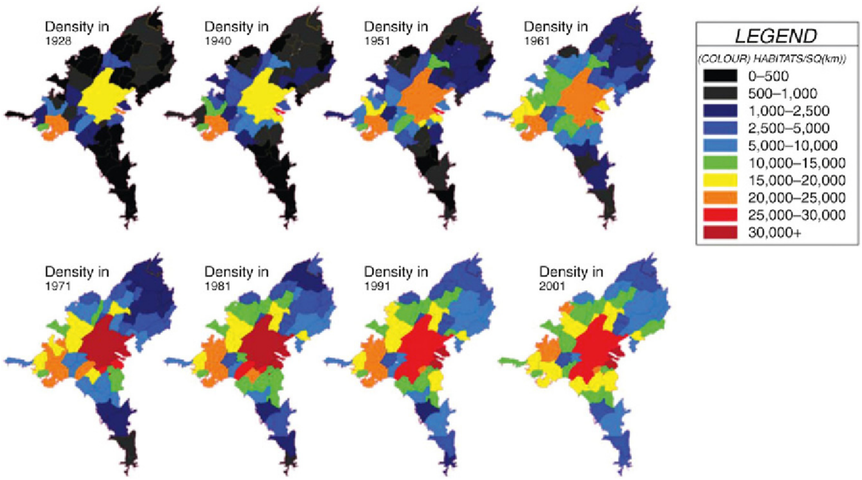

Figure 1.2 ***The evolution of urban density (in terms of inhabitants per square meters) in Athens by districts from 1971 to 2001.*** *(Source: http://en.wikipedia.org/wiki/File:Population_Density_in_Athens.PNG).*

urban structure of Athens dates back to the Otto period (1833–1864)[18], as the logical consequence of selecting Athens as the new capital. The plan is a clear response to the ideological role that a capital city plays. The monumental and hierarchical structure has, as a main reference, the Acropolis, a

[18] Otto and the Bavarian power installed in Nafplion in January 1833. That period it is developed a very keen competition and skepticism among various cities for the establishment of the capital of the state. Since 1831, the architects Kleanthis and Schaubert, old students of Schinkel, begin to prepare a plan for a new city capital in the region of Athens. The ideological acceptance of the state as it is necessary the existence of the project and new standards. The design of architects Kleanthis and Schaubert, one the most advanced for its time, proposed a combination of rectangular grid and radial connections of central spots and large open spaces and marked with its basic choices the center of Athens. In terms of technical design, it is one of the best examples of the era. The area of the project occupies a total of 300 hectares. The plan was submitted to King Otto in late 1832 and adopted in Jul. 1833, while at the same time, the decision was made to transfer the seat of government from Nafplio to Athens. The decision on the establishment of the capital in Athens ended a long-term uncertainty. However, it marked the beginning of a literally chaotic situation on the city plan, because, from the start and beyond any doubt, it appeared that the financial and technical resources to implement the plan were minimal. The successive modifications of the plan, however, changes the projected position of public buildings and especially the palace, the large decrease (to full elimination in practice) of the area reserved for excavations can be attributed in interests on speculation in land, of Athenians and foreign owners of land. These interests were the ones that intertwined with the aims of political parties and the disputes between the state and the municipality and the lack of resources finally led to inactivity on the project and the majority of the original structure, except for the layout of the main axes of the historic triangle – Panepistimiou Avenue and Pireos streets, Ermou and Athena streets – (May, 1929; Biris 1995) that remains in the urban form of the city today.

symbol of the ideological prestige of Athens, and the Old Royal Palace. The position of the ministries surrounding the palace expresses the nature of the new administrative and political power.

As in many other cities, in Athens the trend toward eradicating the suburbs started early, in the period between 1864 and 1909,[19] and was fully eradicated later in the 1970s. The plans for the suburbs from the beginning of the last century are anarchy plots, with no emphasis on urban design or organized public space. Thus, the expansion of the city through suburbs occurred since 1900 (Sarigiannis, 2000); at that time Athens had already acquired one of the urban characteristics that distinguishes the city even now – mismatched large areas in relation to its population size, with extreme (from low to high) density variation and a considerable urban sprawl, where the interests of small and medium property holders almost[20] determine the entire processes of expansion (Asteriadi, 2011).

A nonsolid, but very rapid growth of the manufacturing sector and the consequent rapid expansion of the city occurred again in the period

[19] During this period, until the rise to power of Venizelos and World War I, the growth in industry formalized the role of Athens and Piraeus as the dominant economic pole of the country. Athens gets stronger, with the construction of railways and roads that connect the new capital with Peloponnese and Thessaly and the opening of the Isthmus of Corinth, promoting the capital as the new economic center of the country. Athens' industry was concentrated mainly west of Keramikos area, where the gas and the silk factory are established, from which respective regions took their names (Gazi and Metaksourgio area) and in the north of the port of Piraeus. During that time, there was not a proper study for organizing the overall structure of the city. The pre-existing plan for the center of Athens, after the constant changes and slight extensions to Klenze's plan, had more than 173 amendments, which concern mostly roads narrowing or elimination of public free areas (Biris, 1995). Typical design proposals of that period are the extensions of the existing urban design, with the suburbs been designed without connection to the city, approved ad hoc. It is indicative the situation of the suburb Kato Patissia, closing the Avenue September 3rd, despite the fact that this was planned to be one of the main arteries of the town (this "closing" remained a major obstacle to the urban tissue of Athens until now). In 1907, the population of Athens exceeds the 260,000 inhabitants (Biris, 1995; Mantouvalou, 1988).

[20] However, it is important also to remember another important aspect of the period, which refers to the modernization and role of the state: to restore the capital's connections with the territory, the urban transportation and infrastructure networks (train, gas, electricity, water) is developed, in parallel to the western metropolises' similar construction. But again, it is indicative that even within this context, because of the discussions and oppositions of the main stakeholders of the time with respect to construct roads able to solve the congestion of the central part of the city brought to the result that such infrastructures were never performed.

between the two World Wars,[21] contributing once more to the fragmentation and real estate development of large areas of suburban land without a plan and with scarce forecasting of possible integration with the existing fabric of the city.[22]

The same tendencies continued after the Second World War and even until the present time. However, a dramatic element seems to define the evolution of the urban design space in the Athens Metropolitan Area: a contradictory relationship with respect to the historical time, characterized by the fact that while there is an ideal fascination of and desire to continue an unbroken continuity of Hellenism, the actual urban path is marked by consecutive shocks and discontinuities. The construction of buildings of the 1950s and 1960s, built by entrepreneurs and manufacturers, with the method of payment, sometimes illegally constructed without even an architect's study, turned Athens into an unidentifiable European capital.

The densification trend sped up in the 1980s, and continued at the periphery. Throughout this period, many urban plans were drafted for

[21] The large international financial crisis was combined with the installation of 1,220,000 refugees in Greece. The war period (Balkan, World War I, the Asia Minor campaign), intensified the severity of the problem in Athens compared with other cities of the country, not only in terms of the population but also from an economic and political point of view. The crisis of housing in Athens is acute, while the economic crisis and high inflation block the possibility of housing construction. Rent controls that were imposed in 1916 resulted in the total suspension of all the construction activity. Thus, the addition of 246,000 refugees in Athens comes at a time when there is already a very acute housing shortage (Travlos and Kokkos, 1977; Vergopoulos, 1978).

[22] Illegal construction intensified with the tolerance of the state in the hope that it would help to defuse the housing demand. During this period of illegal widespread construction, further legislative tools were developed for economic cooperatives. In this context, it is worth mentioning that there are some cases where local plans were studied and applied. It is the case of some of the social housing program for the accommodation of refugees. The houses that were built were very few in relation to the number needed. A very large percentage of the refugees were living in huts, constructed by themselves or by people that were interested when there was an available plot from the state. The construction of some urban compounds in different parts of Athens took place (building block settlements for refugees in places like Kaisariani, Dourgouti, Kokkinia, Aghios Dimitrios, Agia Varvara, Peristeri, etc.). These were erected and positioned in urban plots according to the experimental modernist principles implemented in Germany, in particular by Walter Gropius. Besides the suburbs mentioned before, there are some suburbs for the middle class that have been developed as private businesses (Psychiko, Ekali Filothei, Ilioupoli) and are designed as model garden cities, after similar suburbs in Europe (central, round, large open spaces, radial arrangement, gardens).

the overall organization of the city. Alongside these projects, a new urban legislation was revised, often going hand in hand with the urban development of the western countries of Europe.

The city has expanded without following a harmonic overall plan and the organization is considered problematic and very far from the desired European patterns. Typical modern houses characterize the current aspect of the capital. Apartment buildings built both in the center and the periphery took the place of the architectural valuable neoclassical houses (Travlos and Kokkos, 1977).

Nonetheless, Athens appears to retain potential in terms of the ability to rethink its development and rebound.

Surveying the urban planning history of Athens, we encounter the traces of multiple forces; these forces have sometimes amplified and sometimes canceled out one another. The attempts at organized construction, the production of surplus value, the institutional and political shifts, the social reception of issues relating to the city's cultural heritage and environment, the natural disasters, and the influxes of immigrant and refugee populations have all fed into the ever-changing urban landscape.

Ultimately, the cityscape is the face of Athenian society, which is why the history of the formation of Athens' urban fabric has so much to tell us about Greek society as a whole.

The 20th century brought separation and dispersal of buildings to an extent unparalleled in city history. Aerial photos and ground observation confirm this unambiguously – the sharp contrast of built form between the old "city" and its newer additions is inescapable (Grammenos, 2011). However, the 20th century also ushered a new form of agglutinated settlement, the vertical block, which can equal several earlier horizontal blocks in habitable space and thus dramatically increase the potential for the concentration of people.

To classify the different densities encountered in the Athens metropolitan area (AMA), a preliminary survey of the different urban districts has been conducted by visiting, observing, and analyzing the different areas and suburbs in the Attica region. The ethnographic observation has shown that different densities and different urban textures and morphologies shape the urban contexts of Attica. Obviously, they are also characterized by different climatic data, orientation, and so forth at the urban scale, but the territorial morphological asset of the natural boundary conditions around the Athens metropolitan area is the main cause of the different climatic conditions within the different parts of the city, as it will be shown in the next section.

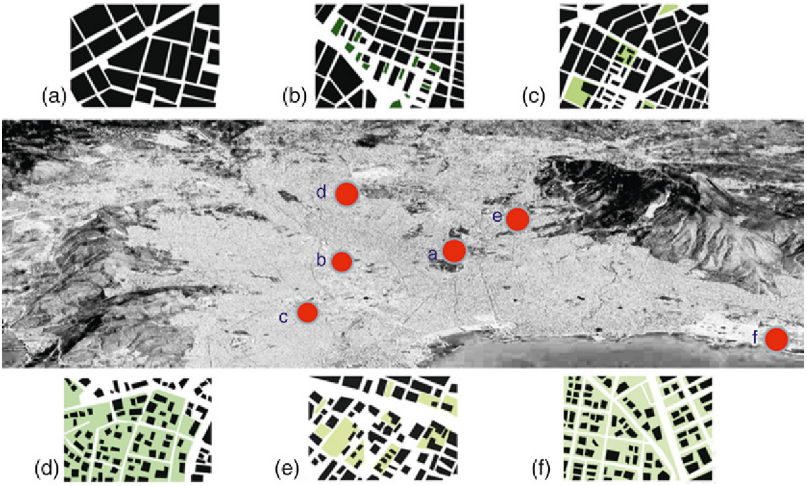

Figure 1.3 ***Main urban textures in the Athens metropolitan area.***

In this preliminary classification, six main areas have been selected to explicate different urban textures and morphologies in the north, south, center, east, and west areas of the AMA. Fig. 1.3 depicts a scheme of the typical urban textures in the AMA, ranging from very dense (a,b) down to suburban (c,d) and peripheral (e,f).

1.2.2.1 The Urban Heat Island in the AMA

In the context of heat island research, the city of Athens represents a highly significant pilot study. Here, increasing urbanization and deficiencies in development control in the urban environment have important consequences on the thermal degradation of urban climate and the environmental efficiency of buildings in the AMA (Cartalis et al., 2001; Hassid et al., 2000). As a consequence of heat balance, air temperatures in densely built urban areas of Athens are higher than the temperatures of the surrounding rural zones.

In Athens, the UHI is the foremost threatening issue affecting the energy demand and the comfort conditions in the built environment. But the Athens climate also presents a significant heating demand in the winter period, as will be illustrated in Chapter 2, when we will consider the total energy demand of selected representative areas. In this context, it is important to recognize that although Athens has winter temperatures that are milder than the freezing winters of Northern Europe, it still has a significant heating demand in its winter season.[23] January is, on average, the coldest month, with usual temperatures around 10°C (50°F), while the average low temperature is 7°C (45°F), and the average high temperature is 13°C (55°F). The lowest ever recorded temperature in Athens in January is −2°C (28°F), while the highest ever recorded temperature is 21°C (70°F). As a combined result of the recent economic crises and energy demands in winter, much of the low-income population has been found to be unable to cover their housing energy needs. Hence, these people live in temperature conditions that are well outside established comfort limits[24] (Santamouris et al., 2014). Therefore, Athens must be considered as a highly representative case study for energy demand conditions, ranging from significant heating needs and high cooling demand in the winter and summer seasons, respectively.

Data compiled by Ferrante (1998) and surveys performed in Athens on the HI intensity, involving more than 30 urban stations, show that during hot summer seasons, urban stations present temperatures that are significantly higher than the ones recorded in the comparable suburban stations (the gap varies from 5 to 15°C). As a consequence, the cooling load of reference buildings in the city center is about twice the value of equivalent buildings in rural areas. Previous research developed within the frame of the research project POLIS in Athens (Ferrante et al., 1998) has shown some appropriate procedures to design the use of natural components – such as green roofs and pedestrian permeable surfaces – within urban canyons.[25] The design of outdoor spaces – even if reduced to the envelope of the buildings because of existing urban constraints within thickly-built urban areas – as well as the use of natural components have been regarded as key means to improving

[23] Athens has a subtropical Mediterranean climate (according to the Köppen classification) since it receives just enough annual precipitation to avoid Köppen's semiarid climate classification. The dominant feature of Athens' climate is alternation between prolonged hot and dry summers and mild winters with moderate rainfall. In fact, rainfall occurs largely between the months of October and April (average of 414.1 mm of yearly precipitation has been registered. July and August are the driest months, where thunderstorms occur sparsely, about once or twice a month. Winters are mild and rainy, with a January average of 8.9°C (48.0°F). Snowstorms in Athens are generally infrequent (though more frequent in the northern suburbs of the city) and can cause disruption when they occur.

[24] For the whole period of the study (Santamouris et al., 2014), climatic data on the outdoor environment were provided by the National Observatory of Athens. The minimum temperatures were recorded during January 2013, (0.9°C), while the corresponding minimum for December was 5.6°C. The average temperatures for December and January were 11.1°C and 10.5°C, respectively.

[25] They are briefly illustrated in Chapter 2 of this book (Mitigations on Urban Canyons in Athens).

urban conditions in relation to both microclimate and reduction of pollutants. By "making-up" the building's surfaces and elevation facades with green components or shading devices, four different scenarios have been proposed in four different urban canyons in downtown Athens. Experimental software research models have been used to quantify the positive effects of these selected passive techniques. Obtained results clearly indicated that outer surfaces' alternative design acts as prior microclimate modifier and deeply improves outdoor air climate and quality (up to two-thirds °C reduction in ambient temperature) (Santamouris, 2001). In Chapter 2, results of these studies are reported with more detailed information.

Other significant physical factors in the thermal performance of urban environments are wind flows and air circulation (Santamouris et al., 1999), (Ricciardelli and Polimeno, 2006) as well as air stratification within urban canyons and open areas. It is clear that the heat island effect and the microclimatic conditions typical of open urban canyons appear to be strongly influenced by thermal properties of the materials and components used in the buildings and on the streets (Bitan, 1992; Buttstädt et al., 2010). The comparative research carried out by GRBES, the Research Group on Buildings Energy and Environmental Studies at the University of Athens, demonstrated that the use of cool-colored materials (Synnefa et al., 2007) and thermochromic building coatings can contribute to energy savings in buildings, providing a thermally comfortable indoor environment and improved urban microclimatic conditions (Karlessi et al., 2009).

Thus, morphological and spatial geometry of the urban textures, as well as the thermal properties of surface coatings and green surfaces have a strong potential on the energy performance and cooling demand reduction in urban settings.

Athens is subject to a strong and predominant "heat island" effect with seasonal temperatures rising 5–7°C, especially concentrated in the higher densely populated areas of the city center. Here, the moderate sized buildings of the suburbs have been progressively substituted by prominent structures, both considerably high and massive, generally squat and heavy, with a reciprocal proximity that alters the winds' flow and further increases soil sealing and heat accumulation. While mitigating the winter cold season, the morphological configurations of the central Athens area lead to a drastic climate change during the hot summer period, generating extreme high temperatures and consequently hazardous health conditions. Of course, this effect also undermines the energy use; in particular, it negatively affects the cooling need and the same performance of the cooling systems since in the maximum temperatures, the air conditioning systems' performance may decrease up to a quarter compared to the average seasonal efficiency.

As reported by Founda (2011), the urbanization of Athens and its effect on the temporal variation of air temperature have been stressed by many researchers, even in very early studies concerning climatic changes of the city. Most studies carried out up until the late 1980s identified the UHI effect on the minimum rather than on the maximum temperature (Katsoulis and Theoharatos, 1985; Katsoulis, 1987). The UHI is reported to be more pronounced in winter and is related to the heat produced by human and anthropogenic activities, especially in the evening hours, whereas mean and maximum temperatures are supposed to be less affected by the urban effect due to the influence of the sea breeze (Katsoulis, 1987). In more recent studies, however, it has been reported that the UHI effect is manifested mainly in the daily maximum temperature, which has increased significantly during the summer since the mid-1970s (eg, Philandras et al., 1999; Founda et al., 2009; Mihalakakou et al., 2004).

Climatic measurements from almost 30 urban and suburban stations as well as specific measurements performed in 10 urban canyons in Athens, Greece, have been used to assess the impact of the urban climate on the energy consumption of buildings (Santamouris, 2001). It is found that for the city of Athens, where the UHI intensity exceeds 10°C, the cooling load of urban buildings may be doubled and the peak electricity load for cooling purposes may be tripled, especially for higher set-point temperatures, while the minimum coefficient of performance (COP) value of air conditioners may be decreased up to 25% because of the higher ambient temperatures. Regarding the potential of natural ventilation techniques when applied to buildings located in urban canyons, it is found that, mainly during the day, this is seriously reduced because of the important decrease of the wind speed inside the canyon. Air flow reduction may be up to 10 times the flow that corresponds to undisturbed ambient wind conditions. Thus the UHI in Athens was found to have a stronger effect on the daily maximum summer temperature (up to 10–15°C for urban and rural/suburban regions); (Santamouris, 2001; Santamouris, 2007, Livada et al., 2002).

Using an ensemble of regional climatic scenarios, Founda and Giannakopoulos (2009) have illustrated that, by the end of the century, maximum and minimum summer air temperatures in Athens are expected to increase by approximately 4°C with respect to 1961–1990. It is also reported that the exceptionally hot summer of 2007 is likely to be the "normal summer" of the period 2071–2100.

Many are the studies, the measurements, and calculations in the AMA that confirmed the existence of a strong HI phenomenon (Mihalakakou et al., 2002; Mihalakakou et al., 2004; Santamouris et al., 1999). The association of the HI with synoptic climatic conditions has been identified (Livada et al., 2002) and the influence of the surface temperature and wind conditions have been analyzed in literature (Papanikolaou et al., 2008; Stathopoulou et al., 2009). In parallel, the impact of various mitigation techniques involving cool and reflective materials has been identified (Doulos et al., 2001; Karlessi et al., 2009; Santamouris, 2001, 2007, 2010). As already stated, all performed research studies on this subject – referring to the "urban HI intensity" as the maximum temperature difference between the city and the surrounding area – demonstrate that the AMA represents a highly significant pilot study: during hot summer seasons (corresponding to the HI upper limit), urban stations present temperatures significantly higher than the ones recorded in the comparable suburban stations (the gap varies from 5 to 15°C). Furthermore, a detailed statistical analysis of the HI characteristics and distribution in the greater Athens area has been carried out (Giannopoulou et al., 2011) using temperature data from 25 stations distributed on the city. Fig. 1.4 reports the location of the meteorological stations used this study.

The presence of the mountains Egaleo at the western part and Parnitha at the northern part and also of the mountains Penteli and Hymettus at the northern and eastern parts, respectively, act as the major natural obstacles at the territorial scale, since it is a barrier against the north winds which dominate during the summer period at the Athens area (Etesian winds). In the analysis, it is concluded that the higher air temperature values were found firstly at the western part, mainly due to the combined effect of industrialization and poor ventilation given by the territorial natural

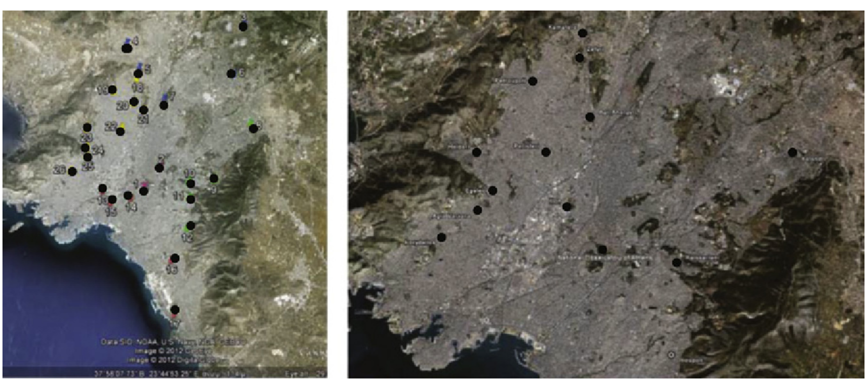

Figure 1.4 ***Location of meteorological stations.***

obstacles mentioned previously. Secondly, high temperature values have been found at the center of Athens, due to the traffic and anthropogenic heat as well as to the presence of continuous impermeable surfaces and densely built areas. Conversely, lower values were found at the northern and the eastern parts of the greater Athens area (Tables 1.1 and 1.2). According

Table 1.1 Values of monthly maximum air temperature for all monitoring stations and mean diurnal and nocturnal temperature differences from the reference station located in the center of the city during June, July, and August

Area	Station	June	July	August
Center of the city	Athens Univ.	33.9 ± 2.65	35.1 ± 2.95	31.9 ± 196
Northern part	N. Erythrea	30.8 ± 2.79	32.4 ± 3.16	31.4 ± 2.63
	Ano Liossia	31.6 ± 2.97	33.8 ± 2.92	32.0 ± 2.10
	Kamatero	33.6 ± 2.61	35.3 ± 3.10	32.1 ± 2.17
	N. Philadelphia	30.0 + 2.35	32.6 ± 2.39	31.1 ± 1.52
	Maroussi	29.6 ± 2.47	32.0 ± 2.19	30.2 ± 1.48
	Mean	31.12 ± 2.980	33.23 ± 2.994	31.36 ± 2.114
Eastern part	Zografou	30.6 ± 2.54	32.4 ± 2.55	30.6 ± 1.78
	Kessariani	32.4 ± 2.99	33.8 ± 2.90	31.5 ± 2.33
	Ilioupooli	32.0 ± 2.47	34.0 ± 2.69	31.5 ± 1.73
	Byronas	32.7 ± 2.79	35.1 ± 2.71	33.5 ± 2.05
	Agia Paraskevi	28.1 ± 1.84	31.0 ± 2.03	30.7 ± 1.47
	Mean	31.17 ± 3.027	33.25 ± 2.930	31.57 ± 2.146
Southern part	Glyfada	29.5 ± 2.67	32.8 ± 2.11	32.6 ± 1.29
	Renti	31.7 + 3.82	35.9 ± 2.90	36.2 ± 1.82
	Elliniko	30.2 ± 3.57	34.6 ± 2.70	35.9 ± 1.58
	Kallithea	32.0 ± 3.61	35.0 ± 2.12	33.6 ± 1.63
	Mochato	32.9 ± 3.38	35.9 ± 1.85	34.5 ± 1.31
	Mean	31.27 ± 3.608	34.84 ± 2.606	34.57 ± 2.503
Western part	Korydallos	30.4 ± 2.41	33.1 ± 2.12	31.2 ± 1.58
	Agia Varvara	32.0 ± 2.76	34.1 ± 2.31	31.8 ± 1.79
	Haidari	33.1 ± 2.98	34.1 ± 2.55	33.0 ± 2.46
	Egaleo	31.1 ± 2.98	33.8 ± 2.35	32.5 ± 1.55
	Petroupoli	33.3 ± 3.25	36.9 ± 3.22	36.2 ± 1.89
	Peristeri	32.8 + 2 62	40.0 ± 4.36	40.6 ± 4.37
	Ilion	32.3 ± 3.02	34.5 ± 2.50	34.2 ± 2.93
	Agioi Anargyroi	32.5 ± 3.23	36.1 ± 2.03	34.7 ± 2.67
	Zefyri	31.6 ± 3.38	35.3 ± 2.82	35.0 ± 1.37
	Mean	32.13 ± 3.065	35.33 ± 3.391	34.37 ± 3.618

Source: Giannopoulou et al. (2011).

Table 1.2 Number of nighttime and daytime hours in which the air temperature exceeds 30°C

Area	Station	June (Day)	June (Night)	July (Day)	July (Night)	August (Day)	August (Night)
Center of the city	Athens Univ.	159	6	271	20	164	3
Northern part	N. Erythrea	93	0	161	1	99	0
	Ano Liossia	151	1	260	9	167	0
	Kamatero	216	1	294	13	195	1
	N. Philadelphia	86	2	227	13	154	0
	Maroussi	102	1	254	7	107	0
	Mean ± s.d.	129.4	1.0	239.2	8.6	144.4	0.2
Eastern part	Zografou	167	2	218	3	117	0
	Kessariani	147	2	265	9	142	0
	Ilioupooli	136	5	260	9	155	0
	Byronas	188	11	323	50	282	13
	Agia Paraskevi	31	1	173	15	130	1
	Mean ± s.d.	133.8	4.2	247.8	17.2	165.2	2.8
Southern part	Glyfada	66	0	239	13	213	3
	Renti	126	5	299	18	298	4
	Elliniko	92	0	277	3	287	0
	Kallithea	140	42	290	23	248	4
	Moschato	115	11	339	44	297	13
	Mean ± s.d.	107.8	11.6	288.8	20.2	268.6	4.8
Western part	Korydallos	118	5	305	28	177	4
	AgiaVarvara	183	6	327	38	197	6
	Haidari	167	8	295	19	198	3
	Egaleo	106	7	265	26	223	4
	Petroupoli	168	5	299	27	245	6
	Peristeri	210	6	349	24	322	0
	Ilion	174	1	311	13	259	0
	Agii Anargyri	168	1	334	17	301	0
	Zefyri	149	1	285	8	278	0
	Mean ± s.d.	160.3	4.4	307.8	21.2	244.4	2.6

Source: Giannopoulou et al. (2011).

with those results, it can be concluded that HI intensity presents its maximum concentration in the center and the western part of Athens area, with up to 5°C with respect to the minimum values.

Concerning the maximum daily air temperature values, it was found that the differences between the eastern and northern stations during June and July and also between the center of Athens and the western stations during July were not statistically significant. As observed, the northern and the eastern parts of the Athens area present a similar temperature regime as a result of the high percentage of green areas and the absence of an industrial zone. On the contrary, the center and the western part of Athens present a similar temperature regime due to the lack of green spaces, the densely built areas, and traffic.

The study of the mean maximum air temperature values for each month and for all the stations has concluded that during June, higher temperatures are recorded at the center of Athens and also at the western part, while during July and August, the higher temperatures are found at the southern and the western part of the greater Athens area. In this study, the distribution of the value of Humidex (H) has been estimated by means of statistical methods. Humidex values have been linked to the probability distribution of the conditions of discomfort ($H> 30$ $H> 40$), and the number of hours that the difficult conditions persist (see Table 1.3). From the study of those cases where $H > 40$, considering the air temperature, relative humidity, and wind speed, it appeared that great discomfort or dangerous discomfort conditions occur, with either very high air temperatures or lower air temperature values, in combination with high relative humidity values (Giannopoulou et al., 2014).

Four significant deductions have been drawn from performed measurements and consequent comparative results:

1. The geographical position of the Athens area and the morphological territorial assets of its boundary conditions characterized by the presence of the surrounding height of the mountains (which exceed 1000 m) contribute to the development of high summer air temperatures in the whole AMA.
2. High-air temperatures are also reinforced by the increased urbanization, industrialization, anthropogenic heat, and the lack of vegetation.
3. In particular, during July and August, the mean and maximum air temperatures at the city center and at the western part of the city are much higher than the corresponding values for the northern and northeastern part of the AMA.

Table 1.3 Monthly air temperatures and relative humidity in five geographical areas of Athens

	June		July		August	
Places	**T (°C)**	**RH (%)**	**T (°C)**	**RH (%)**	**T (°C)**	**RH (%)**
Center of the city	27.0 ± 3.7	40.6 ± 14.5	29.3 ± 3.4	43.8 ± 12.8	28.1 ± 2.9	42.3 ± 9.4
Northern part	26.4 ± 2.1	41.3 ± 12.9	28.5 ± 2.1	44.1 ± 14.1	27.3 ± 1.4	38.7 ± 11.6
Eastern part	26.8 ± 2.1	41.9 ± 11.2	29.0 ± 2.0	42.6 ± 11.6	27.7 ± 1.6	40.6 ± 8.5
Southern part	26.9 ± 2.5	48.0 ± 13.4	29.7 ± 1.7	44.4 ± 13.8	29.0 ± 1.3	39.2 ± 9.8
Western part	27.2 ± 2.3	41.6 ± 13.1	29.8 ± 2.0	40.9 ± 12.5	28.7 ± 1.5	39.2 ± 8.9

Source: Giannopoulou et al. (2014).

4. Furthermore, from the analysis of the mean diurnal and nocturnal air temperatures in all stations and from the difference between them and the reference station located at the center of Athens, it is possible to conclude that HI during the night period is mainly observed at the western part of the city.

Thus, the western Athens metropolitan area, together with central Athens, presents the highest HI intensity of the whole AMA (see Table 1.3).

1.2.3 Policy Background and Nearly Zero Energy Studies

Building on this background, it appears to be extremely difficult to show potential achievement of deep renovation up to nearly zero energy targets in the Athens area. The main question we introduced at the beginning of this chapter "Is it really feasible to technically achieve nZEB targets in existing urban buildings and compounds of Mediterranean cities?" sounds particularly challenging given the climatic and urban conditions described in the previous paragraph.

Before proceeding any further, it is essential to point out what nZEB is assumed to be in the current legislative framework, and briefly report some notes on its definition. In the following paragraph, some case studies – past and recent – are also briefly discussed to enable understanding about which lessons can be recovered. Finally, we present a brief discussion on how to widen the technical knowledge in nZEBs and achieve a deeper penetration in building practice.

1.2.3.1 On the Definition of Nearly Zero Energy Buildings

As introduced briefly at the beginning of this chapter, increased attention on nZEBs has led to the European Commission's proposal in November 2008 for an update of the 2002 *Energy Performance of Buildings Directive* (EPBD). Subsequently, a recast of the same directive was adopted by the European parliament and the Council of the European Union (European Council for an Energy Efficient Economy, updated February 2011), in order to strengthen the energy performance requirements in order to clarify and streamline some of its provisions. Among the highlights of the recast is a strengthening of the energy performance requirements of new buildings across the European Union. For new buildings, the recast fixes the year 2020 as the deadline for all new buildings to be "nearly zero energy" (sooner for public buildings – by the end of 2018) while, for existing buildings, member states are required to draw up national plans to increase the number of nZEBs, though no specific targets have been yet set. Article 2(1a) gives a qualitative definition of what a "nearly zero energy building" is: "A 'nearly zero energy building' is a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby." From this qualitative definition, a wide spectrum of additional specifications have been derived, as illustrated by various authors in literature. In particular, the definition has originated a widespread debate about the issues pertaining to terminology and definitions of buildings that consume very low or zero energy (or carbon), including those with net energy production or are, in other words, "energy positive."[26]

A list of related documents of support measures in accordance with Article 10 Directive, 2010/31/EU, have been developed by different countries (Denmark, France, Greece, Lithuania, Romania, etc.).[27] The subject matter of the directive is defined (Article 1) as the "Performance of buildings within the Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness." In particular, the directive lays down requirements as regards: (1) the common general framework for a methodology for calculating the integrated energy performance of buildings and building units; (2) the application of minimum requirements to the energy performance of new buildings and new building units; (3) the application of minimum requirements to the energy performance of: (a) existing buildings, building units and building elements that are subject to major renovation; (b) building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are retrofitted or replaced; and c) technical building systems whenever they are installed, replaced or upgraded; (4) national plans for increasing the number of nearly zero-energy buildings; (5) energy certification of buildings or building units; (6) regular inspection of heating and air-conditioning systems in buildings; and (7) independent control systems for energy performance certificates and inspection reports.

[26] Comprehensive review studies on the definitions of Zero Energy Buildings (ZEBs), including life cycle assessment (LCA) are reported by many authors (Hernandez and Kenny, 2010; Marszal et al., 2011). A list of related documents of support measures in accordance with Article 10 Directive 2010/31/EU, have been developed by different countries (Denmark, France, Greece, Lithuania, Romania, etc.).

[27] Some countries, like the United Kingdom, have already established comparable targets for all new housing, which will see "net-zero" achieved by 2016.

The directive also states that its requirements are minimum requirements and shall not prevent any member state from maintaining or introducing more stringent measures. These measures shall be compatible with the treaty on the functioning of the European Union and the commission must be notified about them.

As previously noticed, currently a wide range of terms and descriptions are used in discussions on low- and zero-energy buildings. The definition of an nZEB used by the Industry Committee during the negotiations on the recast has been replaced by the less stringent requirement "nearly zero energy building" as opposed to the original "net zero energy building"[28] in the final document adopted. In parallel with the variation of these definitio.ns with respect to the different challenging level of energy requirements, there is not a fully harmonized understanding about what a "net zero energy building" really is. An international study was started in 2008 within the framework of the International Energy Agency "Toward Net Zero Solar Energy Buildings" (Task40/Annex 52, 2008) to attempt to enhance the overall understanding of the concept; thus the objective of this work is to study current net zero, near net zero, and very low energy buildings and to develop a shared, common, and harmonized international framework (Sartori et al., 2010), including design tools, innovative solutions, and guidelines. This includes new requirements on comfort and energy performances (Sartori et al., 2010) grid interactions, and an exhaustive benchmarking of the existing nZEBs already built around the world.

Four well-documented definitions – net zero site energy, net zero source energy, net-zero energy costs, and net-zero energy emissions – have been reported by Torcellini et al. (2006), where pluses and minuses of each condition are discussed.[29] In summary, Torcellini et al. (2006) identified the following main definitions of zero-energy buildings (ZEB):

1. *Net zero site energy*: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
2. *Net zero source energy*: A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers

[28] "A net zero energy building is where, as a result of the very high level of energy efficiency of the building, the overall annual primary energy consumption is equal to or less than the energy production from renewable energy sources on site."

[29] These definitions have been applied and validated to a set of low-energy buildings for which extensive energy data were available; the study shows the design impacts of the definition used for ZEB and the large difference between definitions.

to the primary energy used to generate and deliver the energy to the site (this definition is equivalent to the Industry Committee's definition).

3. *Net zero energy costs*: In a cost ZEB, the amount of money the utility pays the building owner for the energy; the building exports to the grid are at least equal to the amount the owner pays the utility for the energy services and energy used over the course of the year.
4. *Net zero energy emissions*: A net zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources (this is the case of the "Zero Carbon Building," or the ZCB).

Table 1.4 summarizes the nZEB definitions and the corelated pluses and minuses.

1.2.3.2 Energy Performance in the Mediterranean Areas: Examples and Lessons from the Past

To understand the possible strategies to be adopted for low- or zero-energy buildings, it is also important to recall the basic bioclimatic principles of ancient and traditional architecture, which can be either used to make a proposal for the recovery of vernacular constructions with peculiar bioclimatic strategies and/or translated in the present modern buildings (Cañas and Martìn, 2004).

The importance of vernacular or traditional construction as a frame of reference model of bioclimatic architecture is reported by many authors in the literature (Cañas and Martìn, 2004; Coch, 1998). All over the world, houses, small towns, and villages of the past collectively contain some of the best-preserved climatic conscious and aesthetically enjoyable traditional architectural types and techniques. Furthermore, current passive techniques used in reducing the cooling demand of buildings are based on or derive from systems and components used in the traditional and vernacular architecture.[30]

Different research studies in literature on interesting examples of vernacular and traditional architecture have been selected. They are briefly illustrated in the following part of this paragraph.

[30] With respect to the representative or even monumental architecture, the popular architecture has been structured by people as a direct and basic response to their own needs and values (Coch, 1998). These buildings show a greater respect for the existing environment. They use local materials and techniques as far as possible, repeating and slowly modifying the course of history models and take fully into account the constraints imposed by the climate. In spite of the plurality of solutions within the different geographical contexts, it is also interesting to observe how practically identical architectural models are developed in similar climates with highly different cultures and very distant locations.

Table 1.4 ZEB definitions summary

Definition	Pluses	Minuses	Other
Site ZEB	• Easy to implement. • Verifiable through on-site measurements. • Conservative approach to achieving ZEB. • No externalities affect performance, track success over time. • Easy for the building community to understand and communicate. • Encourages energy-efficient building designs.	• Requires more PV export to offset natural gas. • Does not consider all utility costs (can have a low load factor). • Not able to equate fuel types. • Does not account for non-energy differences between fuel types (supply availability, pollution).	
Source ZEB	• Able to equate energy value of fuel types used at the site. • Better model for impact on national energy system. • Easier ZEB to reach.	• Does not account for nonenergy differences between fuel types (supply availability, pollution). • Source calculations too broad (do not account for regional or daily variations in electricity generation heat rates). • Source energy use accounting and fuel switching can have a larger impact than efficiency technologies. • Does not consider all energy costs (can have a low load factor).	• Need to develop site-to-source conversion factors, which require significant amounts of information to define.

(*Continued*)

Table 1.4 ZEB definitions summary (*cont.*)

Definition	Pluses	Minuses	Other
Cost ZEB	• Easy to implement and measure. • Market forces result in a good balance between fuel types. • Allows for demand-responsive control. • Verifiable from utility bills.	• May not reflect impact to national grid for demand, as extra PV generation can be more valuable for reducing demand with on-site storage than exporting to the grid. • Requires net-metering agreements such that exported electricity can offset energy and non-energy charges. • Highly volatile energy rates make for difficult tracking over time.	• Offsetting monthly service and infrastructure charges require going beyond ZEB. • Net metering is not well established; often with capacity limits and at buyback rates lower than retail rates.
Emissions ZEB	• Better model for green power. • Accounts for non-energy differences between fuel types (pollution, greenhouse gases). • Easier ZEB to reach.	• Need appropriate emission factors.	

Source: Torcellini et al. (2006).

Analyzing and reporting 212 cases of old buildings in Spain, significant points have been highlighted: (1) The bioclimatic strategies used in popular constructions correctly respond to the conditions imposed by the climate; (2) Selected strategies and technological tools for the protection against the solar radiation may be found in buildings located in the southern middle part of Spain, where the solar radiation received is very high, while, opposingly, strategies for the use of solar radiation appear in the northern middle part of Spain where the solar radiation is lower; (3) Strategies for the protection against cold temperatures agree with the regions of Spain where the temperatures are minimum; (4) Generally, technological tools for the protection against rain are located mainly in areas where the averages of precipitations are high. In particular, passive regional strategies are: (a) Andalusian "patios" whose function is to accumulate fresh air; (b) Light color of the façade as a mechanism for the protection against solar radiation, since light colors reject the solar rays reducing solar heating; (c) Use of vegetation for the shading of the housing; (d) Orientation of the building for the collection of higher amount of solar radiation in winter than in summer.

Other energy efficient design strategies have been investigated by Manioglu and Yılmaz (2008) in Mardin, a town situated in the hot, dry area of the southeastern Turkey. This study examined building types and bioclimatic cooling techniques by evaluating them in terms of design criteria such as building types and forms, selection of the area, distance between buildings, orientation, and building envelopes. Typical features of this traditional settlement are: (1) orientation (southeast); (2) close distance between buildings; (3) plan type (ie, the courtyard houses); and (4) compact forms to minimize the area affected by the solar radiation. In particular, in the traditional architecture of Mardin, the arranging of close form types in courtyards produced shaded areas. In the courtyards, with the help of water and plants for evaporative cooling, the floor temperature is further minimized by natural elements for cooling (channels and water poured out from the pool).[31] Massive envelope details of these houses are very convenient for continental climates, where the summers are severe with high variations in daily temperature. The thermal mass slows down the heat transfer through the envelope, thus producing lower indoor daytime temperatures. The high heat capacity of the opaque component provides a high time lag for the transmission of the

[31] "Eyvan" and "revak," typical spatial elements of the traditional houses, are used to create shady and cool living spaces during the day.

outside temperature to the internal area, while the low transparency ratio minimizes the direct solar radiation gained through the windows. In this climate, other precautions against the solar radiation are: (1) minimization of the area and the number of windows; (2) construction of a window at a high level to block the floor radiation; (3) minimization of the absorptivity of the facades by white or light colors; (4) providing natural ventilation especially at night; (5) constructing a part of the house underground, which is always cooler than the outer ambient temperature. The research study also attempts to compare the energy performance between a traditional house and a modern house (built after 1990): a simplified thermal evaluation and comparison of a traditional house with a contemporary house have been given by using data derived from measurements of physical data and questionnaires, which have been carried out for 100 buildings. The modern building was constructed by contemporary techniques in compliance with the instructions of Energy Conservation Standard of Turkey. For the measurements, rooms with similar features in modern and traditional houses were chosen. (The main façade of these two rooms are southeast oriented; they present a flat roof; they are situated in the upper floor of both houses; no shading device was used on the facades of both houses).[32] After comparing the obtained results, it has been observed that air temperature and surface wall temperature are much lower in the traditional building than in the modern. In particular research result shows, quite stable and low indoor air temperature values during all the reference day in the traditional building.[33] Similar studies and similar results comparing modern and traditional architecture have been performed in other hot and humid parts of the world.

Architectural structure and environmental performance have been reported also for the case study of the traditional buildings in Florina, in northwestern Greece (Oikonomou and Bougiatioti, 2011). This study was based on the documentation and the analysis of the architectural and bioclimatic aspects of a sample of forty remaining houses of the 19th and the beginning of the 20th centuries. The analysis has been performed considering

[32] The thickness of the walls is 0.8 m in traditional house and 0.25 m in modern house. Thermal properties of the building envelope materials were stone wall for the traditional house 2.33 λ (W/mK) and brick for modern house 0.46 λ (W/mK). Single glazed wooden window framed present a U value of 4.5 W/m^{2}K in traditional house while double-glazed, PVC window framed realize a U value of 2.6 W/m^{2}K in modern house.

[33] Satisfyingly, the measurements also meet the user's perception of indoor temperature in summer, which has been obtained by a questionnaire carried out with 100 occupants in the selected modern and traditional buildings at the same time with the measurements.

the building types and form, the materials and the construction techniques, whereas the analysis of bioclimatic aspects involves the thermal behavior of the building shell, as well as the thermal and the visual comfort conditions. Traditional architecture of Florina is characterized by proper southern or eastern orientation of the buildings and by the exploitation of the prevailing winds. To a large extent, the buildings are oriented to achieve the best possible exploitation of solar radiation for passive solar heating. Natural materials are used with great efficiency and according to their physical properties and thermal characteristics (density, heat capacity, time-lag), as well as their durability, improving the inter-seasonal thermal behavior of the various spaces and enforcing the bioclimatic function of the buildings. In this way, the winter living spaces, which are situated on the ground floor, are characterized by increased thermal mass and reduced thermal losses due to the increased wall thickness and the reduced number of openings, whereas the summer living spaces on the upper floors are characterized by reduced thermal mass and enhanced ventilation due to the light-weight walls and the increased number of windows. As a whole, the traditional buildings evaluated in this study resulted in highly energy efficient buildings, both in the summer and in the cold winter season.[34]

The energy and microclimatic performance of traditional buildings also have been observed in the well-known case of "Sassi," historical hypogenous buildings in southern Italy (Cardinale et al., 2010). The "Sassi" district of Matera, a UNESCO World Heritage since 1993, is described as an exceptional example of traditional bioclimatic Mediterranean architecture. The authors found that both hypogenous units and half-hypogeum – where half of the building is constructed from stone bricks out of the ground level – optimally perform during both summer and winter conditions. They analyzed the energy performance of the hypogenous building structures during one calendar year, finding, again, that the huge thermal mass of the walls ensured constant and regular microclimate indoor conditions throughout the seasons, without relevant differences in the daily thermal oscillation. In spite of some

[34] Computer-aided thermal analysis have shown that for the coldest day (26th January), the main winter living spaces had slight diurnal variation and range (around 0°C with outside temperatures below −12°C. For the hottest day (25th August), while the exterior temperature ranged from 22°C (early in the morning) to 34°C (around noon), the summer living spaces resulted warmer than the outdoor air temperatures in the morning and in the night (25°C), but significantly fresher around noon (29°C). When natural ventilation is inserted as an additional parameter (passive cooling strategy) in the computer analysis, the inside temperature ranges from 23.5 to 27.5°C.

air change need (thermal-hygrometric comfort values in deep hypogenous units are not fully reached), these structures present a null thermal balance during mid-season, while in the summer, the floor loses heat, thereby cooling the environment. The opposite occurs in winter.[35]

As a general rule, it can be stated that incorporation of traditional or traditional-based building techniques into newly designed building may help the design process to use low-cost and achievable, locally based construction practices toward the achievement of zero-energy balance and zero onsite CO_2 emission within the Mediterranean climate (Ferrante and Cascella, 2011). In the reference case study (a newly designed housing development for a site located in the south of Italy), the concurrence of different building components aims to achieve multipurpose objectives within the same building frame.

These components mainly derive from the re-elaboration of traditional forms and techniques (building type – a courtyard house presenting a good balance among natural ventilation and building compactness, high mass envelope features and construction from the local practices, selected passive tools for energy saving). The same components are integrated with systems for energy micro-generation from renewable energy sources (RES), combining existing technologies from RES into traditional building types and consolidated construction practices.

1.2.3.3 Main Passive Technological Tools for Building Cooling

The responsible sources of cooling demand or thermal discomfort in buildings can be listed in the following order: solar radiation, relative humidity, and air temperature (Coch and Serra, 1996). Because of this, to optimize a building's energy performance, rational design and use is crucial. Solar radiation control is the most important strategy and, although much has been written about the efficacy of transparent shading systems, it is important to assess the impact of opaque envelope solar control as well.

[35] The monitoring campaign has confirmed all results obtained through the dynamic analysis. By quantifying the total energy balance of the hypogenous structures, the authors found the following: (1) during the winter season, the heat flow loss from the walls was balanced by the positive energy gain through the floor, which stabilized the temperature that remains constant at about 12–13°C; (2) during mid-season, exchanged heat fluxes are essentially null, resulting in a constant evolution of temperature with values of 15–16°C; and (3) in summer, the heat flow dispersed from the floor counterbalances the incoming heat flow for transmission and ventilation, reducing high summer temperatures. During the summer season, the indoor temperature is in the range of 18–21°C (especially in deep hypogea). It can be concluded that these buildings were built as "zero energy" houses and they can be used today, after conservative and light-method based restoration processes, with limited or null use of technology energy systems.

As shown by Santamouris (2006), passive cooling relies on the use of solar and heat control techniques, heat amortization, and heat dissipation techniques. Intensive research studies carried out on the topic have permitted to develop advanced and low cost systems and techniques that, when applied, can highly contribute to decrease the cooling needs of buildings and improve indoor environmental quality. In particular, as reported by Santamouris (2006), the development of high reflectivity coatings for the building envelope can considerably decrease the solar input to the buildings, while new developments on ventilation technology permits successful dissipation of the excess heat into the ambient air, improving indoor comfort and decreasing the concentration of indoor pollutants.

Various passive cooling systems and their applicability to different climates and building types, as well as strategies for minimizing cooling needs by building design (eg, ventilation cooling, radiant cooling, evaporative cooling systems, ground cooling, cooling of outdoor spaces adjacent the building, etc.) have been comprehensively investigated by Givoni, 1994, 1998a, and 1998b.

More recently, Zinzi (2010) has highlighted the need to fruitfully apply passive building technologies to mitigate the cooling demand increase, reducing the energy consumption in cooled buildings and improving the thermal comfort in not-cooled buildings. The author suggests cool materials as possible strategy options for reducing building cooling loads, since they are material building components that stay cool under the sun because of high solar reflectivity and thermal emittance properties. In particular, because of the high horizontal solar radiation at Mediterranean latitudes during the cooling season, roofing systems may be considered key and strategic envelope components for the solar control (Zinzi, 2010). The case-study-based research reported by Zinzi (2010) demonstrates the positive impact of the technology in terms of cooling and total energy savings as well as on the indoor thermal conditions in Mediterranean buildings. In particular, the author states that the effect of cool roofs has an important impact on the following: (1) Energy performance of insulated buildings – built in the Mediterranean north rim – with the optimization of heating and cooling performance; (2) Energy performance of existing noninsulated buildings below 40 degree latitude and for all the existing buildings to be renovated with energy measures such as roof insulation; (3) Temperature profiles in noninsulated buildings and with high external surface-to-volume ratio. These configurations ensure enhanced performance of cool roof technology, with a strong decrease of discomfort hours. More insulated and compact structures still benefit from cool roof applications, but the advantages may be amplified by the contextual application of other passive techniques, such as night ventilation, more radical window shading strategies, and increased thermal mass; (4) Positive impact in terms of energy performance backs up other critical issues related to cool roofs: the environmental impact in terms of mitigation of the UHI and an effective answer to global warming, which is critical in large urban areas.

Performances of various passive techniques in hot and arid regions by using roof cooling were also performed by other studies (Nahar et al., 2003). Here, the evaporative cooling has been found to be the best solution for the conventional roof, but it requires high water consumption. Therefore, pieces of white glazed tiles stuck over the roof have been selected as a valid alternative tool to reduce heat load from the roof and decrease the indoor air temperatures, among a range of other passive techniques.[36]

One of the best performing cooling strategies via the roof-cooling technique is the use of vegetated green roofs (Niachou et al., 2001). This technology will be diffusely mentioned as a retrofitting strategy in the future development of this work (see Chapters 2 and 3).

Integrated water and energy management in the urban context is one major route toward environmental sustainability and the reduction of carbon dioxide emissions into the atmosphere. This passive cooling system has been investigated, in terms of expected benefits for the building and the urban environment, by many authors. A review of related worldwide experiences is reported for comparison purposes by Fioretti et al. (2010). This investigation is related to the specific climatic context of the Mediterranean region. Full-scale experimental results are provided from two case studies, located in northwest and central Italy, consisting of two fully monitored green roofs on top of public buildings. The attenuation of solar radiation through the vegetation layer is evaluated as well as the thermal insulation performance of the green roof structure. The daily heat flowing through the roof surface was quantified; results showed that the green roof outperforms the reference roof, therefore it significantly reduces the daily energy demand

[36] A large set of possible tools were used over the roof of different experimental units for cooling the environment inside test structures: (1) painting of roof with white cement; (2) thermal insulation over the roof; (3) nocturnal cooling, that is, a shallow pond with a 100 mm water column 40-mm thick and movable; (4) thermal insulation over the roof; (5) evaporative cooling, that is, roof is provided with gunny bags soaked with water with the help of a storage; (6) tank and dripper for controlling water without any pump, (7) broken white glazed tile pieces stuck over the roof, (8) air void insulation, that is, inverted earthen pots having 100-mm diameter and 125-mm height were provided over the roof, and (9) roof covered with Sania, a local insulating material used over the huts in the arid regions and the controlled unit without any treatment.

of the building. In fact, the most important effects created by a green roof consist of the reduction of the surface temperature and the attenuation of temperature fluctuations. In a traditional roof, made of highly absorptive materials, the horizontal external surface can reach very high temperatures due to the combination of the air temperature and the solar irradiation absorption, which determines a strong thermal load. By this analysis, it was possible to evaluate the time delay effects due to the green roof rather than the reduction in temperature alone. The green roof has a lower temperature level due to the plant shading, insulation, and evaporative transpiration of the foils apparatus. As for water management, it is confirmed that green roofs significantly mitigate storm water runoff generation – which may occur even in a Mediterranean climate – in terms of runoff volume reduction, peak attenuation, and increase of concentration time.

Green roofs, high-reflection roofs, wall planting, green parks, roadside trees, and the like are all desirable from the viewpoint of building and urban planning. Improvement in the surface of buildings and structures that have been covered with cement and asphalt concrete are some of the measures to mitigate the urban heat island phenomenon (Ferrante and Mihalakakou, 2001; Julia et al., 2009; Sfakianaki et al., 2009). The use and effects of highly reflective painting for cooling roofs and road pavements has been examined by many authors (Santamouris, 2001; Spala et al., 2008; Shashua-Bar et al., 2010). Among others, Akbari et al. (1997, 2009), from the heat island group of the Lawrence Berkeley National Laboratory, have studied different solutions and techniques for reducing UHI's effects and energy consumption by different building fabrics and urban surface types.

Surface heat budget on green roofs and high-reflection roofs for mitigation of the UHI have been studied by Takebayashi and Moriyama (2007).[37]

[37] In this study, surface temperature, net radiation, and water content ratio of green roofs and high reflection roofs have been observed, comparing the heat and water budget to each other. In the daytime, the temperature of the cement concrete surface, the surface with highly reflective grey paint, bare soil surface, green surface, and the surface with highly reflective white paint have been observed to be in descending order. On a surface with highly reflective white paint, the sensible heat flux was observed to be small because of the low net radiation due to high solar reflectance. On the green surface, the sensible heat flux was small, too, because of the large latent heat flux by evaporation, although the net radiation was large. On the cement concrete surface and the surface with a highly reflective grey paint, the sensible heat fluxes have been observed to have almost the same values because of similar solar reflectance. Methods to estimate the quantity of evaporation, evaporative efficiency, heat conductivity, and thermal capacity are explained, and the observation data is applied to these methods.

Green roofs and high reflection roofs have performed significantly in successfully mitigating UHI and keeping buildings cooler.

Ventilation is another strategic passive technique for building cooling. Proper ventilation of urban buildings can contribute significantly to decreasing the energy consumption for air conditioning, improving indoor comfort, reducing the concentration of indoor pollutants, and protecting public health (Santamouris, 2006). Design and integration of efficient natural ventilation systems and components like wind and solar towers improve indoor thermal comfort. Natural ventilation can contribute to improving thermal comfort, decreasing the need for air conditioning, and improving indoor air quality in the developed world. Experimental studies have shown that effective night ventilation in office buildings, for example, may reduce the overheating hours by half and reduce the cooling load by at least 55%.

Important research studies have been carried out on appropriate and advanced ventilation techniques (Santamouris and Wouters, 2006). The main achievements of these studies are:(1) better understanding of the air flow phenomena and of the expected comfort benefits, in particular in the dense urban environment, and development of efficient and practical procedures to design natural and hybrid ventilation systems and configurations (Allard and Ghiaus, 2006); and (2) technological developments mainly on the field of hybrid and mechanical ventilation that greatly contribute to a more comfortable and healthy indoor environment (De Gids, 2006).

The appropriate design of windows permits an increase in air speed in households and improves comfort by cooling down the human body through the mechanisms of convection, radiation, and perspiration. Cross-ventilation and vertical ventilation increase airflow rates and lower internal temperatures. Although the appropriate levels of air velocity to achieve comfort is a widely discussed topic within the scientific community (Tanabe and Kimura, 1994; Arens et al., 1984), studies performed in hot and humid climates confirm that increased air speed, especially at higher temperatures, enhances thermal comfort (Hien and Tanamas, 2002).

Vertical air extraction and wind catchers are also very efficient techniques. In particular, wind-catcher systems have proven to deliver effective natural ventilation. Once again, these systems derive from past technologies, employed in buildings in the Middle East for more than 3000 years. In the modern wind catchers, the principles of wind effect and passive stack effect are considered in the design of the stack, which is often divided into two halves or four quadrants/segments with the division running the full length of the stack. Although they have different names in different parts of the southeastern Mediterranean region, the basic physical principles may be investigated according to similar geometrical forms (Bahadori, 1994; Elmualim et al., 2001; McCarthy, 1999).

An increasing number of wind-catcher and cool-tower systems (Etzion et al., 1997; Hurdle, 2001; Swainson, 1997) have been applied into commercial buildings and residential buildings (ie, the Queen's Buildings at Demonfort University and the Ben-Gurion University of the Negev – or the International Centre for Desert Studies in Negev, Israel) and their performance is still evaluated by many authors in literature. Among many others, Li and Mak (2007) performed the evaluation of a wind-catcher system using computational fluid dynamics, demonstrating that wind-catcher cooling potential is very effective, although a precise design study has to be planned in relation to the wind conditions of the specific site, since its behavior is greatly influenced by the external wind speed and direction with respect to the wind-catcher quadrants.

Furthermore, as illustrated in the examples from traditional architecture, the significance of mass is of crucial importance for the reduction of cooling load in buildings. This is an important property of the building envelope for energy conservation, since excess heat is stored in it and dissipated at a later stage when needed. In this way, the indoor temperature fluctuations are regulated and overheating is avoided. These temperature fluctuations could be due to: (1) diurnal fluctuations of outdoor temperatures; (2) internal gains; or (3) incident solar radiation especially in rooms with south glazing surfaces. The aspects relating to mass are of particular significance for countries with large diurnal fluctuations for the displacement and dissipating potential of mass. In these contexts, ensuring high values of superficial mass and adequate levels of the damping and phase-displacement of the thermal wave is essential. Thus, many authors (Santamouris, 2001, 2006; Givoni, 1994, 1998a; Cañas and Martìn, 2004; Ferrante and Cascella, 2011), reported research and applied studies on the effectiveness of thermal mass in the bioclimatic design for building cooling in hot or Mediterranean areas.

1.2.3.4 On the Combination of Passive and Active Techniques for Building Cooling

In the search for further energy exploitation within the building sector, researchers are attempting to discover, measure, and evaluate the energy-saving potential achievable from the combination of active and passive techniques. In this context, automatic control and implementing an active system to prevent overheating in summer represent crucial strategies. In a recent study, Ochoa et al. (2008) have explored the influence of incorporating intelligence in buildings in hot climates, to achieve glare and solar radiation control. Through the perspective of energy consumption and user comfort, with an emphasis on lighting, the study shows how decisions made in the early design stages can affect those of later ones.[38] Finally, the combination of optimized active features (fan ventilation elements and automatic controls) with passive design strategies offers very promising energy savings and glare control at the same time.[39]

Furthermore, current studies are investigating the potential of combining both active energy generation systems from renewable energy sources (RES) and passive techniques. By coupling active features and correct passive design strategies, consistent savings may be achieved. In particular, recent studies exploiting the radiative cooling capacity of active energy producers have led to the production of a new photovoltaic-thermal (PVT) system (Eicker and Dalibard, 2011), which has been developed with the goal of providing both electrical and cooling energy for buildings. Experimental studies of PVT collectors were carried out in Stuttgart to validate a simulation model, which calculates the night radiative heat exchange with the sky. Larger PVT frameless module surfaces were then

[38] By means of computer energy modeling, a prototype office unit is used to evaluate energy performance and visual comfort in three parametric series. The first one is the result of the incorporation of active features alone, the second one is guided by intelligent passive design strategies, and the third one is the combination of both approaches. Here, to analyze the influence of active features and passive design, an office module will be studied in the city of Haifa, Israel (32.51N, 351E), with a regional climate usually classified as Csa (warm summers and mild winters) in the Köppen scale (also "meso-thermal/humid continental," due to its location in the Mediterranean coastal plain). The building is a free-standing structure, with similar glazed facades in all four main orientations, with the view portions made of clear double glazing. Results show that energy savings in the "passive design strategies only" (sun shading elements, daylight redirection elements, glazing elements, etc.) were among the largest – from 60 kWh/m^2 per year (base-case) to around 24 kWh/m^2 per year.

[39] Combining active features and correct passive design strategies gives consistent savings of around 50–55%, compared to a conventional situation. By these options, intelligent or smart buildings offer flexibility and convenience, such as rapid temporary changes, options to open individual windows or operate specific blinds.

implemented in a residential ZEB and tested under the climatic conditions of Madrid.[40]

1.2.3.5 Current Research Studies and Projects on Zero-Energy Building in the Mediterranean Climate

Other studies have attempted to evaluate the energy and comfort behavior of building models by comparing their predicted and/or measured values in different climate conditions. Simulation is employed as the main research method for these studies. By simulating a standard passive house (a house with heating energy demand equal to 10–16 kWh/m^2 y) in different locations throughout the Mediterranean and European regions, Grove-Smith (2010) illustrated how the general and basic principles of passive houses seem to work in Mediterranean warm climates; this finding also has been considered generally valid, although for southern locations like Palermo and Seville, passive systems conceived for northern climates would require de-humidification measures, as can be observed by obtained sensible and latent values in Table 1.5.

Table 1.5 Simulated results of a same passive building in different locations

	Mannheim	Torino	Madrid	Seville	Palermo
Insulation wall [cm]	25	20	10	8	6
Insulation roof [cm]	35	25	25	20	20
Insulation basement [cm]	20	15	6	0	0
U window frames [W/(m^{2}K)]	0.72	0.72	0.72	1.6	1.6
U-value glazing [W/(m^{2}K)]	0.7	1.2	1.2	1.2	1.2
Humidity control for cooling	No	Yes	No	No	Yes
Heating demand [kWh/(m^2 y)]	15.6	14.8	12.7	4.6	3.1
Sensible cooling [kWh/(m^2 y)]	0	0.8	0.4	4.2	7.2
Latent cooling [kWh/(m^2 y)]	0	2.3	0	0	7.2

Source: Grove-Smith (2010).

[40] Measured cooling power levels were between 60 and 65 W m^{-2}, when the PVT collector was used to cool a warm storage tank and 40–45 W m^{-2}, when the energy was directly used to cool a ceiling. The ratio of cooling energy to electrical energy required for pumping water through the PVT collector at night was excellent with values between 17 and 30. The simulated summer cooling energy production per square meter of PVT collector in the Madrid/Spain climatic conditions is 51 kWh m^{-2} a^{-1}. In addition to the thermal cooling gain, 205 kWh m^{-2} a^{-1} of AC electricity is produced under Spanish conditions.

Therefore, it seems that some of the winter requirements (sufficient insulation of roofs, walls, double low-e glazing, south-facing windows, some thermal mass) may be useful for energy saving in the summertime if solar shading/control, light control, and appropriate ventilation techniques are also applied.

Among the recent research studies on low- and zero-energy housing is the experience of a regional project financed by the European Union (Wenzel, Deutsche Gesellschaft für Technische Zusammenarbeit mbH, GTZ, German Agency for Technical Cooperation). This project supports the design, construction, and monitoring of ten low-energy demonstration buildings in ten southern and eastern Mediterranean countries (MED-ENEC www.med-enec.com). In the report, some important issues on energy efficiency in the Mediterranean are discussed. In particular, it states that: (1) High energy savings can be achieved in buildings with a variety of partly mature and partly innovative technologies; (2) Low- and even zero-energy houses and green buildings are technically feasible in the Mediterranean region; (3) Economic considerations limit the broad application of some of these technologies and thus reduce the technical potential for energy savings in a large-scale dissemination; (4) The most cost-efficient technology mix, according to the type of building, the climate zone, energy prices, and the availability of know-how and technologies needs to be identified;(5) High transaction costs such as substantial initial learning and search costs put the profitability of low-energy buildings in the region at risk and constrain the development of respective markets; (6) When using a cost-efficient technology mix and if mitigating transaction costs, low-energy buildings become attractive with energy savings of 20–60% in most of the countries, and incremental costs of 10–15%, as well as short pay back periods; (7) Government support and incentives are necessary for overcoming the initial high transaction costs and market failures and for boosting energy efficiency in buildings; and, finally, (8) Subsidies on energy are the most important single constraint for broad dissemination in some of the countries in the Mediterranean region.

Results of these pilot projects show that high primary energy savings of up to 100% – compared to conventional buildings in the same country – are technically possible. These energy savings correspond to anywhere from 3 to 307 tons of avoided CO_2 annually, according to the different sizes of the buildings and the chosen energy efficiency concept. The average primary energy savings achieved is 57%, compared to a conventional building of the same size and comfort (concerning heating and cooling).[41]

The cost-effective results have been analyzed to deliver an overview of the economic performance indicators of the pilot projects. In this context, the payback periods have been considered as the more important indicators. The simple payback calculation method has been used by dividing the value of the annual energy costs savings (assuming a 5% annual increase in energy prices) by the incremental costs of the building, compared to a conventional building. When analyzing the economic performance figures, major differences among the pilot projects become obvious. On the one hand, the Lebanese Project is the most attractive with payback occurring in roughly one year. The paybacks for five other projects seem to be moderate with a payback period of around 10 years. However, four projects are clearly unattractive with paybacks of 18 to nearly 70 years. On average[42] the new buildings needed incremental investments of about 30%, and show a payback period of about 20 years. If, however, broad dissemination of low-energy buildings in the region is the first priority, economic considerations, that is, the relation of energy savings to additional cost, limit the use of available technologies to the most cost-efficient "smart technology mix." The feasible technology mix may be different according to the type of building, the climate zone, the national energy prices, and the availability of know-how and technologies. The integrated and mixed use of different energy forms to be

[41] Finally, the behavior of the inhabitant is crucial for realizing the theoretical savings potential. In fact, when shading devices are not used properly, when windows are left open while heating or cooling, energy-efficient technologies may not have the desired effects. In some MED-ENEC pilot projects (Jordan and Israel), users of the building receive written guidelines and explanations for the handling the installed equipment and for energy-efficient procedures and behavior. In addition, a part of the theoretical savings potential may be "lost" in comfort increase, that is, the rooms are a bit warmer in winter and slightly colder in summer ("rebound effect"). This is particularly true in countries where thermal comfort is rather poor. It should be noted that significant additional energy savings potential exists on the urban planning level.

[42] Except the Tunisian project, which is a special building with rather expensive unconventional features. In this case, attracting "green" clients by demonstrating the "state of the art" and maximizing the energy savings was a major objective. Therefore, a mix of mature and innovative but rather expensive technologies such as large photovoltaic electricity generation or solar cooling was chosen. This approach makes the pilot project an interesting place to visit and learn from, but reduces potential for dissemination.

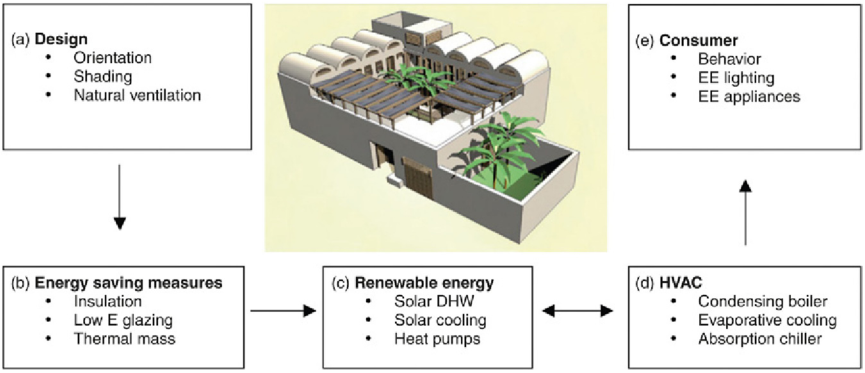

Figure 1.5 ***Integrated EE-approach for buildings.*** *(Source: MED-ENEC, Carsten Petersdorff, ecofys).*

considered in passive and low-energy building within the hot regions is summed up in Fig. 1.5.

This integrated approach helps reduce incremental costs and improve the payback period. Experiences from pilot projects like the MED-ENEC pilot projects lead us to move toward more specific and regionally related assessment, considering the ranking of technologies according to their cost-effectiveness in the specific country or region. While some technologies, such as photovoltaic capacity, are sensible to national framework conditions (eg, they may be cost-effective in Israel, where a feed-in tariff exists, or in African countries, where grid connection is significantly lower than in the Mediterranean region), some others may seem less attractive. Thus, passive design features, such as orientation of the building, shading, natural ventilation, and the use of daylight are free or very cheap in the design phase, and are therefore always cost-efficient for new buildings. Insulation of roofs and walls as well as efficient lighting and solar water heaters prove to be equally in the top ranking.

The MED-ENEC pilot project developers have encountered major constraints, especially high and often uncompetitive costs. These effects are not specific for the MEDA region (MGI 05/2007); other groups have reported similar conditions. One of the conclusions that may be derived from the MED-ENEC pilot project is that "government must lead." This is true not only for the Mediterranean region but for all regions and countries. Setting regulations, and providing standards and enforcing them, are necessary but not sufficient conditions for success. As the value chain in the building sector is long and diversified with plenty of stakeholders acting on individual perceptions of risks and benefits, it is of the highest importance that economic signals such as energy tariffs, incentives, and sanctions orient the actors in the market. However, resistance to change, initial market failures, and high-transaction costs usually slow down or even impede development of the market for energy-efficient products and services. An integrated package encompassing regulations and standards (including control and enforcement), financial support and incentives, information, training, and education, as well as research and development activities, has to be part of improved economic framework conditions. Further research to identify the most effective (and cost-effective) policy mix must be developed, since finding a "best" policy instrument is probably impossible.[43] The lessons learned from the MED-ENEC project seem to be applicable for most emerging and developing countries. An appropriate policy mix according to different framework conditions is always necessary. Countries with very low energy prices need strong political will through enforced regulations and standards and significant subsidies for energy-efficient products and services while reducing non-targeted energy subsidies and, at the same time, protecting the vulnerable part of the population. Countries where framework conditions are more favorable and where the private sector is strong should focus instead on policy packages with information, training, quality control, technology transfer, and credit program components.

Recent progress has been made on low-energy and passive buildings by the research and projects of the Passivehaus Institute. In the last ten years, northern and central Europe (and in particular, Germany) has seen increasing interest in the Passivhaus Construction Standard. Homes built according to this standard are buildings that provide a comfortable indoor climate in winter without the need for a conventional heating system.[44] The success of the Passivhaus Institute in Darmstadt,

[43] Each country needs to work out a comprehensive analysis of individual framework conditions and barriers and has to design an adapted policy package. In this process, stakeholder participation, definition, and monitoring of quantitative objectives and the synergetic combination of instruments are major general success factors (IEA 03/2008, UNEP 09/2007, ECOFYS 03/2007, WEC 2008, GTZ/Wuppertal Institute/UNEP 2007).

[44] To achieve this standard, it is essential that the building's space heat load does not exceed 10 W/m^2 living area in order to be able to use a simple air pre-heater. Simulations and measurements have shown that for the typical German climate such a design leads to an annual demand for space heating of 15 $kWh/(m^2\ y)$. Passive houses therefore require roughly 85% less energy for heating than a house built to existing German building regulations. The total primary energy demand, including household electricity, is limited to 120 $kWh/(m^2\ y)$. In 1991, Wolfgang Feist and Bo Adamson applied the passive design approach to a house in Darmstadt, with the objective of providing a showcase low-energy

(*Continued*)

home for the German climate at a reasonable cost. By 1995, based on the successful first experiment (both in terms of energy consumption and comfort), the same passive systems were applied again in a second construction in 1995 in Groß-Umstadt. From these experiences, Feist had codified the passive design of the Darmstadt and Groß-Umstadt homes, into the Passivhaus standard. The standard fundamentally consists of three elements: (1) an energy limit (heating and cooling); (2) a quality requirement (thermal comfort); and (3) a defined set of preferred passive systems that allow the energy limit and quality requirement to be met cost effectively. The "Passive-On" consortium has therefore formulated a revised proposal for the application of the Passivhaus standard in warm European climates, taking into account the aforementioned climatic issues and contents. According to Passive-On, the Passive house standard for the warm European climate is defined in six points: 1. *Heating criterion:* Useful energy demand for space heating not exceeding 15 kWh per m^2 of net habitable floor area per year.[2] of net habitable floor area per year. 2. *Cooling criterion:* Useful, sensible energy demand for space cooling not exceeding 15 kWh per m^2 net habitable floor area per year. 3. *Primary energy criterion:* The primary energy demand for all energy services, including heating, domestic hot water, auxiliary, and household electricity, does not exceed 120 kWh per m^2 net habitable floor area per annum. 4. *Air-tightness:* If good indoor air quality and high thermal comfort are achieved by means of a mechanical ventilation system, the building envelope should have a pressurization test (50 Pa) result according to EN 13829 of no more than 0.6 ach-1. For locations with winter design ambient temperatures above 0°C, a pressurization test result of 1.0 h-1 is usually sufficient to achieve the heating criterion. 5. *Comfort criterion room temperature, winter:* The operative room temperatures can be kept above 20°C in winter, using the aforementioned amount of energy. 6. *Comfort criterion room temperature, summer:* In warm and hot seasons, operative room temperatures remain within the comfort range defined in EN 15251.

To achieve the Passivhaus standard, it is necessary that indoor summer temperatures, more specifically operative temperatures, remain lower than the maximum temperatures defined by the EN 15251 standard. According to EN 15251 standard, acceptable comfort temperatures depend on the type of system used to provide summer comfort. If cooling is provided by an active system, then indoor temperatures must respect those defined by the comfort model originally proposed by Fanger or the predicted mean vote (PMV) model (Fanger, 1967, 1994; Fanger et al., 1974, 1975, 1988). Instead, if summer comfort is provided by passive cooling strategies, the higher temperature limit is set by the adaptive model, which is the model taking into account the ability of occupants of buildings to adapt to the prevailing climate (adaptive comfort model). Compared to the Fanger Model, the adaptive model considers a wider range of temperatures as "comfortable" and therefore allows for easier integration of passive cooling technologies. For example, applying the adaptive algorithm defined in the EN 15251 standard to typical annual weather data predicts maximum summer neutral temperatures (in correspondence with a sequence of hot days) for Frankfurt, Milan, Lisbon, and Seville as, respectively, 26.1°C, 27.2°C, 26.7°C, and 28.7°C. As a comparison, a building cooled by an active air conditioning system will work to a fixed set point chosen between 23 and 26°C. In more recent years, some international standards (e.g., the US norm ASHRAE 55 2004 and the European norm EN 15251) have proposed adaptive comfort models based on in-field comfort surveys. These have thus replaced the previous Fanger-based temperature standards with "adaptive" ones for indoor temperature in naturally ventilated buildings.

Germany naturally led to the question of whether this program might be applicable in other countries, with particular reference to the Mediterranean region. This question is central to some recent research dissemination projects funded under the IEE program by the European Commission, such as the "Passive-On" project (http://www.passive-on.org/en/), which primarily addresses the question of the applicability of Passivhaus standards in southern Europe. In fact, although in central Europe (eg, Germany, Austria, northern Italy, etc.) passive design is increasingly associated with the Passivhaus standard, this is not necessarily the case in southern Europe (eg, Spain, Italy, Portugal, and Greece). The project examined how to take the Passivhaus concept forward, especially in southern Europe. In these regions, the problem of household energy use is not only to provide warm houses in winter but also, and in some cases more importantly, to provide cool houses in summer. The Passive-On project has lead to three major outcomes: (1) For architects and building designers, the project has developed design guidelines and enhanced the PHPP software design tool for developing cost-effective, all-season passive houses in both heating load and cooling load climates; (2) For policy makers, the project has provided a set of policy proposals that examine the barriers and the solutions that EU, national, and local governments can adopt to promote the more widespread development of passive houses.

The Passivhaus standards have been applied in the five partner countries of Passive-On (France, Spain, Portugal, Italy, and the United Kingdom). They have been performed as national "exercises," formulated according to the standard typology of a semidetached three-bedroom house. The exercises revealed that heating loads are relatively low in many southern European countries and generally stay below the 15 kWh/m^2 mark. Comparatively, however, they are marginal to other household energy requirements such as water heating, lighting, and appliances. Results showed that in many cases, there are cooling loads to take into account but that often these can be met by passive strategies alone.

For the Portugal case, for example, the starting point for the Passivhaus proposal was a single floor, two-bedroom house, complying with the Portuguese national building regulations for 2006. The current proposal takes into account the local climate (case study for Lisbon), the construction standards, and the technical and economic framework.[45] The three main aspects explored in the proposed house are: relation with the sun, ventilation for cooling, and high thermal mass to control temperature swings. The house combines the ability to collect solar heat (large south windows) and the capacity to regulate inside temperature with its high thermal inertia. Since solar availability is quite high in Portugal, even during the heating season, a key factor in this house is the relation with the solar radiation, captured both directly (windows) and indirectly (thermal solar system). Large windows are mainly oriented south, which increases the useful solar gains during winter. Smaller areas are oriented east and west and minimal areas are oriented to the north. Solar protection is chosen according to the orientation: overhangs to the south windows, thus reducing the solar incidence during summer, and exterior Venetian blinds in all windows. Strategies adopted for the design of a Passivhaus for the heating and

[45] Here the level of insulation in walls and roofs goes well beyond the national standards and the air infiltration is controlled (about 0.8 ach at 50 Pa). A very important feature of the proposal is the use of a thermal solar system. The current proposal extends the solar installation of thermal systems from the compulsory limit use of Portuguese thermal regulation for buildings (solar system for domestic hot water) to also cover a significant portion of the heating demand, by increasing the solar panel area and using a low temperature hydraulic heat distribution (radiant floor). As proposed for the Passivhaus standard, the active heating and cooling capacity is limited to 10 W/m^2. The extra costs of the proposed Passivhaus for Portugal were 57 €/m^2 with a payback period of 12 years. To further reduce heat losses and gains, 150 mm and 100 mm of insulation are proposed for the roof and exterior walls, with U-values of 0.23 W/m^{2}K and 0.32 W/m^{2}K, respectively. Windows facing south correspond to around 60% of the total glazed area; about 20% of glazed area faces east and another 20% west. Low-emission double glazing can be very effective in colder climates of Portugal, but in most situations, standard double glazing is more cost-effective (U-values of 2.9 W/m^{2}K for standard double glazing and 1.9 W/m^{2}K for low-emission glazing are considered). Performance: energy and comfort. The annual heating energy demand of the Passivhaus proposed for Portugal has been estimated as 16.9 kWh/m^2, of which 11 kWh/m^2 are supplied by the solar system (in this analysis, priority of the solar system is given to heating and the solar fraction for domestic hot water is 48%). The annual cooling energy demand is 3.7 kWh/m^2. The sum of net heating and cooling demand is 9.6 kWh/m2 year, against limits of heating and cooling by regulatory tools in Lisbon, are 73.5 and 32 kWh/m^2 year, respectively. The current house, with an active cooling, has a Fanger comfort index of 811 (the house is penalized by the influence of the radiant temperature of the high glazed area). If no active cooling is present, the adaptive comfort index (AI2) applies (ASHRAE 55). For the proposed Passivhaus for Portugal, the AI2 was 16. For this house, the resultant temperature is kept below 25˚C for 71% of the occupied time, and below 28 °C during 98% of the occupied time. In winter, the low power heating system of 10 W/m2 is in use, resulting in only 8% of time with a resultant temperature below 19.5°C (lower resultant temperature achieved is 18°C).

cooling climate of Lisbon can be successful, both regarding the energy demand limits and the comfort level requirements.

1.3 DISCUSSION

Since today the reserves of conventional energy resources are drastically depleted, it becomes imperative to look at the reduction of energy demand as the primary option for decreasing energy consumption and to achieve natural cooling within our buildings. To reach this objective, it is important to look into the past for suggestions and possible solutions. In no way is it being suggested that we should copy traditional building types or abandon the available technology to return to construction practices of the past. However, there are basic principles that can be derived from traditional architecture, for example: correct orientation and placement of buildings and their components, openings to promote day lighting and natural ventilation during the cooling period, distribution of thermal mass, the use of local materials, and so forth. These practices may be considered as the first (and lower cost) bioclimatic options to design or redesign a low-energy building. In fact, the architectural design process usually moves from the conceptual features (definition of massing, orientation, form) to the specific requirements (thermal mass, solar and lighting control, mechanical ventilation type).

It should be taken into account that, as the design process advances, earlier and often free of costs- decisions, which could have an enormous influence on the building performance, are costly and difficult – when not impossible – to change (Ferrante, 2012).

Examples from the analyses of pilot case studies (MED-ENEC project, Passivhaus) have shown that passive design features, such as orientation of the building, shading, natural ventilation, and the use of daylight are free or very cheap in the design phase, and are therefore always cost-efficient for new buildings. Insulation of roofs and walls as well as efficient lighting and solar water heaters proved to be equally in the top ranking of cost-effective solutions, in most cases.

However, although climatic building design strategies are important, it cannot be stated that any one of them has a higher priority than any other; the large number of elements existing in the market today, together with constraints limiting their applicability, make it necessary for designers to have tools that help them to identify the best combinations for any specific situation. In this context, the cost-effective analysis, together with the life cycle evaluation of solutions, may represent useful components of a strategic framework plan aimed at the incorporation of zero-energy concepts in building construction.

Under the assumption that sustainability in construction should be first and foremost achieved through the passive building conception, to achieve nZEB buildings we should make use of the major advantage from building type and the potential energy subsystems building components (area of external surfaces/volume ratio[46] walls, orientation, ventilation strategies, etc.) and that of its surroundings (landscape, shape, and orientation). For example, as it can be observed from the analysis of the traditional bioclimatic examples in architecture, in warm and hot climates and/or during the summer season, a permeable form of the building type can be advantageously designed to achieve shadowed areas and improved natural ventilation. Inversely, for the winter period, the same passive principles should lead to a solution providing a more compact form and reduced values of surface-volume (S/V) ratio, which is the most beneficial strategy during the winter, especially for inland locations with high seasonal thermal range and fluctuations. Thus, taking into account the need for ventilation (cross-ventilation and vertical air extraction provided by internal courtyard and vertical ducts) the S/V ratios in Mediterranean climate should consider a reasonable balance between natural ventilation requirements in the hot summer period and thermal outflow in the colder winter season. A good compromise could be found in the use of variable or movable systems and components (ie, glazing or opaque sliding systems) to close off parts of the building, thus resulting in a more compact, less dissipative space, to reduce the external surface areas in the cold winter season; variable components can be removed or kept open in the summer season, so as to increase the surface area of heat exchange and ensure ventilation (especially at night, when air temperature decreases). The search for such an adaptive strategy for buildings brings to mind the concept of adaptive comfort adopted by humans and also the similar adaptation capacity of many other living organisms. Unfortunately, this strategy is often connected with higher investment and maintenance costs.

[46] The surface-area-to-volume ratio is also defined the surface-to-volume ratio and it is variously denoted Sa/Vol or SA:V. It represents the amount of surface area per unit volume of an object or collection of objects. For a given volume, the object with the smallest surface area (and therefore with the smaller surface-area-to-volume ratio) is the sphere. By contrast, objects with tiny spikes will have very large surface area for a given volume.

As a general rule, when conceiving and designing options for buildings in the Mediterranean zone, we should always remember that northern European design decisions sometimes have been adopted in southern latitudes with counterproductive results (eg, large windows, or solar greenhouses, high compactness, high-insulation performing materials, etc., may produce summer discomfort in the Mediterranean region). Generally, the building envelope design should be focused on technological solutions able to guarantee an adequate balance between the thermal insulation requirements in the winter season and the thermal mass in the hot summer season. In this framework, as an example, constructive typology in masonry brick walls ensures high values of superficial mass and adequate levels of the damping and phase-displacement of the thermal wave (Ferrante and Cascella, 2011).

With reference to legislative measures in the frame of ZEBs, as pointed out by Torcellini et al (2006) "A good ZEB definition should first encourage energy efficiency, and then use renewable energy sources available on site. A building that buys all its energy from a wind farm or other central location has little incentive to reduce building loads, which is why we refer to this as an off-site ZEB." Thus, taking into account that "it is almost always easier to save energy than to produce energy" it is necessary to:

- Set specific energy supply options and establish a hierarchy of them in relation to the specificity of sites, energy prices, and cultural and social aspects.
- Consider ZEB as an additional step with respect to the Passivhaus principles, not as an alternative to them. Since the energy savings from passive cooling and heating is the first and foremost criteria to be considered in ZEB, it would be particularly important to fix an "internal limit" of passive requirements within ZEBs. In this way, ZEB can be considered not different from but integrated with the passive house concepts. A new standard should be framed in order to encourage low-energy buildings and not only high-energy performing buildings.
- Suggest new forms for future standards, which are more in keeping with the objectives of the EPBD on zero-energy building (European Council for an Energy Efficient Economy, February 2011).

Of course, setting regulations and standards and enforcing them is a necessary but not sufficient condition for success. As the value chain in the building sector is complex, with plenty of stakeholders acting on individual perceptions of risks and benefits, it is of highest importance that economic signals such as energy tariffs, incentives, and sanctions orient the actors in the market. Furthermore, integrated packages of regulations/standards and financial support/incentives should be combined with information, training, and education as well as research and development activities.

Thus, to achieve the correct approach toward ZEBs, it is necessary to start from the radical reduction of energy demand for cooling, heating, lighting, and ventilation; the use of RES to cover the remaining energy demand should be considered as the secondary and consequent step.

Reported examples and studies have shown the technical feasibility of ZEBs in the context of European and Mediterranean regions.

Over the years, there has been a growing interest among stakeholders, architects, and entrepreneurs to include energy-efficient tools and techniques in buildings as a way to achieve buildings that comply with stringent energy codes and national goals of reducing dangerous emissions, together with improving corporate image. Reported case and research studies demonstrate the technical feasibility of nZEBs both in colder and warmer areas of the Mediterranean region.

Despite growing interest in nZEB buildings, given the recognized increasing problems related to global overheating and fuel poverty, there is a crucial risk of underestimating the growing energy demand for cooling and heating purposes in the Mediterranean region. This is mainly due to the following, often intertwined and concurrent factors:

- More attention paid to nZEBs in the northern and colder climate areas compared to the southern regions. Consequently, a relatively new approach of passive and low-energy buildings within the nZEB and current European policies directive needs to be further investigated with more specific reference to cooling demand and summer energy performance.
- Use of light, low-inertia building components in modern architecture and culture, with subsequent limitation of the capacity to control building thermal performance with respect to mass and dense buildings materials, ultimately resulting in further high energy consumption
- Lack of knowledge and understanding of the potential to use available construction systems and techniques (which can be also derived from traditional passive cooling systems)
- Less favorable social and economical conditions in the Mediterranean countries, compared to the northern and central Europe
- Technical, economic, and even social barriers with respect to the integration of passive techniques and RES to achieve nZEBs in the context of existing building stock and urban settings.

1.4 FURTHER STEPS

As introduced in the first part of this chapter, the majority of these studies refer to newly conceived buildings and new development plans; but, obviously, when approaching a refurbishment project, the freedom degrees are extremely reduced when compared to the design of a new building. Thus, the further challenge would be to widen technical ZEB knowledge in existing built environments, shifting our technical understanding on energy efficiency from new developments and newly conceived buildings into the reality of existing urban settings. In the Mediterranean areas, there is a special need for efficient schemes where zero-energy requirements, energy construction quality, and technological flexibility can fit with the different economic and social possibilities, within an extended building stock, often in degraded or abandoned conditions. These existing urban settings represent the biggest challenges both in carbon terms – because of the large amount of existing building stock – and for the social impact they may generate on the local economy. In this case, the integration of passive technologies and renewable energy sources are the real challenge for the architectural and engineering projects of future generations. Yet, these actual built environments, with their special concentration of technical and socioeconomic problems, are ripe for innovative responses to energy-related issues and climate change.

Thus, to deal with the main issues arising from the state-of-the-art in low- and zero-energy building within the warm and hot climate regions in the Mediterranean area, we need further research studies and design implementation. We do need to take the chance to intervene in the real material parts of the actual cities, in a project-based, but sorted and ranked manner. In these hypothetical scenarios, according the different degrees of possible transformation of existing built environments, the project is not the scope, but becomes the main the tool of our research study, the effective device to verify the techno-economic feasibility of systemic retrofitting.

First and foremost, these studies should be indented to turn future designers' and public stakeholders' priorities away from new pilot zero-energy experiments and toward demonstration buildings to spread interventions in the existing buildings of actual urban environments; we should then analyze, share, and present this opportunity as a creative and sustainable challenge for future generations of architects, planners, industrial designers, and researchers. In fact, there is thus a lack of comprehensive information on the possible intersections between the BATs and a concrete inclusive approach to users' needs. This is because close collaboration between physicians, engineers, architects, energy companies, stakeholders, and urban dwellers, amongst others, is missing, which is probably why progress in this area is still limited to date.

In this context, recent studies, design proposals, and simulations of building energy retrofitting scenarios (Ferrante and Cascella, 2011) has already proved that huge energy savings may be achieved in winter by adding different coatings to existing buildings. In particular, the combination of new building coatings such as sun-spaces or buffer zones and RES, drastically reduce the energy performance indexes of the buildings up to the target of an nZEB. These studies, performed during the winter season so far, need to be further investigated in order to quantify the cooling demand reduction of the proposed scenarios during hot summer conditions.

Finally, real urban environments, or RUEs (streets, squares, courtyards, and connected residential buildings) are here indicated as the core of the search for new intersections between urban dwellers and energy-related issues. An effective action should explore the technical mechanisms that can promote the concrete synergies between economic constraints, users' expectations, and EE systems and production, in renewed forms of urban retrofitting.

The complexity of the urban environments in the Mediterranean areas has highlighted an increasing need for:

- Further exploration of urban geometry for achieving better understanding of current energy demand within the different residential areas of the city. This further exploration will be observed and quantified with reference to the building blocks in the urban textures considered as the "solid" part of the city and to the open-street environments, considering the buildings and the related open spaces as the core focus of energy investigation and trying to outline the possible cumulative effects of all the buildings and open areas of the city.
- Energy retrofitting actions in existing building stocks within localized, ground-based urban environments
- Feasibility of small-scale and distributed RES in local urban environments

Thus, the next steps to be undertaken may be summed up as follows:

1. In order to evaluate the energy demand and potential of an urban environment, it is possible to select reference case studies, representative of the different urban conditions of a whole discretized city model based on different urban units, corresponding to the building blocks and the related street/open area in RUEs.

2. In these "units," retrofitting actions toward zero-energy RUEs can be hypothesized and validated exploring both passive physical components (green and EE techniques for surfaces and coating materials) and energy micro-generating technologies by RES – solar, photovoltaic (PV), Aeolian, and so forth.
3. The economical feasibility of these actions in RUEs can more easily lead to economically and socially competitive actions and lead the drive toward a zero-energy future.

The goals of next chapters are to study, evaluate, and demonstrate the technical feasibility of nZEBs throughout representative RUEs of the AMA. To achieve this purpose, the energy performance of selected typical residential buildings in the urban Athens area will been investigated in detail in order to properly identify the buildings' energy requirements in winter and summer conditions and, finally, to propose a targeted retrofitting hypothesis toward the goal of increasing the number of nZEBs.

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CHAPTER 2

Nearly Zero Energy Urban Settings (ZEUS)

2.1 SEARCHING FOR HOMOGENEOUS URBAN AREAS AND URBAN UNITS TO DEPICT A CITY MODEL FOR ATHENS

Urban and geographical studies of urban textures' discontinuity within and around the city have been highly and deeply investigated by the discipline of urban morphology (Whitehand, 2009; Conzen M.R.G, 1988, 2004; Conzen, P.P, 2009). In particular, these studies are concentrated on the different urban structures derived from the tendency of the expanding metropolis toward the homogeneous conglomeration of the flat cityscape around the city core, which is the foremost dominant mark of the so-called dispersed city (Segal and Verbakel, 2008).[1]

Processes of suburbanization have made it difficult to distinguish the growth of the city from its suburbs in many different urban contexts (Phelps et al., 2010). Phelps and colleagues also reported a large set of terminology innovations describing outer cities or edge cities, which are variously termed "techno-burbs" (Fishman, 1987), "edge cities" (Garreau, 1991), "edgeless cities" (Lang, 2003), or even long-standing processes of sub-urbanization (Bruegmann, 2005; Hayden, 2003; Berger, 2014).

Thus, the general outcome of the dispersed city seems to be a society where the values of the rural and the urban blend, resulting in more uncertain places, indifferent to both the city and the countryside (Donadieu, 1998). As a result, the urban-rural areas, conquered by gray industrial fields, expanding transportation networks, fragmented built areas, and social desolation, urgently call for new ideas. Correspondingly, the loss of human recognition within the city is even more striking as we move from the city center outwards.[2]

[1] One of the consequences of this process is that the farming community around the cities is sharply declining, uncertain about the images that the future has in store for it, since its spaces are continuously invaded by the expanding city: on the one hand the city is increasingly suburban and the rural areas are correspondingly becoming increasingly urbanized (Donadieu, 1998).

[2] Generally, the more recent expansions in periurban contexts, compared to historic areas, present different features of legibility of urban form, in the specific correlation with pathways, public and open spaces. The strong corelation among closed and open spaces has been

(*Continued*)

Towards Nearly Zero Energy
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The study of this discontinuity does present deep co-relations to the interpretation of urban landscape as the geographical mosaic of urban units (Whitehand, 2009) and the Conzenian theory of fringe belts formation (Conzen, 1988, 2004) whose definition, conceptualization, theory, and applied validation on several case studies have been reported by a large set of contributions in urban morphology (Conzen, 2009; Curdes, 2010). As reported by Whitehand (2009), there is a need for much greater clarity in the methods of characterizing and delimiting the urban units and their aggregation in the mosaic of the urban landscape and for a wider appreciation of their role in planning. The methodological approach toward the knowledge of urban context can also be seen as the typological process of the buildings, at the different scalar correlations among building types, pathways, and textures forming the overall urban structure (Caniggia and Maffei, 1984).

As shown in the previous chapter, so far the metropolitan Athens area has expanded according to the same process. Furthermore, due to additional peculiar gaps derived from the process of substitution and transformation of buildings involving the historical parts of the city, a consistent suburban character appears to be diffusely present in the overall context of the city, embracing the central and peripheral areas as well. The Athens cityscape reveals a contradictory, dense, and disordered but fascinating structure as a whole (Fig. 2.1).

Here, the dramatic city scene seems to define a sort of a conflicting relationship with respect to the historical time: buildings of the 1970s and 1980s overlap the historical urban path, contrasting the old, residual, often abandoned, but still lasting, historical houses of the last century and marking the urban landscape with consecutive shocks and discontinuities.

As described in Chapter 1, the strong densification trend sped up in the 1980s in the central areas of the cities, destroying and substituting many historical buildings while continuing its spread at the periphery. Nowadays, the higher and massive buildings of the 1950s, 1960s, up to the 1980s, co-exist with lower, historical buildings, creating a series of gaps among the volumetric structure of the city, with a variable series of "blind" façades

reported by Hillier (1996), which also refers to previous studies when declaring that we cannot create a space inside without also making a space outside. Thus it's possible to point out a clear conflict between the "calibrated" structure of historical villages developed along natural or anthropic boundaries and the absence of these relations in recent expansions. In fact, moving outward from the city center, generally plots become more fragmented, less tied to fixation lines (Conzen, 2009).

Figure 2.1 ***Discontinuities, historic, and new buildings in the cityscape of Athens.*** Bettazzi Maria Beatrice, Athens, 2015.

facing public urban spots and open areas, thus infusing them with an unidentifiable urban character (Fig. 2.2). Overall, gaps between buildings do exist in many areas of the city and between different building types (Figs. 2.3–2.5).

In this complex scenario, it is extremely ambitious to aim at identifying urban compounds to be assumed as different and repeatable units of a possible discretized city model. Nonetheless, to evaluate the energy demand and the energy-saving potential of urban environments, it is necessary to select reference case studies representative of the different urban conditions and corresponding to the building blocks and the related street/open area in real urban environments, the aforementioned RUEs.

In an attempt to achieve a categorization of typical and significant urban environments, it is necessary to introduce the concept of urban density, since it represents the most crucial aspect to be studied and applied in the planning and redesign of new and existing urban contexts.

2.1.1 Notes on the Concept of Urban Density

Urban density, in its various and different definitions, is the basic tool of the urban zoning; it is conceived as the most diffuse and necessary tool to shape cities, imposing an order on the urban development, and regulating future growth. In a city as large and as eclectic as Athens, zoning regulations are crucial to preserve the existing built environment and, at the same time, foster potential innovative new developments. In large cities and metropolitan areas, zoning provides specifications on end-use and size of buildings,

Figure 2.2 ***A nine-story massive building of the 1980s (on right and in the background) coexists with a two-floor historical building.*** A.F., Evripidou central Athens area, 2014.

contributing to the characterization of diversity of the many neighborhoods that constitute the city.[3]

As discussed, Athens has been characterized by an uncontrolled growth of massive and quite tall buildings in the early 20th century, due to the

[3] Different classes can be based on the discrete values (strong, medium, weak) of three parameters in urban planning: building continuity (continuous, medium, discontinuous), surface density (strong, medium, weak), building height (low, medium, high). The surface density is the ratio between the surface of the buildings at the ground level and the surface of the concerned area. A strong building continuity indicates that buildings predominantly structure

(*Continued*)

Figure 2.3 ***A new building, two-levels high, in the corner between two five-floor buildings (on the right and in the background).*** A.F., Central Athens area, 2015.

urban spaces. Adjacent buildings, streets and artificial pavements cover more than 80% of the area. Vegetation is scarcely used, except in linear arrangement. A building discontinuity indicates that buildings and artificial pavements cover with discontinuity large spaces. Vegetation surfaces coexist with mineral spaces. The use of discrete values implies to get threshold values. Main used parameters are: Building continuity (Discontinuous: isolated buildings; Means: some group of adjacent buildings; Continuous: linear or block arrangement); Surface density (Weak: less than 15%; Means: from 15 to 30%; Strong: more than 30%); Building height (Low: from one to four floors; Means: from five to ten floors; High: more than ten floors). Threshold values may be adjusted or modified to take into account various urban contexts. To limit the study of this work and to fit the correspondence with the Athens area case study, we will mainly deal with downtown urban fabrics characterized by medium and strong density, continuous, medium-high height.

Figure 2.4 ***A new three-floor building between two nine-story buildings.*** A.F., Evripidou central Athens area, 2014.

improvement of building techniques, like the use of reinforced concrete structures. Consequently the sudden enlargement of housing demand, has resulted from the continuous increase of the population.[4]

[4] Half a century later, a Modern emphasis had grown over public plazas and open spaces in general. Moreover the new car-based society required new spaces for parking. Therefore the next release of the zoning resolution included car park requirements and bulk regulations and provided extra floor bonus incentives for the creation of public plazas. Nowadays the zoning resolution is a planning tool constantly updated by large cities, with some main focuses like promoting mixed uses, keeping the city streets vibrant, and generating zoning for special districts, to enhance the character of special neighborhoods.

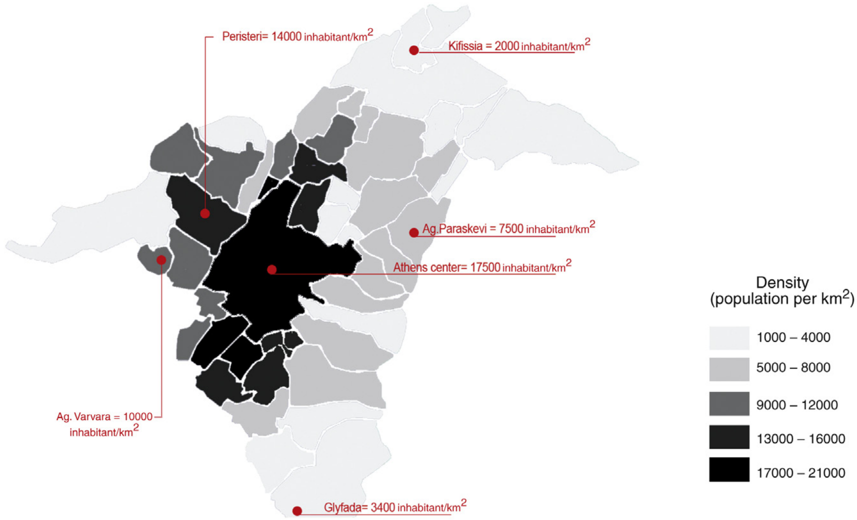


Figure 2.5 ***Density of population in six representative districts of Athens.***

The urban density in a residential area can be calculated in different ways, but there are essentially three that are most usual: (1) the ratio between the number of residential units and the urban horizontal surface; (2) the ratio between the number of inhabitants and the urban horizontal surface; and (3) the ratio between the residential surfaces and the urban horizontal surface. Although the first method is the most commonly used by the urban planner in new developments,[5] it has the disadvantage that it is strictly dependent from the actual destination and use of the specific buildings. The second ratio index (2) is used by landscape designers, geographers, and infrastructure engineers, since it is extremely useful in the calculation of the environmental urban load in a specific built context and the consequent dimensioning of its infrastructural network systems. The third ratio index is the floor area ratio (FAR), and it is indicated as a measurement to identify the density of a particular region (Reale, 2008). This index can be calculated by dividing the sum of all the built surfaces by the square meters of the total urban open area. FAR is one of the more commonly used indexes by urban planners and designers. In fact, in the zoning resolution, the floor area is defined as the sum of the gross areas of several floors of a building or buildings, measured from exterior faces of exterior walls or from the center lines of walls separating two buildings. In Figs 2.5 and 2.7 are mapped the density of population and the FAR in six representative districts of Athens. Even if it does not provide information about the functional use of the urban surfaces (public

[5] It is especially used from Spanish urban planners and architects (Mozas and Fernandez, 2004).

spaces, services, real occupied dwellings, etc.), it represents the most effective ratio to express the numerical incidence of the existing volumetric forms in the built environment. In particular, a FAR below 1 represents a low density, 1–2 represents a medium density, and above 2 indicates a high/very high urban density[6]; a FAR around 3 or more is considered extremely high.

In other terms, the FAR is the total floor area on a zoning lot, divided by the lot area of the same zoning lot. FAR is also sometimes called floor space ratio (FSR), floor space index (FSI), site ratio, or plot ratio; it is the ratio of a building's total floor area (gross floor area) to the size of the piece of land upon which it is built. This value is often used as a zoning regulatory tool for different zoning districts and it can also refer to limits imposed on such a ratio. The floor area ratio can be used in zoning to limit the amount of construction in a specific area. For example, if the relevant zoning ordinance permits construction on a parcel, and if construction must adhere to a 0.10 FAR, then the total area of all floors in all buildings constructed on the parcel must be no more than one-tenth the area of the parcel itself.

The corresponding formula is:

$$FAR = \frac{\text{Total area of all the buildings' floor } \textit{or total gross floor area}}{\text{Area of the urban plot}}$$

The floor area of a building usually does not include cellar spaces, elevator or stair bulkheads, accessory water tanks or cooling towers, attic space providing structural headroom, floor space in open or roofed terraces, bridges, breezeways or porches, floor space used for mechanical equipment, the lowest story of a residential building, floor space in exterior not enclosed balconies, and the like.

If the area of the plot is 100 m^2, then 100 m^2 of gross floor area has been built on the plot. In this case, four floors of 25 m^2 each are built on a site of 100 m^2, with a resulting FAR of 1.0. Thus, the same FAR could have been obtained in the different following options:

A one-story building on 100% of the site ($1 \times 1 = 1.0$)
A two-story building on 50% of the site ($2 \times 0.50 = 1.0$)
A four-story building on 25% of the site ($4 \times 0.25 = 1.0$)

[6] A FAR of 1.5 is quite high, although this density is not unusual in historical city centers like Florence, Venice or central Paris, and is considerably exceeded in most of Manhattan. It requires four-story buildings and narrow streets with limited interior courtyards. Higher buildings would leave more room for streets and gardens, but they are hardly present in the old historical centers of the cities.

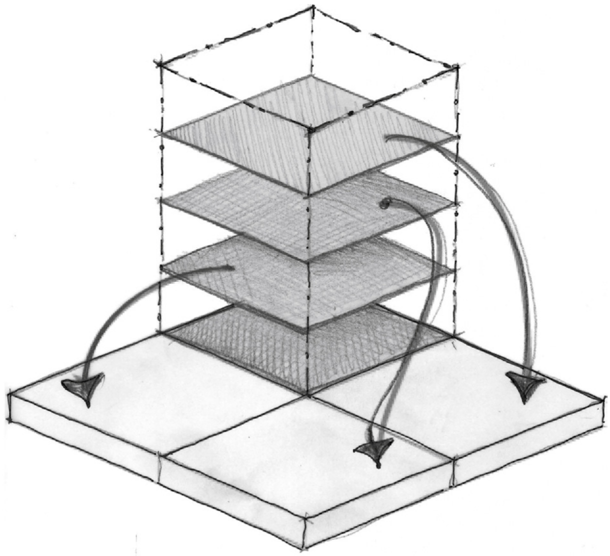


Figure 2.6 ***Floor area ratio (FAR) in the case of a four-story building covering one-quarter of the site.***

The example reported shows a FAR of 1.0 in the case of a four-story building covering one-quarter of the site (Fig. 2.6).

Thus, the same FAR can express either a single-story building consuming the entire allowable area in one floor, or a multistory building that rises

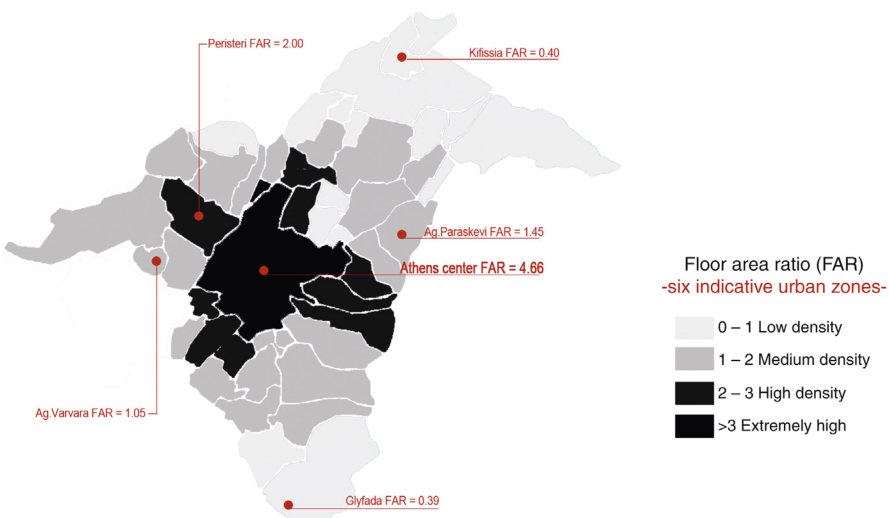


Figure 2.7 ***FAR in the six selected contexts of Athens.***

higher above the plane of the land. In this second case, the building will consequently result in a smaller footprint with respect to a single-story building of the same total floor area. Notwithstanding the manifest degree of approximation of the FAR, which disregards important other parameters, like height, width, or length, it is important to notice that the floor area ratio well correlates with other factors relevant to zoning regulation, such as the total parking area that would be required for an office building, the total number of units that might be available for residential use, total load on municipal infrastructural services, and so forth. In fact, the amounts of these other important urban parameters are nearly constant for a given total floor area, regardless of how total gross floor area is distributed in parallel and/or perpendicularly with respect to the ground level.

Nevertheless, the form is the "genetic code" for the relationship between the building and the urban microclimate and disregarding the shape of urban fabrics, the way they "confine" with the outdoor spaces, would imply a macroscopic misstep.

As a matter of fact, two basic parameters

1. the compactness of buildings and building blocks,
2. and the ability of structures to exchange air

are fully related with the form of the building envelope with respect to its surrounding open areas and the way they border one another. To account for this, the factor of compactness, expressed by the envelope area to volume ratio (Ae/V) has to be considered. The compactness is measured by the ratio of the total surfaces of external envelopes (Ae) and the total volume (V) of the buildings or consecutive building blocks; the surface includes the floor space at the ground level, while deducting wall-to-wall surfaces between adjacent buildings. Thus, at the urban level, outer surfaces connected with a similar neighboring house will not be included (no heat exchange between thermal zones assumed at the same indoor temperature).[7]

A cross-section of building blocks and different densely built urban areas in the major parts of Athens has been chosen. Overall, we compared in the main different urban contexts characterized by different population per km^2

[7] The surface-area-to-volume ratio has physical dimension L−1 (inverse length) and is therefore expressed in units of inverse distance. As an example, a cube with sides of length 1 cm will have a surface area of 6 cm^2 and a volume of 1 cm^3. The surface to volume ratio for this cube is thus given by the following formula: SA:V= 6 cm^2/1 cm^3 = 6 cm^{-1}. For a given shape, SA:V is inversely proportional to size. A cube 2 cm on a side has a ratio of 3 cm^{-1}, half that of a cube 1 cm on a side. The basic geometric forms have different ratios: the ball is 4.83 cm^{-1}, the cube, as shown is 6 cm^{-1}, a pyramid 7.21 cm^{-1}.

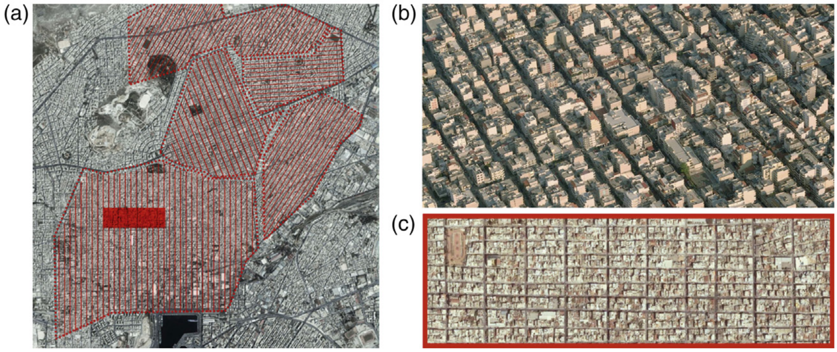


Figure 2.8 (a) An example of "homogeneous areas" at the large urban scale within the Athens central area; (b, c) Aerial view and zenith view of the urban section (a) within the homogeneous district.

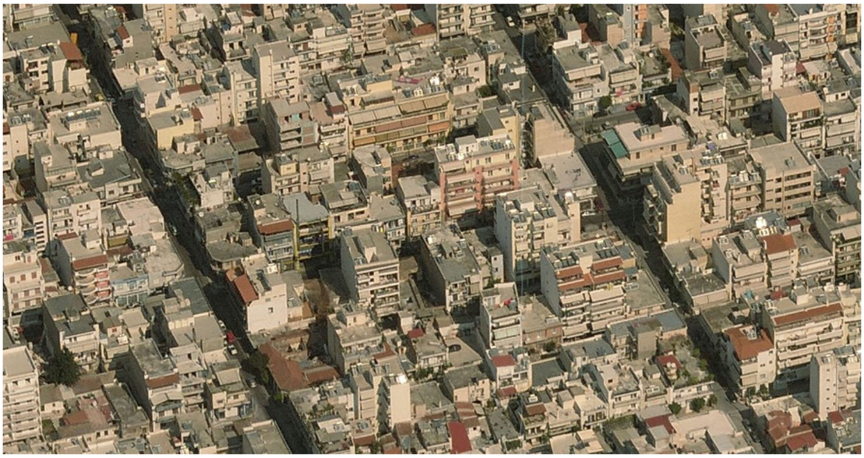


Figure 2.9 ***A detailed 3D view of the sample reported in Fig. 2.8.***

as reported in Fig. 2.5. Within these main urban areas, a further subdivision has been identified to extrapolate areas with homogeneous textures, as reported in Figs. 2.8 and 2.9.

By means of 3D reconstruction of these "apparently homogeneous" districts (Fig. 2.10), we compared the Ae/V ratio for different urban block types. The Ae/V ratio of the encountered blocks and urban structures includes all annexes behind the buildings.

Results are shown in Table 2.1.

As observed, being the ratio between the envelope surfaces and the volume a building type depending index, a large range of Ae/V ratios'

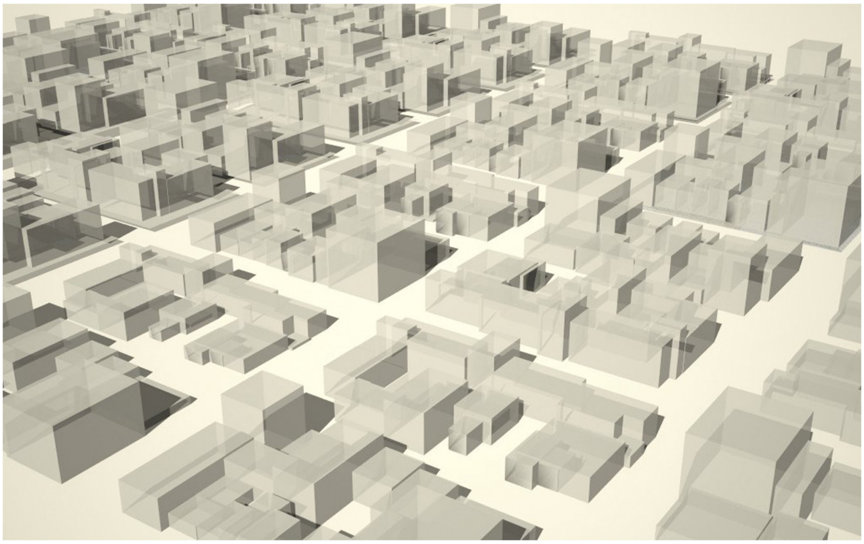


Figure 2.10 ***An example of the 3D models used to calculate Ae/V ratio for different urban block types in the homogeneous districts.***

Table 2.1 Different densities in the selected urban districts

AMA's selected districts	Number of inhabitants/km²	FAR	(Ae/V)
Kifissia	2,000	0.40	0.28–0.68
Glyfada	3,200	0.39	0.33–0.63
Aghia Paraskevi	7,500	1.45	0.38–0.59
Aghia Varvara	10,000	1.05	0.28–0.43
Peristeri (social housing urban complex)	14,000	1.99	0.27–0.45
Center (Evripidou courtyard)	17,500	4.66	0.27

variations has been recorded in similar homogeneous districts. As an example, in the elegant district of Kifissia, north of Athens, both detached houses, villas, and residential apartment buildings' blocks are present, thus resulting in the coexistence of houses and urban blocks form very porous to highly compact. On the other side, a similar variation has been encountered in the opposite case of the central Athens area. In fact, given the typical consecutive shocks and discontinuities in the urban landscape of Athens, a large set of envelope area to volume ratio (Ae/V) has been recorded in the same homogeneous district of downtown Athens. Here, if all classical blocks from the last century have a ratio lower than 0,5, the juxtaposition of higher building blocks with lower buildings – either historical or new – increases the amount of external envelopes' surfaces. The ratio of the irregular morphologies ranges from 0,27 in highly dense and homogeneous urban courtyards up to 0,68, reaching values, which are comparable to low-dense urban districts like Kifissia and Glyfada.

Once again, the articulated geometry and the urban morphology depicted in the urban environments of the Athens metropolitan area has highlighted the need for a more detailed, case-study based exploration of selected urban geometry in localized real urban environments. In the following section, additional considerations are discussed to finally identify three potential case studies.

2.2 CASE STUDIES' SELECTION AS POTENTIAL REITERATIVE UNITS AT THE DISTRICT CITY SCALE

The selection of representative case studies should respond to:

1. The need of comprising several urban textures including both dense urban contexts gathered in the typical courtyards of the historical parts of the city and the peripheral urban areas where the stand-alone building types represent the large majority with respect to other buildings.
2. The necessity of properly comparing both low-dense, medium, and high-rise building types and connected urban areas in order to develop a comprehensive study considering very different urban environments in a complex and articulated area like the metropolitan area of Athens.[8]
3. The ambitious goal of estimating the feasibility of nearly zero energy settings in the whole city, including urban settings affected by poorest climatic conditions in terms of heat island effect, higher temperatures, lowest rate of natural ventilation, urban degradation, etc.[9]

[8] The comparison of different aspects in different city contexts is at the basis of the strategic aim of achieving nearly zero urban settings throughout a whole city and to understand the potential integration of mutual intersections among the different physical components (green, surfaces, coating materials, new buildings envelopes) and their effects on urban climate.

[9] In this context it is necessary to note that we need to deal with easily accessible geometrical and climatic measured data. We referred here to developed and on-going research and correlated studies of GRBES (Group Building Environmental Studies), Department of Physics at the National and Kapodistrian University of Athens, coordinated by Professor Mattheos Santamouris on specific case study of the Athens metropolitan area. Measurements have been performed by GRBES in many areas of downtown city and on selected representative areas in the periphery (Municipalities of Aghia Varvara, Peristeri, Kifissia, Glyfada, etc.).

With reference to this last point, we recall here the analyses reported in Chapter 1. They highlighted that, during July and August, the city center and at the western part of the city present much higher mean and maximum air temperatures than the corresponding values in the northern and northeastern part of the AMA.[10] Being that the western areas, together with the central Athens zone, are affected by the highest heat island (HI) intensity of the whole AMA, they are assumed to be the ideal candidates due to their poorest climatic conditions. These aspects, together with the need for considering the different density requirements, dense urban contexts gathered in the typical courtyards and peripheral urban areas with stand-alone building types, has led to the selection of three representative urban compounds, with three very different urban textures and building types, located in the critical areas of the AMA with respect to climatic conditions and urban degradation: Aghia Varvara, Peristeri, and Evripidou.

In the western urban districts of Aghia Varvara and Peristeri, we selected two urban settings occupied by social housing of the 1960s, with typical structures built by reinforced concrete and infill walls. Conversely, in the Evripidou central Athens areas, the selected case study consists of a very dense urban setting made up of adjacent buildings with different dimensions grouped in the distinctive courtyard of the historical parts of the city. The selection of these three real urban settings is representative because of their morphological, climatic, urban, and building type aspects. In fact, these three urban areas also represent three differently dense urban compounds (Fig. 2.11). As far as it regards the energy demand investigation, the three case studies may be assumed as potential reiterative units at the district city scale.

2.3 THREE REPRESENTATIVE URBAN ENVIRONMENTS IN THE AMA

Thus, coherently with the critical issues previously discussed, the research study has been conducted on case studies specifically selected for their representativeness, both in terms of geographical location and climatic

[10] As shown, this is due to the natural territorial morphology of the Athens Area and to increased urbanization, impermeable areas, industrialization, anthropogenic heat and the lack of vegetation. Furthermore, from the analysis of the mean diurnal and nocturnal air temperatures in all stations and from the difference between them and the reference station located at the center of Athens, it is possible to conclude that HI during the night period is mainly observed at the western part of the city (Aghia Varvara and Peristeri).

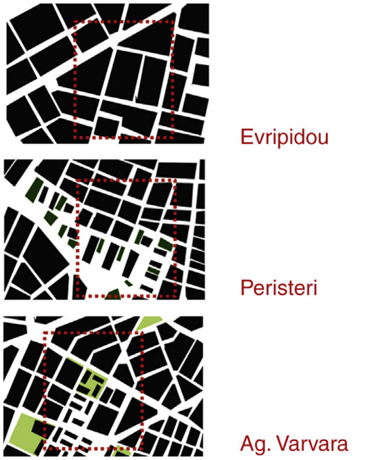


Figure 2.11 ***A schematic representation of the three selected areas in Athens.***

Figure 2.12 ***Aghia Varvara compound presents similar building blocks with different orientation and layouts.***

conditions (the western and central part of the AMA) and for the constructive and building types in each specific urban context.

The two western compounds in the Athens' peripheral area both consist of stand-alone block buildings, although there are important differences and variations in the building types and consistency of these two RUEs: while the Aghia Varvara compound presents similar building blocks with different orientation and layouts, the Peristeri Workers House urban setting is featured with different building types, namely the double block buildings, the tower, and the block buildings (Figs. 2.12 and 2.13).

From the constructive point of view, all the building types in the two RUEs consist of a series of block buildings with a structure made of reinforced concrete and infill walls. This construction type is massively present

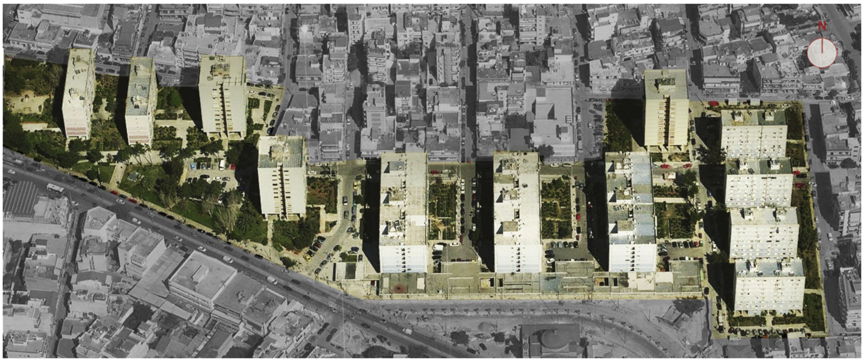


Figure 2.13 ***Peristeri workers house urban setting is featured with different building types (the double block buildings, the tower, and the block buildings).***

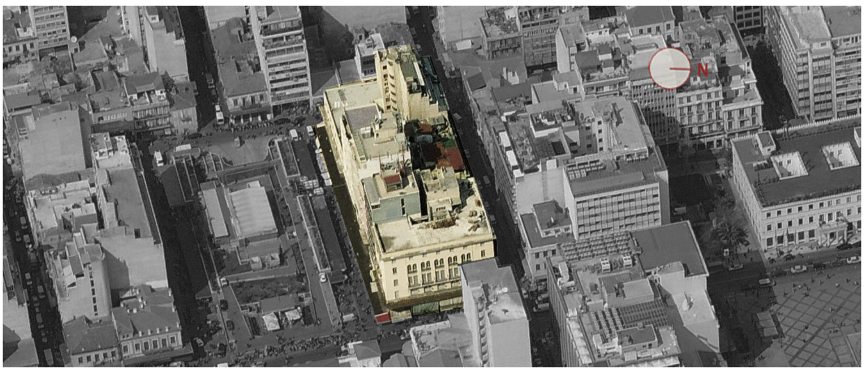


Figure 2.14 ***Evripidou central Athens courtyard with the typical aggregation of the historical center of the city.***

throughout AMA suburbs and it is also typically connected with similar building blocks all over Europe (Fig. 2.14) (Table 2.2).[11]

For the case study of Aghia Varvara, two building types recur, with different orientations, throughout the whole social housing urban compound: they have been named as building "Type A" and "Type B" (Figs. 2.15 and 2.16 and correspondent facades in Figs. 2.17–2.20).

The base case building used in the simulation is a four-story residential building with a roof area of 337 m^2, total floor area of 1093 m^2 and 15 m

[11] Generally, modern buildings constructed after World War II represent the larger majority (about the 60%) of the existing building stock in EU. This percentage even increases (about the 70–75%) if we confine the analysis within the boundaries of the Mediterranean European countries (Greece, Cyprus, Spain, Portugal, etc.) and slightly increases for Italy, as well (about 65%) (Ferrante, 2014).

Table 2.2 Different densities in the selected case studies

Selected case studies	**Number of inhabitants/ plot (estimated)**	**FAR**	**(Ae/V)**
Aghia Varvara	10,000	1.05	0.42*
Peristeri	14,000	1.99	0.28*
Evripidou	17,500	4.66	0.95

* In the case of Peristeri and Aghia Varvara Ae/V values refer to the single building types (tower, block, double block).

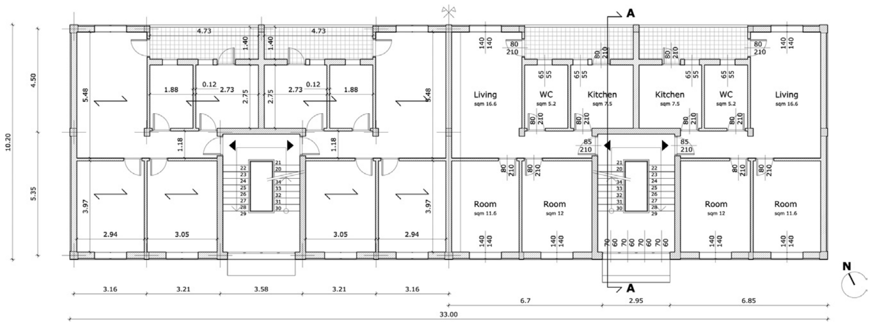


Figure 2.15 *Block building Type A in Aghia Varvara (type plan).*

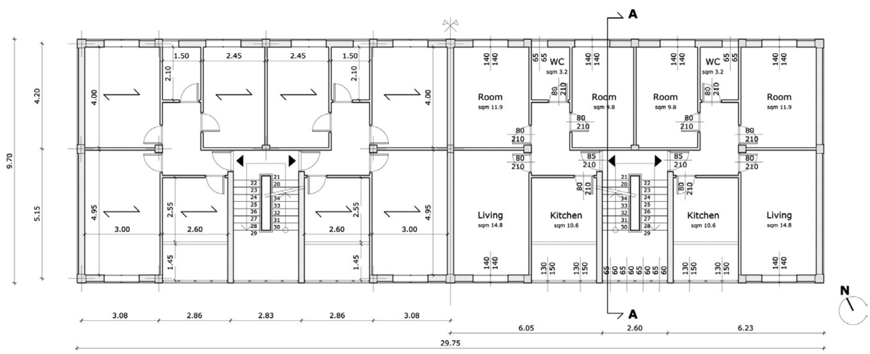


Figure 2.16 *Block building Type B in Aghia Varvara (type plan).*

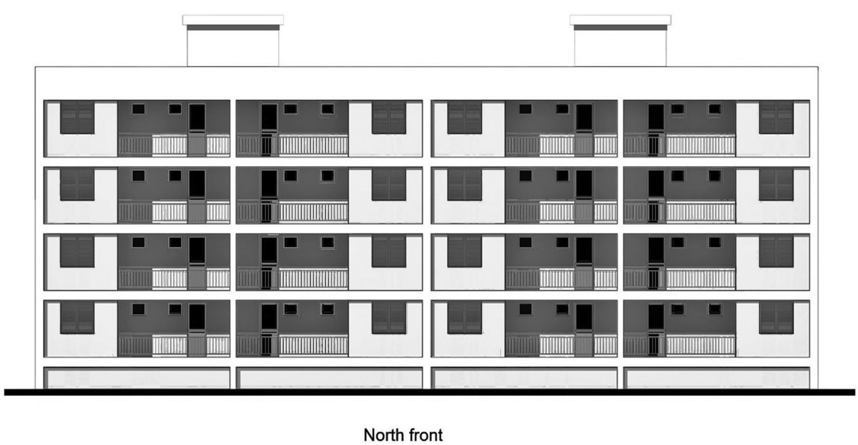
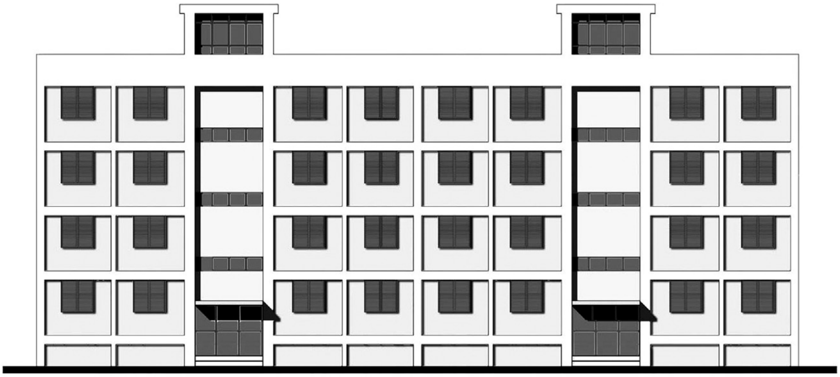
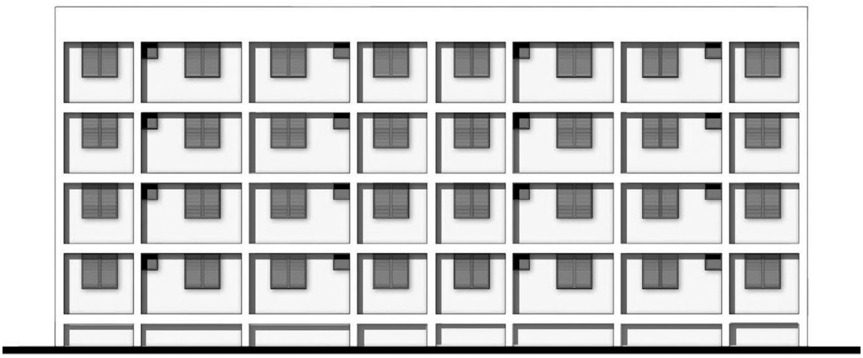


Figure 2.17 *North front block building Type A.*



South front

Figure 2.18 ***South front block building Type A.***



North front

Figure 2.19 ***North front block building Type B.***

South front

Figure 2.20 ***South front block building Type B.***

height. Indeed, these two building types slightly differ for internal distribution and partitions and consequently they could be defined as two variants of the same building type (Fig. 2.21).

Conversely, the urban compound in Peristeri is characterized by the presence of massive volumes with different building types and building

Figure 2.21 ***Aghia Varvara urban compound formed by recurring building types presenting different orientation and layouts.***

geometry.[12] In particular, the Peristeri urban settings consists of 12 stand-alone buildings segmented in four main building types:

1. Three "tower buildings" (T11)
2. Three double building blocks north-south oriented (A7)
3. Four building blocks east-west oriented (T7)
4. Two building blocks north-south oriented (B6)

All these buildings are residential with the sole exception of the B6 building type, which houses small businesses, shops, offices, and retail at the ground floor level on the south side.

For Peristeri urban settings, real facades' reconstruction of the different building types has been used (Figs. 2.22–2.28) in order to understand current modifications/appropriations of the building spaces indicating thermal and comfort needs of the inhabitants. This analysis has also been developed as a first step toward the ethnographic analysis in the whole urban context.[13]

The ethnographic observation of end-users appropriations that are visible on the buildings' envelopes can be summarized in the following four types of modifications introduced by urban dwellers in the specific Peristeri urban compound case study:

1. The addition of shading devices
2. HWAC and heat pump components hanging on the facades
3. Modifications in window size
4. Space appropriation of balconies and loggias to create additional internal spaces

[12] The urban compound extension is 37,820 m^2, of which 25,713 (68%) is occupied by building construction and impermeable surfaces (parking areas and streets); the remaining 32% is a green open area. The build area represents the 29% (7,504 m^2) of the total impermeable surfaces.

[13] These analyses have been developed as a first step to depict and predict urban dwellers' behaviors and expectations and use them as an in-put in the redesign process of the buildings. Thanks to the complementary research developed at the School of Psychology, Trinity College Dublin, TCD, in the Aerospace Psychology Research Group (APRG), the study has been implemented with the use of ethnographic research to inform the technical aspects of design with a proper consideration of the end user needs and expectations. To inform this study with the criteria of user-centered design and user requirements specifications a social survey and meetings with the inhabitants have been performed in collaboration with the Municipality of Peristeri. In order to support the development of EE solutions in socio-oriented RUEs in the use of appropriate social engagement methods and user-driven design technologies, it is necessary to involve users, build competences, create/implement a real demand for EE solutions. The social engagement methods include: (1) functional analysis of socio technical systems; (2) human and organizational factors best practices, (3) user requirements elicitation and ethnographic research. The use of ethnographic research and the real representation of the buildings through photos is a key passage to inform the technical aspects of design with a proper consideration of the end user needs and expectations.

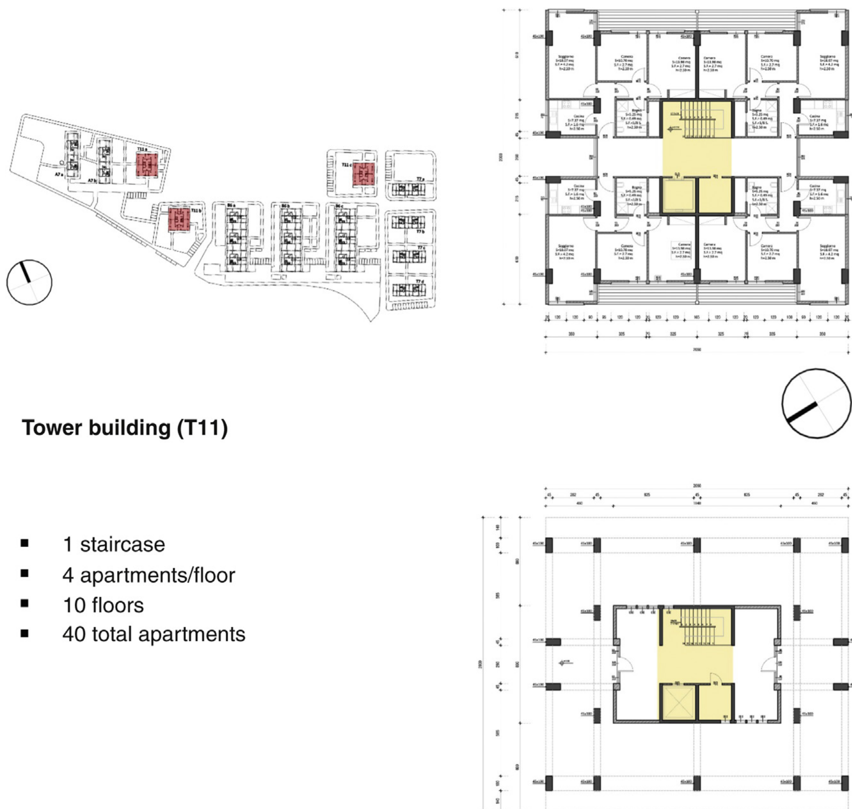


Figure 2.22 ***Ground-level plan and type plan of the tower buildings type in the urban compound of Peristeri (T11).*** On the left, location of the tower building type in the urban setting of Peristeri.

The ethnographic survey has revealed a generally higher presence of modification by users and inhabitants in the south, west, and east facades of the buildings.[14]

Conversely, the urban courtyard selected as the reference case study of Evripidou is representative of the dense built historical area in the core

[14] These modifications have been used to drive the redesign process related to the energy retrofitting of the buildings, tackling them by means of an interdisciplinary, both sociotechnical and physical-engineering approach. Research and design have been focused on the following important incremental/alternative aspects: (1) Study of the energy demand/potential of indoor building types; this research addresses the indoor energy performance of existing building types in the searching of a higher target (zero energy/emissions RUEs), as well as the potential of mutual synergies between outdoor and indoor microclimate improvements. (2) Feasibility studies of possible new additional envelopes and spaces/volumes to be tackled both as passive

(*Continued*)

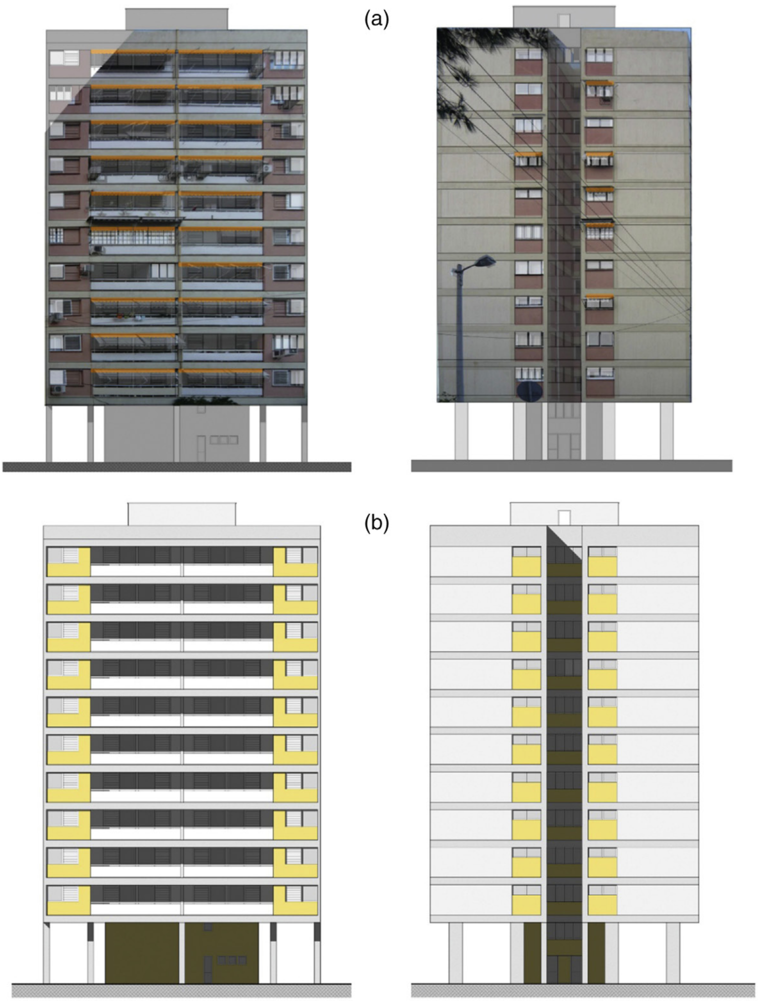


Figure 2.23 South and north facades (a); east and west facades (b) with photographic reconstruction of the tower building block in Peristeri.

tools (incrementing thermal mass, insulation, building compactness) and as possible forms of responding to urban dwellers' requirements. As it will be shown in Chapter 1, the potential adds on can be also considered as a result of combined ethnographic and end user needs research aimed at delivering forms of customized and variable components of self-expression in urban environment with respect to urban dwellers and users' expectations. For the case of Peristeri, in order to meet social aspects related to the possible retrofitting options, a social survey has been developed in collaboration with the School of Psychology, Trinity College Dublin, in the Aerospace Psychology Research Group (APRG). Thanks to the close and effective collaboration with the Municipality of Peristeri, the developed questionnaire (translated into Greek language) has been delivered to sample building blocks (the towers and the block building T7).

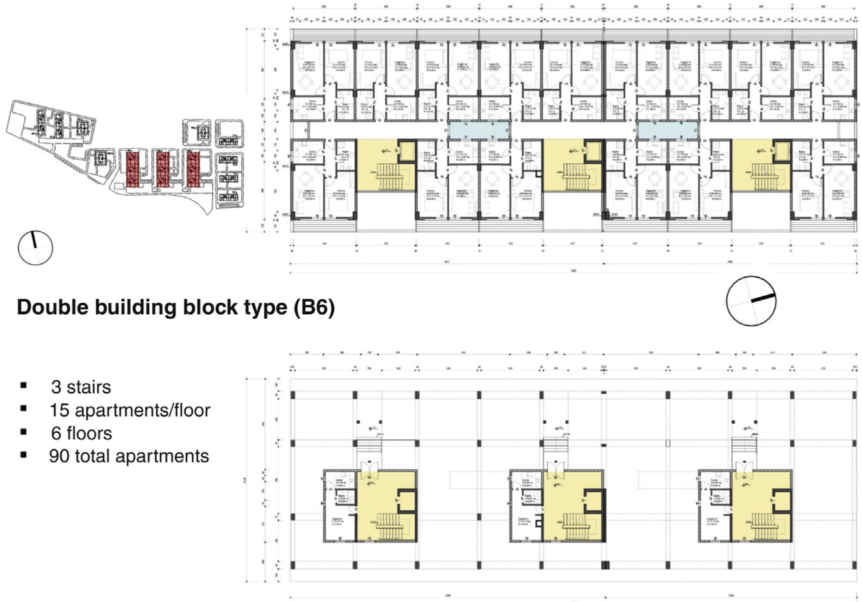


Figure 2.24 ***Type floor (up) and ground floor (down) of one of the three double building blocks (B6).*** On the left, location of the double building block type in the urban setting of Peristeri.

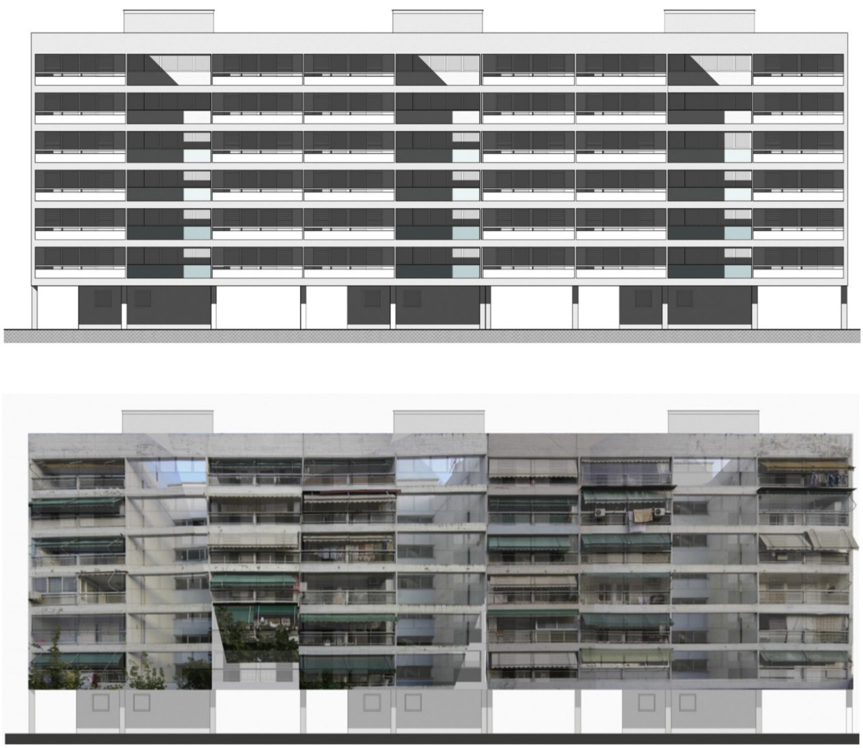


Figure 2.25 ***East facade and photographic reconstruction in the double building blocks in Peristeri.***

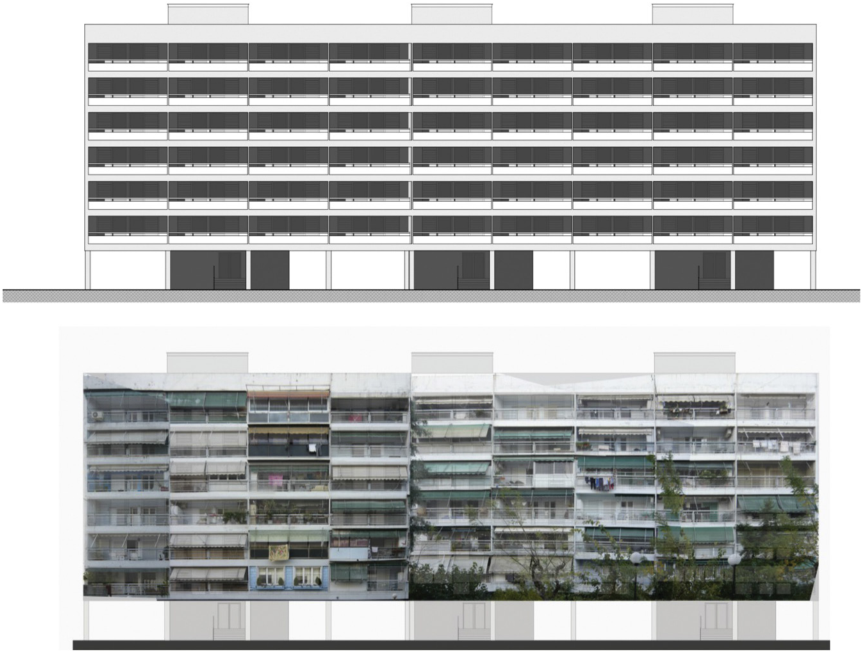


Figure 2.26 ***West facade and photographic reconstruction in the double building blocks in Peristeri.***

Building block type (T7)

- 2 stairs
- 4 apartments/floor
- 7 floors
- 28 total apartments

Figure 2.27 ***Ground and type floor of one of the four building blocks (T7).*** On the left, location of the double building block type in the urban setting of Peristeri.

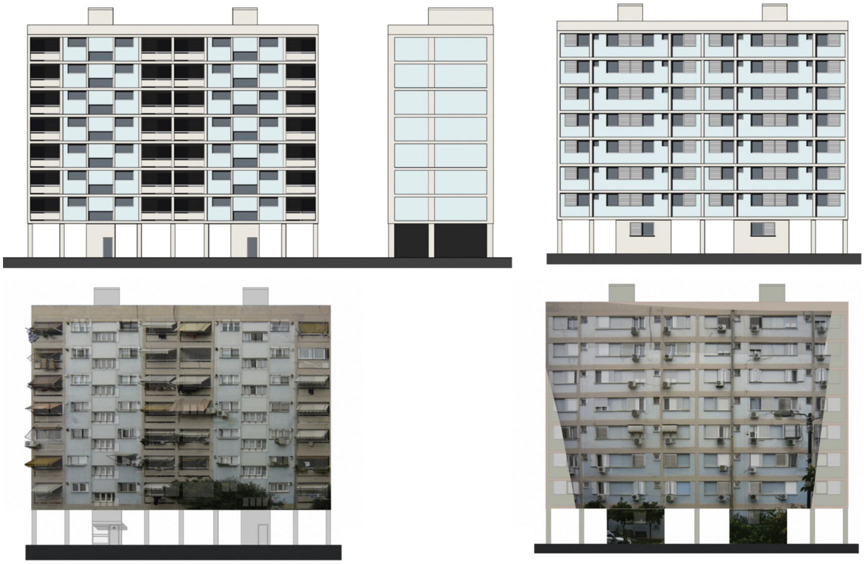


Figure 2.28 ***North and south facades and photographic reconstruction in the building block in Peristeri.***

center of the city; more specifically, the selected area is also enhanced by the presence of many public services like the municipal hall, several civic and administrative offices as well as the central Athens market.[15] A single urban compartment between via Sofokleous and Athinas Street formed by 11 adjacent building blocks – mainly residential housing – has been selected for further investigation. The majority of these buildings' blocks present one floor for retail at the ground level. The type of construction dates back to between 1965 and 1970 for almost all buildings, with the exception of the older buildings 4 and 6, which date back to the 1940s.

As observed, among the main differences between this case study and the previously examined urban compounds is the population density, clearly increasing from Aghia Varvara (11,000 inhabitant/km^2), through Peristeri (14,000 inhabitant/km^2) up to the center of Athens (18,000 inhabitant/km^2). Nonetheless, the most significant data to be considered in this case is the FAR, which reaches an extremely high value. In fact, while the

[15] The considered area of Psiri is surrounded by the streets Peiraios, Athinas, Evripidou, and Tsaldari. The total surface of the area is 105.116 m^2, of which 99.607 m^2 is occupied by buildings and infrastructure, while the remaining 5509 m^2 present small green spots and courtyards as fragments between the buildings. The analyzed area occupies a surface of 2.600 m^2, 2291 m^2 of buildings and 309 m^2 of interior courtyards. All buildings have a gross floor area of 11.249 m^2 (see Fig. 2.29).

calculated FAR for the Psiri district ranges from 2.5 to 3.5, the correspondent value of the selected area, considering it strictly within the borders of the surrounding streets, grows up to 4.33 (Fig. 2.29).

As for the previous case studies, all the supporting structures consist of a frame of reinforced concrete beams and pillars and opaque components of semi-perforated (hollow) masonry blocks (Figs. 2.30–2.32).

Figure 2.29 ***3D reconstruction of Psiri district and calculation of correspondent density expressed as FAR for the selected urban courtyard (darker).***

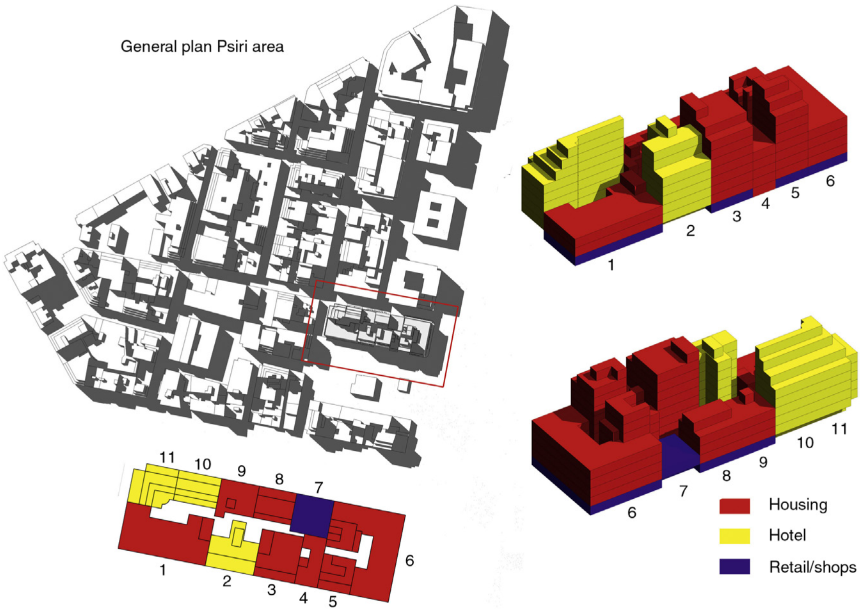


Figure 2.30 ***Site map and use destination of the selected buildings (darker, 7) in the urban courtyard of Evripidou.***

Taking into account the overall complexity that has emerged in the urban morphology of Athens, its unidentifiable urban character, the diffuse presence of gaps between buildings and the diverse building types, the selected representative urban settings can be assumed as different but replicaple units in the representation of the residential areas in the whole a city.

2.3.1 The Energy Demand in the Selected Urban Environments

The evaluation of the energy performance of existing buildings is necessary; it is the preliminary step toward defining the most appropriate solutions to reducing buildings' energy requirements and examining whether and how they can be turned into nearly zero-energy buildings. Thus, to study and evaluate the technical feasibility of nZEBs, the aforementioned real case studies have been analyzed by using simulation tools[16] to assess the energy

[16] All simulations have been performed by using Design Builder, a fully featured interface using EnergyPlus platform to detect energy, carbon, lighting, and comfort performance of buildings. EnergyPlus is the US Departments of Energy's third generation dynamic building energy simulation engine for modeling building, heating, cooling, lighting, ventilating, and other energy flows. It has been validated under the comparative Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs BESTEST/ASHARE STD 140.

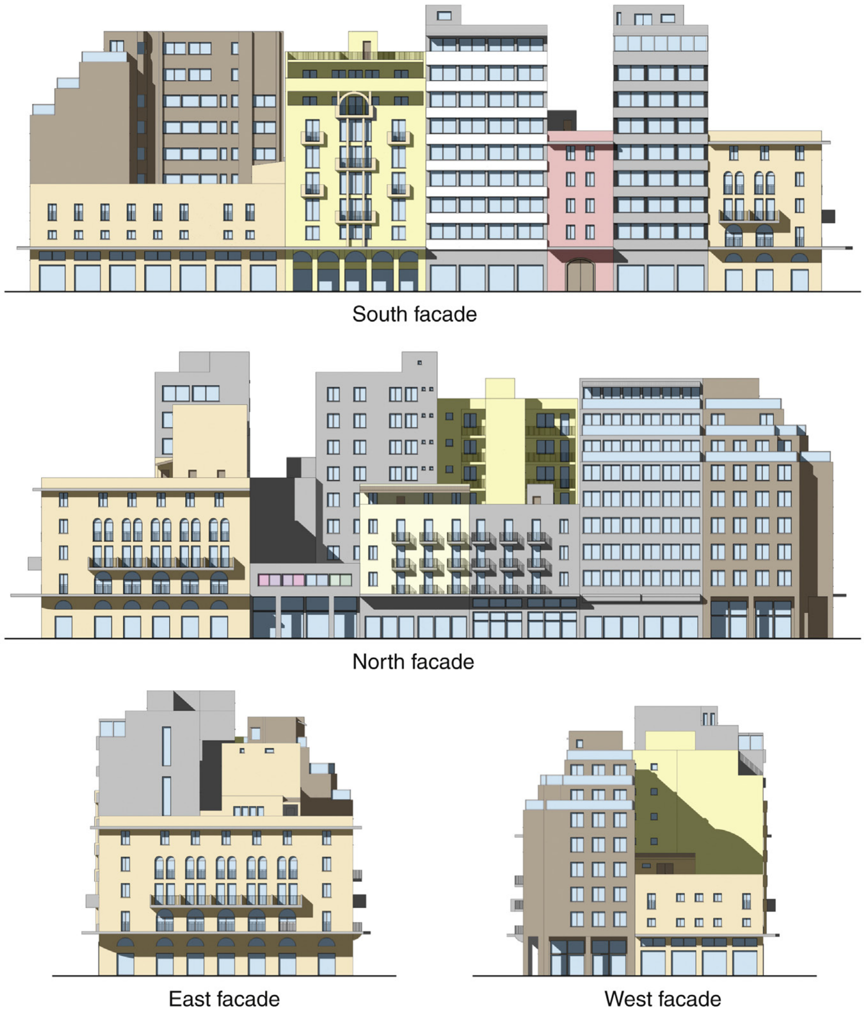


Figure 2.31 ***Buildings' elevations – south, north, east, and west oriented.***

performance in the as-built scenario. To run energy simulations in buildings, it is necessary to define the internal thermal zones of a built environment,[17] Thus, separate volumes for each building or set of buildings have to be identified as correspondent thermal zones,[18] In order to avoid an excessive

[17] A list of levels and sublevels from the building up to the division of opaque and transparent parts is generally created to run accurate dynamic simulations.
[18] 3D models for each case study have been developed to redesign the exact positioning of all opaque and transparent surfaces and climate data settings.

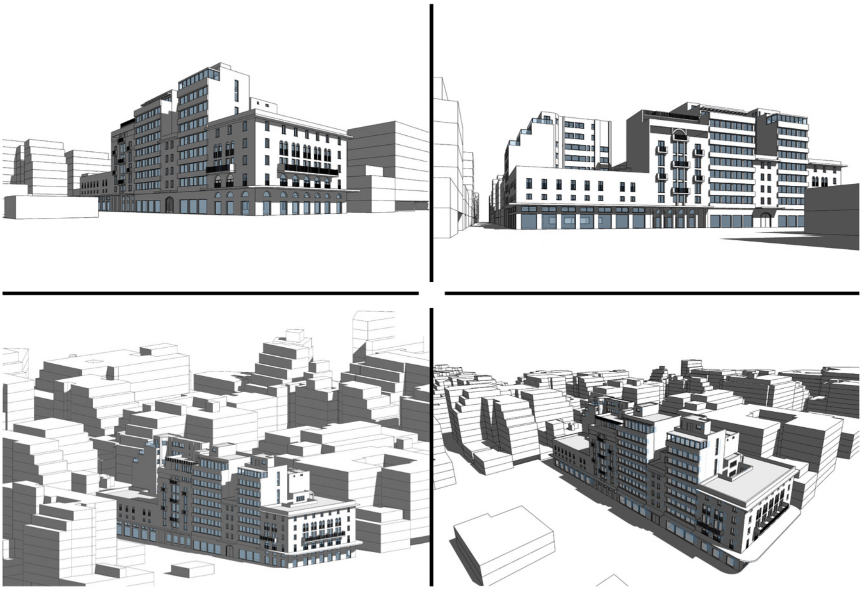


Figure 2.32 ***Reconstruction of the main 3D perspective views in the Evripidou urban courtyard.***

fragmentation of data and achieve comparable results among the case studies, a number of common input data has been assumed and estimated.[19] The operating programs of the systems follow the schedule indicated in Table 2.3.

[19] Among the common characters assumed for the different cases is the plant systems' equipment. Each building is assumed equipped with a central heating system using gasoil as fossil fuel. In all the visited building of Peristeri and Aghia Varvara cast iron radiators are installed in the rooms of the apartments, therefore they are assumed as terminal heating plant components in all case studies. In all the different urban settings, the ethnographic observation has showed how the majority of residential units (about 95%) are equipped with air conditioning units; some others (30–38%) use solar systems for domestic hot water. The light sources are mainly of domestic type, such as incandescent light bulbs or compact fluorescent lamps. All the buildings have a structure of reinforced concrete and exterior surfaces made up by hollow bricks and treated with plaster. Neither the flat roofs nor the vertical surfaces are insulated; in the majority of apartments the windows consist of aluminum frame systems and single glazed transparent components, prevailingly equipped with exterior shutters as windows' shading devices. The assumed operating program and the performance of the plant system do not affect the rightness of the conclusions because they have been kept constant in all simulations.

Table 2.3 The operating programs of the plant systems

Seasons	Heating	Cooling	DHW
Summer (Apr.–Oct.) (workdays and weekends)	Off (00.00–24.00)	On (00.00–24.00) (rooms) 07.00–23.00 (living, kitchen)	On/according to occupancy
Winter (Nov.–Apr.) (workdays and weekends)	On (00.00–24.00)	Off (00.00–24.00)	On/according to occupancy

Other common data inputs are: local weather data,[20] activity, occupation and ventilation,[21] which are characteristics of the plant systems. However, the existing differences among the scale, the consistency, and the building types of these urban contexts have implied a different approach in the degree of detail applied between them. Thus, different criteria have been conceived and adopted for determining the thermal zones in the different buildings in the energy analysis of the three case studies, following decremented level of details: from the more meticulous definition in the case

[20] A file containing all the hourly climatic data, as the dry bulb, temperature, wet bulb temperature, wind speed and direction, solar height, solar azimuth, atmospheric pressure, and direct and diffuse solar radiation is contained in the default weather data. These data have been compared with simulations performed in various climatic stations of the Athens metropolitan area (GRBES, Prof Santamouris) and, in particular with measures gathered in Peristeri urban compounds. Similarities among these data have lead to the conclusion that no necessary changes should be made at this stage of the analysis.

[21] The models reported the actual organization of the plan of the building, in the different level of detail specified after this note in the plain text. In each floor the different thermal zones assumed correspond to various rooms like kitchens, bathrooms, bedrooms, living rooms, and condominium areas like stairwells. The criterion chosen to make the partition into thermal zones was to differentiate rooms depending on the specific activities that are carried out in them. This made it possible to associate to each zone an activity program, built according to the average behavior of local users. The activity program defines the occupation times and ways, the use of appliances, the opening of the windows and the operation of manual or mechanical ventilation and it is used by Energy Plus to evaluate internal energy contributions. According to size and type, three up to six people usually occupies each apartment, thus a density of 0.05 people per m^2 has been assumed. The default occupancy program has been slightly changed to consider the specific composition of the dwellers: it has been estimated that about the 40% of the population is a non-working age residents, so most of them are present and carry out activities in their apartments during the whole day, while the 60% of the residents are working people and from Monday to Friday, between 9:30 am and 5:30 pm, are not at home. According to this, occupancy profiles were created for each thermal zone.

of the Aghia Varvara urban compound, through the intermediate level of detail energy investigations in Peristeri and finally, to a less definite scale in Evripidou central area.

Thus, for the case of Aghia Varvara,[22] the analysis has been conducted considering a *unit-oriented* subdivision of the main thermal zones, with the units relating to the representative apartments, which in turn have been evaluated in two separate environments consisting of day-living spaces and night areas.

Secondly, for the case of Peristeri, the analysis has been conducted considering both a *building type and apartments type* oriented focus, considering the main thermal zones corresponding to the single apartments, each one consisting in one single thermal zone.

Finally, in the Evripidou central Athens area, an *urban oriented analysis* has been developed to focus on the different energy performances of each building block. In this case, a more approximate subdivision has been operated, which consists of defining each floor in each building of the urban courtyard as a different thermal zone.

For both the two western urban settings of Aghia Varvara and Peristeri and the Evripidou urban courtyard, the following research tasks have been designed and developed:

- Evaluation of the overall energy performance and sensitivity analysis of its variability as a function of the different orientation of the buildings as well as of different internal distribution; simulations have been performed for each unit type.[23]
- Evaluation of the energy performance and sensitivity analysis of its variability related to the different arrangement of the surrounding buildings within the same urban compound.
- Results simulation and comparison in terms of comfort, energy contributions, and overall heat balance, in order to: (1) identify the main

[22] As described in the previous paragraph, Aghia Varvara RUE consists of a dense social housing urban complex of the 1960s, presenting a set of 15 similar residential buildings with different orientation and layouts; this aspect marks out this urban compound as the ideal candidate for a sensitivity analysis of energy simulations as a function of the different urban constraints and boundary conditions. In fact, all the buildings can be traced back to two similar layout models consisting of block buildings with two internal staircases serving four apartments in each floor per four floors.

[23] In Aghia Varvara units correspond to the residential apartments. Given the level of detail, in this case apartments have been subdivided in sleeping areas and living areas; in Peristeri units correspond to the apartments, while for the case study of Evripidou each floor in each buildings constitutes a different thermal zone.

critical problems affecting the building types, (2) classify them according to the their effects on the overall energy balance of the building, and (3) propose targeted solutions.

- Design of building refurbishment interventions and options in the selected reference building (presenting the worst energy and climatic response).
- Running a simulation of the effects that the alternative design scenarios would produce on the overall energy balance of the building, so as to understand the effectiveness of the different retrofitting options in terms of energy response.
- Final evaluation of the obtained results in terms of cost-effectiveness and quality.

2.3.1.1 Aghia Varvara

The main thermal parameters in Aghia Varvara are provided for the horizontal ground, intermediate, and roof floors as well as for the external building envelope. (Tables reporting the main thermal properties of the ground floor layers, the roofs, and the glazing components estimated for each building in each case study are reported in the Appendix)

As already specified, the real plan layout has been reported in the model, so on each floor, different zones have been created, which correspond to the various rooms: kitchens, bathrooms, bedrooms, living rooms, and condominium stairs.[24]

Detailed and articulated simulations have been performed for the "Type A" building,[25] considered in its four different configurations (named A1, A2, A3, and A4) and for all the types of residential units. These have been depicted and analyzed as a function of their different position in the building block (Fig. 2.33).

Thus, the energy performance has been evaluated both in relation to the buildings' orientation and the internal layout in each apartment type. In fact, to achieve a correct and efficient comparison, the different rooms have been considered merged in the two main categories of living space (consisting of a kitchen, a bathroom, and a living room) and sleeping area (bedrooms).

[24] The selected criterion to operate a proper partition into different thermal zones follows both geometrical and specific human activities carried out in each room.

[25] As described, the structural system of the similar buildings is very simple, made up by a regular grid of beams and pillars, with presumably prefabricated slabs as horizontal elements. The foundation mat leans on a concrete screed. The foundation has a waterproofing layer and no insulation is provided in the ground floor level.

Figure 2.33 ***Type A buildings in the Aghia Varvara urban compound.*** Different subtypes (A1, A2, A3, A4) are identified as a function of different exposures in relation to the sleeping and living areas of the single residential units.

This categorization, together with the existing different exposition of the building blocks A1, A2, A3, and A4 have formed a precise classification of main geometrical and thermal characteristics of each residential unit in relation to its position in the different building blocks. In particular, Table 2.4 shows the orientation of living and sleeping areas of the buildings as they are named, while, considering the type and the number of exposed surfaces (Table 2.5 and Fig. 2.34), the apartments can be classified according to common/recurrent characteristics. All the apartments present exposed surfaces as listed in Table 2.5, with an outdoor ambient area facing the external surroundings and one surface facing the common stairs, which can be considered as a semi-exterior unconditioned space (and they are represented as such in the model).

Simulations have been performed taking into account the main geometrical and construction building data (see the Appendix), the existing correspondence between different units' subtypes, and the different orientations (see Fig. 2.35).

Table 2.4 Classification of the building residential units as a function of different orientation of the internal thermal zones

Building	Living area facing	Sleeping area facing
A1	North	South
A2	South	North
A3	West	East
A4	East	West

Table 2.5 Classification of the building residential units as a function of different exposition and their different location within the building volume

Residential units	Exposed surfaces			
1	—	Side wall	Ground floor	2 facades
2	—	Side wall	—	2 facades
3	Roof	Side wall	—	2 facades
4	—	—	Ground floor	2 facades
5	—	—	—	2 facades
6	Roof	—	—	2 facades
7	—	Side wall	Ground floor	2 facades
8	—	Side wall	—	2 facades
9	Roof	Side wall	—	2 facades

Figure 2.34 ***Different residential units considered in the energy analysis.***

By means of the previously described classification, it is possible to identify the differences in the energy balances of apartments having identical geometrical characteristics, but different orientations. These simulations also document the proper understanding of the variability of situations from unit to unit in the different building blocks. The first pair of charts, which shows the behavior of living and sleeping areas of apartment 1 in building A1, are reported in Fig. 2.36. The sleeping area of the building A1 is south-oriented, thus it receives large solar gains. On the contrary, the living area is north-oriented,

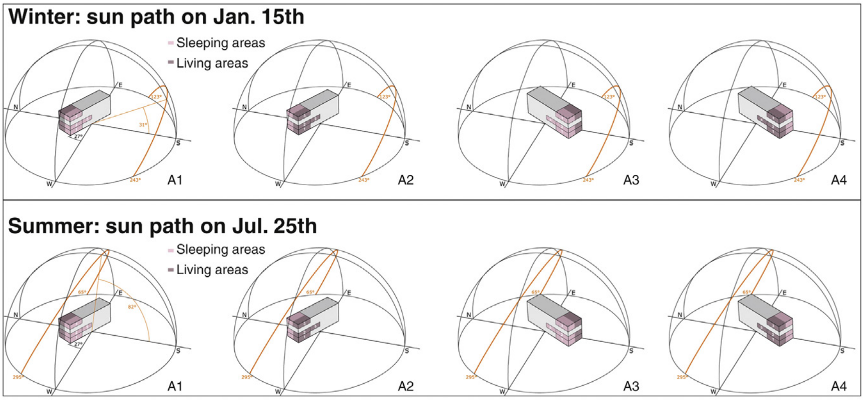


Figure 2.35 ***Solar path in cold winter season's and hot summer period's representative day in the four building types.***

thus it receives smaller solar gains through windows (about 40% of those received from the sleeping area). The high solar gains in the sleeping area help to lower the heating need of the area, which is still much higher than the other apartments and higher than the average of the building. This is due to the particular position in contact with the ground. However, in the living area, the solar gains are so small that they do not constitute a substantial reduction in the heating load. The second pair of graphs shows the energy balance of the same apartment type placed in the building with an opposite orientation, with the sleeping area facing north and the south-oriented living area. As observed, the behavior of the two zones is qualitatively similar to the previous case; in fact, from the graph, we see a similar trend, but results shown in Fig. 2.37 show important differences in absolute values.

All sleeping areas and living areas have the same geometrical and technical features, but the total exposed surface of the living area is approximately 40% greater than that of the sleeping area, and the total glazed surface of the living area is approximately 40% higher than the sleeping area in absolute value, as well. For this reason, in wintertime, the living area of building A2 receives 40% more solar gains through the windows compared to the sleeping area in building A1, although both of them are south-oriented; the opposite happens for the two complementary areas facing north. The case of building A2 presents a particularly favorable orientation because solar gains are concentrated in the living area, so they are properly exploited. In both cases, however, the higher solar gains imply a decrease of the heating; solar gains are obviously more effective in lowering the heating load of the whole apartment when they are concentrated in the living area. As shown in Fig. 2.37, in building A2, the 20% increase in daily solar gains led to a

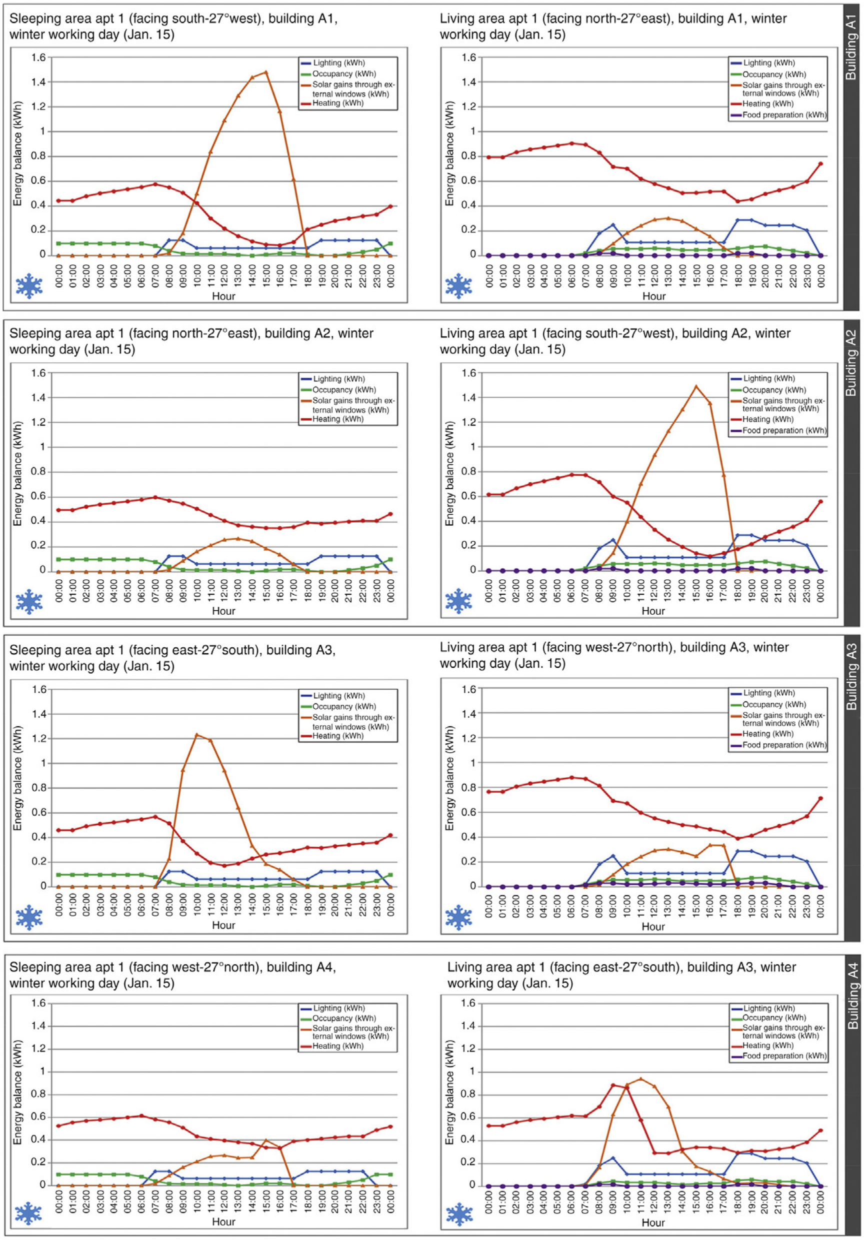


Figure 2.36 ***Charts of the simulation for the type unit 1 (ground floor) in the representative winter day.***

Apt1 (ground floor) winter		Facing	Exposed wall	Glazing surface		Glazing surface aligned with the outer wall		Lightning		Food preparation		Occupancy		Solar gains		Heating		
								max	daily tot	max	daily tot	max	daily tot	max	daily tot	max A.M.	max P.M.	daily tot
			m²	m²		m²		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
A1	Sleeping	S-W	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	—	0.099	1.134	1.233	5.896	0.568	0.352	9.309
	Living	N-E	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	0.335	2.339	0.878	0.567	15.891
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		8.235			25.2
A2	Sleeping	N-E	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	—	0.099	1.134	0.266	1.630	0.598	0.410	11.505
	Living	S-W	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	1.486	8.239	0.774	0.408	11.413
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		9.869			22.918
	Δ(A2-A1)								+0.00%						+19.84%			–9.06%
A3	Sleeping	E-S	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	—	0.099	1.134	1.479	8.615	0.576	0.333	8.708
	Living	W-N	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	0.302	1.851	0.905	0.598	16.691
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		10.466			25.399
	Δ(A3-A1)								+0.00%						+27.09%			+0.79%
A4	Sleeping	W-N	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	—	0.099	1.134	0.398	2.227	0.614	0.488	11.826
	Living	E-S	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	0.941	4.991	0.886	0.326	12.05
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		7.218			23.876
	Δ(A4-A1)								+0.00%						–12.35%			–5.25%

Figure 2.37 ***Numerical values and main difference in the energy performance of apartment type 1 in the four building configurations during winter.***

correspondent decrease of the heating load by 9%, compared to the same unit in building block A1, which shows an opposite result. The third pair of graphs shows the energy balance of building A3, which is perpendicular to building A1, with an east-27°-south-oriented sleeping area and opposite-oriented living area. Once more, similar to building A1, the wide solar gains are not exploited in an efficient way to decrease the heating load, because they are concentrated in the sleeping area. Despite major solar contributions, the heating load is almost the same as that in case A1. Similar behavior has been recorded for case A4 (last pair of graphs in Fig. 2.36). Between unit 1 in building A3 and unit 1 in A4, there is a parallelism similar to the one existing between the cases in buildings A1 and A2.

The same simulations have been performed for the type 1 unit in the different building blocks, but instead for a representative day of the hot summer season (Fig. 2.38). While in winter solar gains are a positive resource that help to offset the required energy loads for the heating system, in the hot summer season they greatly exacerbate the energy balance, as they contribute to overheating the internal spaces. The south-oriented sleeping area of apartment 1, building A1 (first pair of charts, on the left in Fig. 2.36) receives solar gains similar to the amount it receives in the winter, but during the summer they are concentrated in the afternoon. The north-oriented living area instead receives solar gains during the morning. Both thermal zones overheated just when people started to use them, so the comfort conditions are hardly achieved.

In general, as solar gains are of a greater magnitude, the load for cooling is more relevant, but in all the considered cases concerning apartment 1, the cooling loads are very low; this is because the position of the residential unit in contact with the ground strongly influences the heat balance of apartment 1. While in winter conditions this position increases the need for heating, in the summer season, the same position reduces the cooling need. The effect of

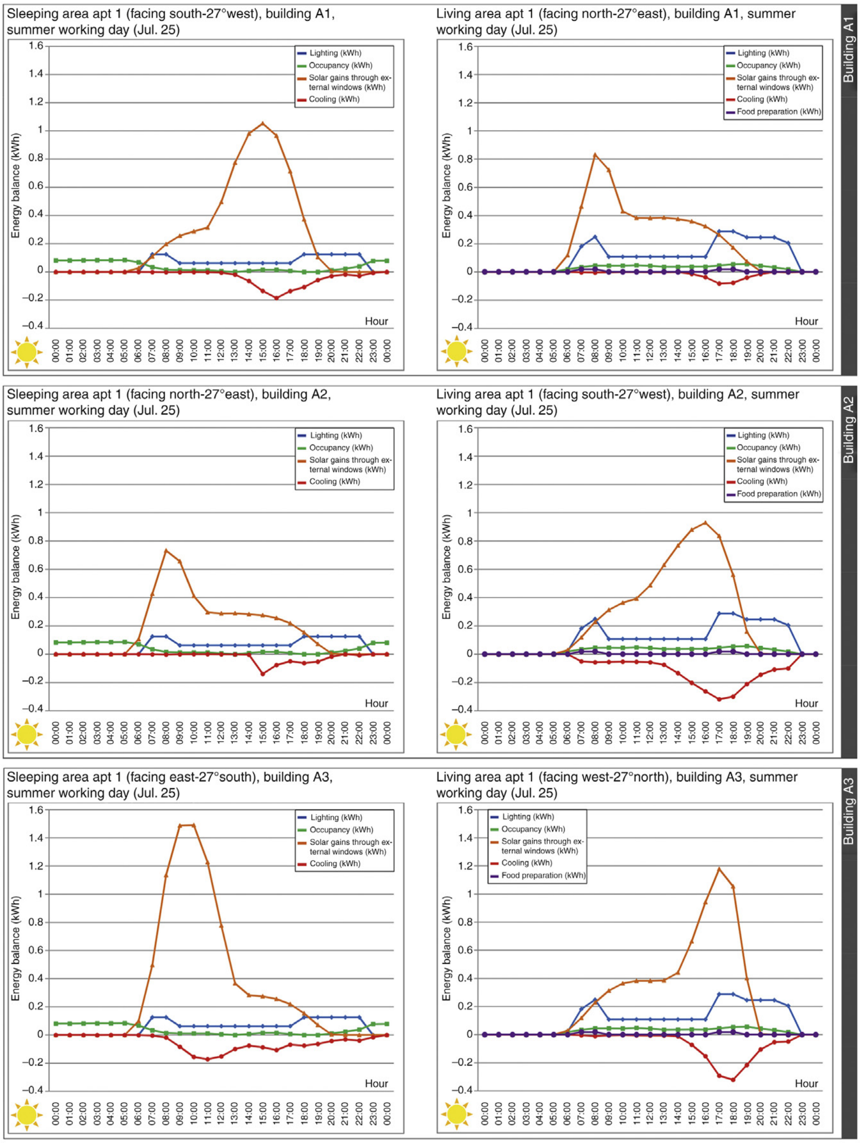


Figure 2.38 ***Charts of the simulation for the type unit 1 (ground floor) in the representative summer day.***

contact with the ground affects only the apartments situated on the ground floor and does not influence the other residential units (Fig. 2.39).

Conversely, larger differences are recorded due to the particular location of apartment 3, positioned just below the roof. Its position has direct consequences, especially in summer. In fact, from the graphs shown in Figs. 2.40

Apt1 (ground floor) summer		Facing	Exposed wall	Glazing surface		Glazing surface aligned with the outer wall		Lightning		Food preparation		Occupancy		Solar gains		Cooling	
								max	daily tot	max	daily tot	max	daily tot	max	daily tot	max	daily tot
			m²	m²		m²		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
A1	Sleeping	S-W	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	—	0.099	1.134	1.052	6.659	0.185	0.799
	Living	N-E	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	0.831	5.294	0.082	0.284
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		11.953		1.083
A2	Sleeping	N-E	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	–	0.099	1.134	0.732	4.467	0.177	2.821
	Living	S-W	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	0.929	6.696	0.320	2.187
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		11.163		5.008
	Δ(A2-A1)								0.00%						–6.61%		+362%
A3	Sleeping	E-S	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	—	0.099	1.134	1.490	8.341	0.172	1.284
	Living	W-N	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	1.178	6.888	0.321	1.310
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		15.229		2.594
	Δ(A3-A1)								0.00%						+27.41%		+140%
A4	Sleeping	W-N	31.59	3.92	12.41%	3.92	100%	0.125	1.437	—	—	0.099	1.134	1.383	7.146	0.277	1.385
	Living	E-S	45.06	6.04	13.40%	1.96	32.45%	0.287	2.828	0.016	0.083	0.069	0.788	1.213	7.477	0.206	1.855
	Total		76.65	9.96	12.99%	5.88	59.04%		4.265		0.083		1.922		14.623		3.24
	Δ(A4-A1)								0.00%						+22.34%		+199%

Figure 2.39 ***Numerical values and main differences in the energy performance of apartment type 1 in the four building configurations during summer.***

and 2.41, it is immediately evident that there is high overheating generalized to all the environments, with a consequent high cooling demand. The first pair of graphs in Fig. 2.40 shows the energy balance of apartment 3 in building A1, with the sleeping area facing south, which receives significant solar gains through the windows during the afternoon and, vice versa, the living area faces north and receives them in the morning. Assuming that the trend of the direct radiation on the roof is similar to that of direct solar gains through the windows, it explains the curve of cooling load in relation to that of solar gains. The second pair of graphs shown in Fig. 2.38 shows the same apartment in building A2. The sleeping area exposed to the north and the south-facing living area receive a total solar input through the windows of about 8% less, compared to the previous case, even if the same change in the cooling load cannot be seen. This outcome, together with high dispersions and energy intakes across the surfaces, implies that the energy balance of the apartment located below the roof is much more influenced by the effects of direct radiation on the roof than from the direct radiation entering through the windows. The graphs in Figs 2.40 and 2.41 show the performance of apartment 3 in buildings A1, A2, A3 and A4, which have an orientation perpendicular to the two previous cases.

Apart from quantitative differences depending on the difference in the glazing surface, areas with the same exposure have a similar behavior. Thus, east-oriented areas receive large solar gains during the morning; similarly, west-oriented areas show the peaks of their curves of cooling load in the afternoon. Looking at the quantitative values, the behavior of the apartments that are east-west oriented is similar, since in both cases, the quantities involved have a gap between them of less than 5%.

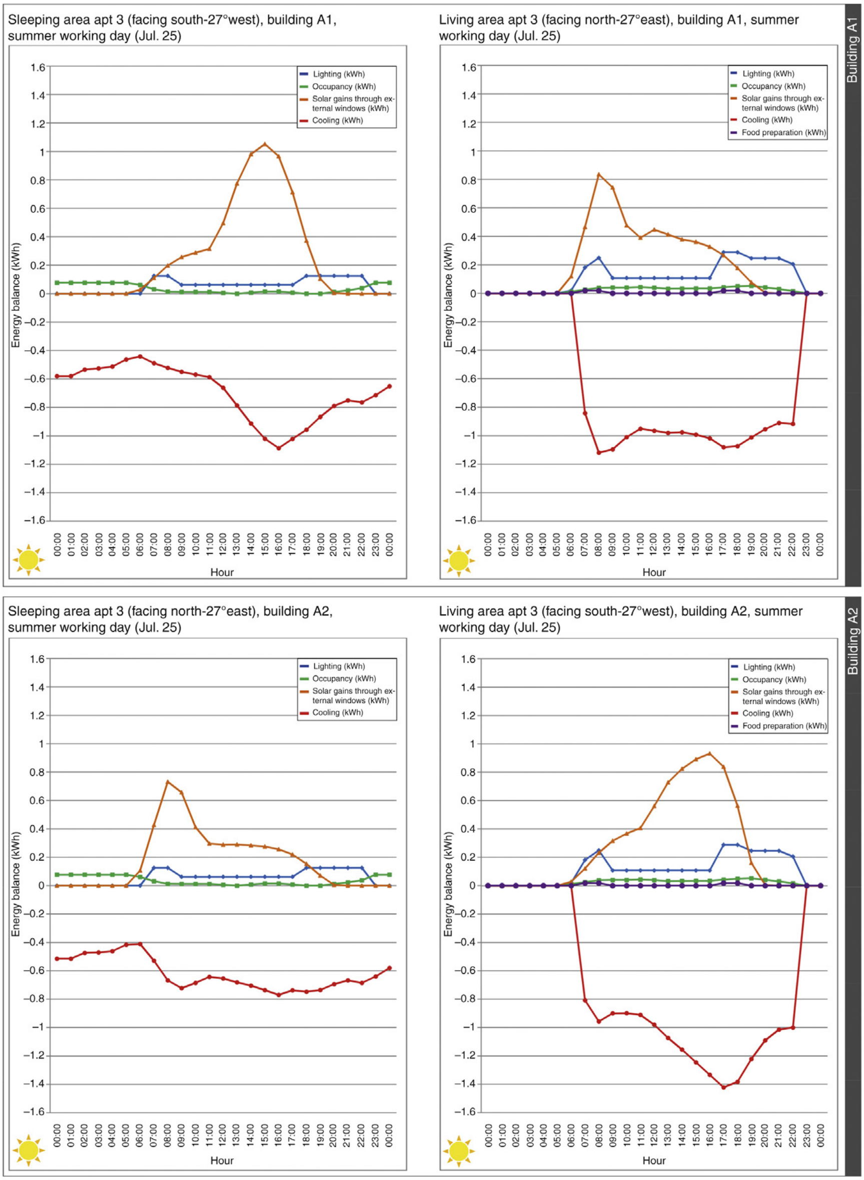


Figure 2.40 ***Charts of the simulation for the type unit 3 (under the roof) in building A1 and A2 in the summer representative day.***

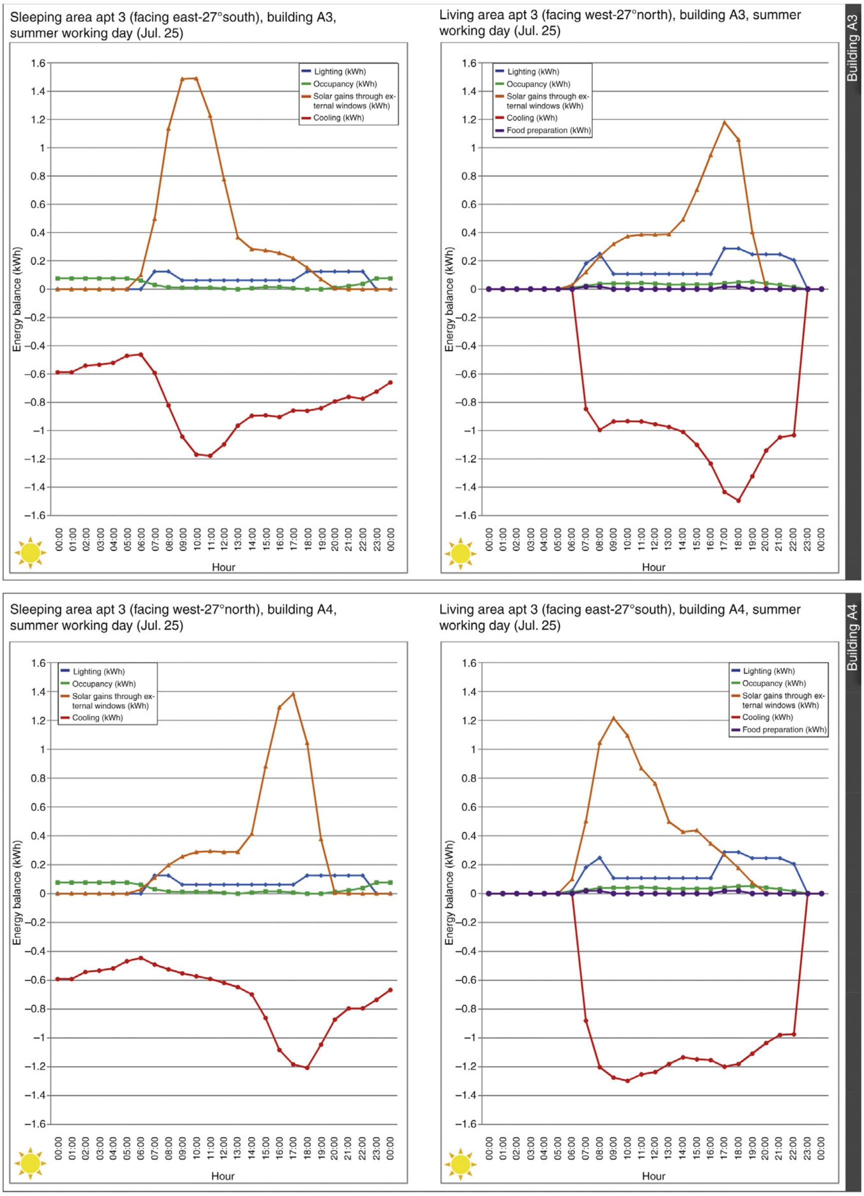


Figure 2.41 ***Charts of the simulation for the type unit 3 (under the roof) in building A3 and A4 in the summer representative day.***

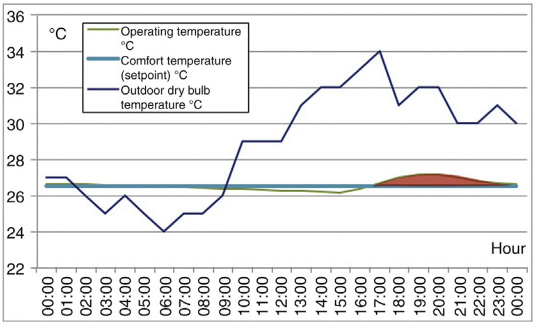


Figure 2.42 ***Overheating in the sleeping area of apartment 3, building A3.***

In the apartments located under the flat roof, despite the action of the cooling system, the overheating cannot be counterbalanced by the plant, which induces a state of high discomfort inside (Fig. 2.42). This occurs in all orientations, although some quantitative differences can be observed.[26]

Just as apartment 1 was strongly influenced by the contact with the ground, in the same way, apartment 3 suffers from its peculiar position. Apartments at the ground level are affected by aggravated winter conditions which are counterbalanced by improved comfort condition in summer; instead, the presence of the roof acts in both seasons, thus greatly exacerbating the balance both in summer and in winter conditions. Comparing the dispersion values and the contributions across the different surfaces, it is found that the roof generates higher dispersions in winter conditions and higher heat gains in summer conditions, compared to all other exposed surfaces. Comparing only the values of heating and cooling loads for apartments 2 and 3 in each orientation, there is a general increase of 20–25% for heating and 30–35% for cooling. This general consideration therefore applies to all the apartments placed on the top floor, arranged in any orientation. The same apartments in the building in the other two perpendicular orientations A3 and A4, while experiencing some slight advantage in winter conditions and in summer conditions respectively, are still less efficient; this occurs especially during summer, when the main facades are exposed to direct sunlight for most of the day, due to the building's axis inclination. The mutual comparison between the thermal balance and the energy

[26] The graph in Fig. 2.42 shows in detail the sleeping area of apartment 3 in the building A3: during the afternoon it can be noted that the internal temperature is still higher than the temperature of comfort, assumed to be 26°C in summer conditions (red area in the graph). In that time there has been a condition of discomfort and a feeling of warmth, but this difficulty cannot be overcome unless considering a general refurbishment program.

performance of different unit types in relation to the different building position clearly indicates that one of the most critical issues to be considered in the energy rehabilitation of the existing building is the roof level. Thus, we may assume that in the design phase of a refurbishment project, the evaluation of interventions aimed at improving the thermal performance in this specific area of the building is especially crucial.

The study carried out on building orientation allows researchers to assess the impact that a general choice like the orientation of the building has on the occupants' comfort and on the quality of the confined environments, as well as on the energy balance and on the future consumption, all as early as the design phase. The detailed information given in the simulation performed on a case-based and case-by-case variability basis is a necessary step toward producing tailored and more effective guidelines for energy-efficient retrofitting operations, in order to achieve nZEBs in existing buildings. Table 2.6 summarizes the obtained results in qualitative terms.

Considering *both* the winter and the summer conditions, the building oriented in a more efficient direction is the building A2, with the living area exposed to south-27° west and the sleeping area to north-27° east; this arrangement has been proved to achieve a fair energy performance by limiting the period of direct solar gains through the windows. As an alternative option, building A3, with a living area oriented at west-27° north and the sleeping area facing east-27° south, also showed fair performance. The east-west orientation is less energy-efficient than the previous orientation, but it still allows good utilization and control of solar radiation in both seasons. Throughout the analysis phase, the data were presented in terms of needs and contributions; however, according to the general aim, it is necessary to

Table 2.6 Qualitative evaluations of various orientations of the building residential units as a function of different orientations of the building blocks

	APT 1		APT 2		APT 3		APT 4		
Building	**WINT**	**SUM**	**WINT**	**SUM**	**WINT**	**SUM**	**WINT**	**SUM**	
A1	−	+	−	+	−	+	−	+	Generally negative
A2	+	+	+	+	+	+	+	+	Generally positive
A3	−	−	+	−	+	−	−	−	Generally negative
A4	+	−	+	−	+	−	+	−	Generally positive

deliver them in terms of indexes EPh (index of primary energy for heating in winter, which is the annual average energy requirements of the building for heating only per square meter) and EPc (index of primary energy for summer cooling), calculated according to their respective periods. They will then be used in the design phase to evaluate the effectiveness and performance of the interventions proposed.

The run simulations on the whole heating and cooling period shown are reported in Table 2.7; as can be observed, they are consistent with qualitative aspects reported previously in Table 2.6. These values have been calculated without considering the plants and thus represent the requirements of the building during the heated period (from Nov. 1 to Mar. 31) and the cooling period (that is the remaining period, from Apr. 1 to Oct. 31).

However, to properly assess the real energy consumption, systems cannot be ignored.

Considering the plants' contribution (assuming they have an efficiency $\eta = 0.85$, for the heating system plants and an energy efficiency ratio (EER) equal to 1,67 for the cooling system plant, consistent with the choices presumed so far), the amount of the corresponding indexes is reported in Table 2.8.

The simulations presented were carried out throughout the heating and cooling periods. In order to make the data more functional to the goal of

Table 2.7 Quantitative evaluations of the various orientations of the building residential units as a function of the different orientations of the building blocks

Building	EPh (kWh/m² year)	EPc (kWh/m² year)
A1	84	58
A2	78	59
A3	80	65
A4	77	63

Table 2.8 Qualitative evaluations of the various orientations of the building residential units as a function of the different orientations of the building blocks. Values include the plant systems' consumption

Building	$EPh_{(plant)}$ (kWh_t/m^2 year)	$EPc_{(plant)}$ (kWh_e/m^2 year)
A1	99	35
A2	91	35
A3	94	39
A4	91	38

this work, they have been presented in terms of daily data, using as a reference the days of Jan. 15th for the winter condition and Jul. 25th for the summer condition, as they have been identified as days having an average behavior for the relative seasons.

In addition, two weeks were selected as the weeks presenting the most extreme weather conditions (ie, they are the hottest and the coldest part of the year), because these weeks may point out particular aspects to be considered for the overall evaluation of building behavior under the worst climatic conditions. From the annual simulation, it is also noticeable that in the intermediate seasons near the period of switching on or off of the heating, the building as a whole requires a heating load and, at the same time, a cooling load. To reach the temperature and comfort set-points, there is the need to heat certain areas at certain times and to cool others (the data are obtained as sums of individual contributions and not as averages).

To obtain data comparable on an annual scale in order to numerically evaluate the performance of the various buildings and compare them with each other and with the results of similar studies, the indices EPh and EPc were chosen. They are calculated according to their respective reference periods and reported for the entire year. These benchmarks are useful to perform a comprehensive comparison between the buildings, but they incorporate a media operation that gives a good idea of the building's overall behavior, losing some detail in particular aspects. This means that, while it is correct to compare the performance of different buildings through their EPh and EPc, we can not expect to necessarily find the same values locally, that is, at the level of individual apartment.

Considering the presence of each apartment type within the same building block, the total EPh (kWh/m^2 year) and EPc (kWh/m^2 year) is obviously given by the mean value derived from the sum of all 16 apartments of the building. For the building block, these values are: EPh = 81.44 and EPc = 53.56.

Table 2.9 shows the value of EPh and EPc calculated for the different types of apartments, for example in building A1. The found values, and therefore the consequent consumptions, for the various apartments are very different from unit to unit and they may vary significantly from the value of the whole building. As shown, apartment 1, for example, is in contact with the ground and this greatly increases its heating requirement in winter conditions, but it also improve its summer energy performance; apartment 3, located on the third floor under the noninsulated roof, presents high heating and cooling load, especially in the summer because of the overheating of

Table 2.9 Qualitative evaluations of the mean energy performance indexes for the building residential units in building A1 for the winter and summer seasons

Apartment	EPh (kWh/m^2 year)	EPc (kWh/m^2 year)
APT 1	96	24
APT 2	71	66
APT 3	80	75
APT 4	96	24
APT 5	63	53
APT 6	80	75
APT 7	96	24
APT 8	71	66
APT 9	80	75

the roof due to direct radiation. The intermediate apartments such as 2 and 5 have some surfaces touching environments at their same temperature but also have a lower number of exposed surfaces, so their energy balances are lightened both in winter and summer conditions. Thus, to properly evaluate retrofitting interventions at building scale, by referring to the indices for the entire building, we should not forget the differences occurring at local level.

2.3.1.2 Peristeri

Taking into account the considerations developed for the previous case study, each building type has been split into different representative thermal zones corresponding to the real apartments of each building block.[27] The selection of the representative units (apartments) has been made according to both the position of the unit within the building block and with respect to the solar orientation, as shown in Figs. 2.43–2.45. As also described for the Aghia Varvara urban compound case study, the structural system of the buildings is very simple, made up by a regular grid of beams and pillars, with presumably prefabricated slabs as horizontal elements. The main thermal parameters provided for the horizontal ground, intermediate, and roof floors as well as for the external building envelope have been considered the same as the previous case study (see the Appendix). In the previous case study of the Aghia Varvara urban compound, the energy performance of residential units showed greater differences as a function of the position of the unit in relation to the building orientation.

[27] Tables reporting the main thermal properties of the ground floor layers, the roofs and the glazing components estimated for each building in each case study are reported in the Appendix.

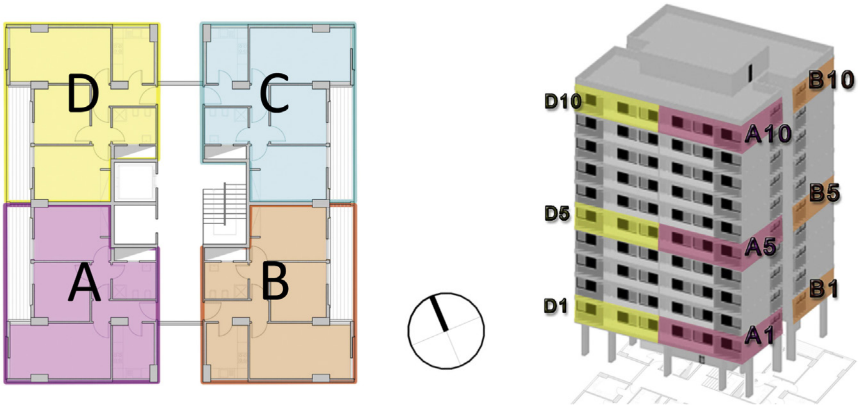


Figure 2.43 ***Apartments as thermal zones the tower building (T11) in the Peristeri urban setting.***

Figure 2.44 ***Apartments as thermal zones in the double block building (B6) in Peristeri.***

Figure 2.45 ***Apartments as thermal zones in the selected building block (T7) in Peristeri.***

Energy simulations have been performed for each building type, both in cold winter and hot summer seasons. The synthetic results for the tower building (T11), the double building block (B6), and the building block T7 are reported in Tables 2.10–2.12. The tables evaluate quantitatively the energy performance indexes of the single units as a function of their different locations within the specific building.

Table 2.10 Energy performance indexes of the different units in the tower building T11.

Apartment/thermal zone	EPh (kWh/m^2 year)	EPc (kWh/m^2 year)
A1	89	64
A5	75	54
A10	101	72
B1	100	67
B5	94	61
B10	113	73
C1	89	49
C5	75	43
C10	101	57
D1	99	52
D5	87	45
D10	107	62

Table 2.11 Energy performance indexes of the different units in the double building block B6

Apartment/thermal zone	EPh (kWh/m^2 year)	EPc (kWh/m^2 year)
A1	111	36
A4	89	42
A6	124	45
B1	115	40
B4	94	47
B6	129	49
C1	103	30
C4	82	34
C6	116	39
D1	107	33
D4	94	37
D6	129	43
E1	112	31
E4	90	31
E6	126	37
F1	107	29
F4	90	33
F6	125	38

To highlight the different energy demands of the single reference units as a function of both the position of the unit within the building block and the solar orientation, the graphs shown in Fig. 2.37 have been developed. As

Table 2.12 Energy performance indexes of the different units in the building block T7

Apartment/thermal zone	EPh (kWh/m² year)	EPc (kWh/m² year)
A1	113	89
A4	99	96
A7	167	106
B1	59	84
B4	71	89
B7	145	102
C1	84	95
C4	81	92
C7	170	102

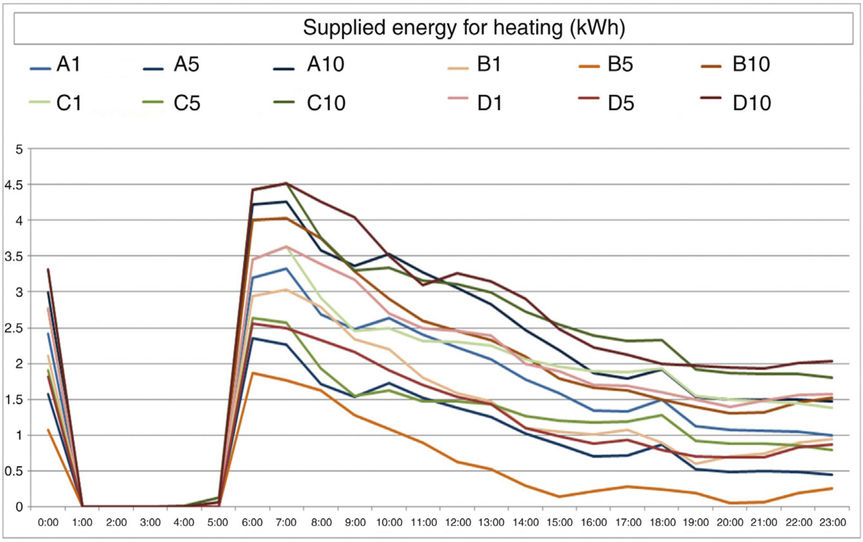


Figure 2.46 ***Different energy supplied in winter for the tower building.***

expected,[28] the most energy-consuming units (both in the summer and the winter season) are the apartments located on the upper floors, just underneath the flat roof of the building. Conversely, the less energy-consuming units (both in the summer and the winter season) are the apartments located on the intermediate floors. As an example, Fig. 2.46 reports the different levels of energy supplied for the representative day in winter time.

Again, substantial differences in the energy demand may also be observed by comparing the residential units in a same-floor location, but

[28] Similarly to the previous study case of Aghia Varvara.

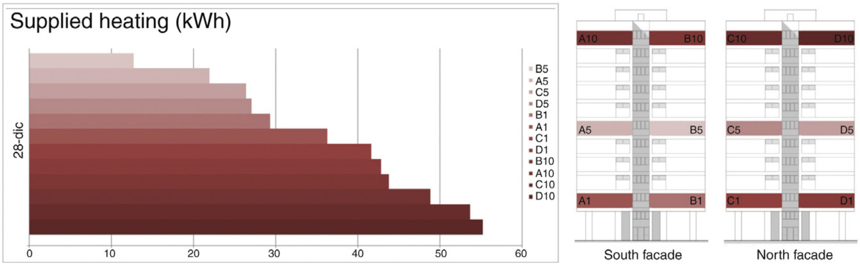


Figure 2.47 ***The graphs highlight the different levels of energy in the winter season of the reference units as a function of the position and orientation of the units within the building block.***

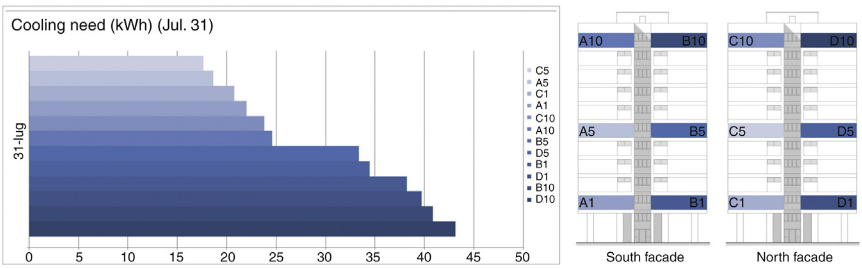


Figure 2.48 ***The graphs highlight the different levels of energy in the summer season of the reference units as a function of the position and orientation of the units within the building block.***

with different solar orientations. As shown on the right side of Figs. 2.47 and 2.48, south-oriented apartments are less energy demanding than the corresponding north-oriented ones, both in summer and winter conditions.

2.3.1.3 Evripidou

As indicated before, the case of Evripidou is different from the cases of urban stand-alone buildings like Aghia Varvara and Peristeri. In Evripidou, buildings were considered by their volumes, using some assumptions to simplify the implementation of the model as a whole courtyard at the level of the urban scale. In particular, it was decided to perform energy simulations for each floor of the building, with few considerations of the internal partitions of each of the residential units; however, all the partitions toward unconditioned spaces like stairwells and technical volumes were taken into account. Some additional partitions have been included inside the floor to simulate the existing thermal mass, thus achieving an approximate *facsimile* condition. Each floor in each building has been considered as a whole thermal zone with internal partitions assumed as internal mass. These hypotheses were chosen because they do not affect the objectives' results, since they are not considered a relevant error for the requested level of detail in the context of an urban energy investigation.

As mentioned, the subdivision of the planes was performed in a simplified way, identifying the unheated areas, such as stairwells and elevators, and realizing the approximate internal partitions of the different zones for each floor. Building construction elements, such as thickness and height of external walls and floors, have been imputed. Tables reporting the main thermal properties and the stratigraphic description of the building envelopes' components of the ground-floor layers, the roofs, and the glazing components estimated for each building in each case study are reported in the Appendix.

The input data described in the previous paragraphs have been included in the first dynamic simulation to determine the thermal energy demand and, subsequently, the energy required to maintain internal thermal and comfort conditions. Several physical factors have been considered in addition to the external air temperatures: solar gains, direct gains for occupants, lighting, computer and equipment contributions, and so forth. The final results are presented in graphical form: along the abscissa is the time interval and along the *y*-axis are the measurement units of the chart objects (temperature, radiation, etc.). The main data categories can be grouped by: location (site data), thermal comfort, internal contribution, annual heating, and ventilation systems.

To analyze these data, references have been made to the first building, simulated considering the whole annual period (see Fig. 2.48) summary data tables have been exported via Excel and calculations have been performed for all of the buildings, to be assessed on the total consumption. In Table 2.13, mean energy performance values are illustrated for winter and summer energy demand.

The results' analysis in the as built conditions is reported in Table 2.13.

2.3.1.4 Brief Notes on the Energy Demand in the Different Urban Settings

The performed analyses show the paramount importance of bioclimatic approach in the planning and design to pursue the goal of a low energy-consuming built environment. The site, the building orientation, the organization of the blocks, and the single units inside them play a very important role in determining the energy consumption and its variation. Unfortunately, when we deal with existing built environments and buildings, all

Table 2.13 Calculation of the winter and summer needs of all analyzed buildings (as built scenario) in Evripidou

Buildings	EPh (kWh/m² year)	EPc (kWh/m² year)
1	54	39
2	57	35
3	33	38
4	59	45
5	47	41
6	43	31
7	70	49
8	53	42
9	24	19
10	39	38
11	43	41
Mean values	47	38

these passive components are not variables to be defined, but they are already defined as critical features or potential strengths and they can only be used as input for the design stage of refurbishment intervention.

However, despite the very different contexts under study and the diverse levels of energy demand registered between the single units forming the building blocks and the urban settings, a general deduction arises from the comparison of the main physical and energetic variables we are facing with highly energy-consuming buildings. In the urban context, the energy performance indexes are variable between 44 and 88kWh/m^2 year for heating demand and between 36 and 100 kWh/m^2 year for cooling demand. Lowest values of energy demand in the heating and summer can be observed in the case of Evripidou, given by the dense urban form and by a very low the ratio (Ae/V)= 0.27, as seen in Section 2.1.1 at the beginning of this chapter

Overall, performed calculations denoted high-energy consumption as given by the sum of both cooling and heating demand, in turn derived from the typical climate of Athens (with very hot summers but also cooler winters) and the very low quality of buildings' construction components associated with the poor energy performance.

2.3.2 The Energy-Saving Potential of Retrofitting Options

Notwithstanding the limitations encountered in existing urban contexts, many are the possible retrofitting options to reach energy savings in the renovation process of existing buildings.

Generally, "energy retrofit" or "deep energy retrofit" to achieve nZEBs implies replacing existing systems in a building or in a set of buildings with similar, higher performing and higher quality systems to achieve a consistent reduction of energy consumption in the existing building.

In this framework, a profound and transversal debate is occurring among researchers, practitioners, urban planners, designers, energy managers, and main stakeholders on the building construction market on whether it is necessary that these buildings be renovated "deeply" or not. Agreed definitions of deep renovation (retrofit/refurbishment) and the major challenges surrounding this issue are discussed by Shnapp et al. (2013) and Bettgenhäuser et al. (2014). According to these sources, it is a prerequisite that existing buildings are renovated "deeply" for the building sector to meet global energy reduction objectives.[29] Based on the findings collected in these research studies, definitions relating to deep renovations were established by Shnapp et al. (2013).[30] *Deep renovation* or *deep energy renovation* is a term for

[29] The global building performance network's (GBPN) mission is to dramatically reduce the energy use of existing buildings and consequently reduce the GHG emissions associated. GBPN facilitates this by following a "deep energy efficiency scenario."

[30] Deep refurbishment or deep energy refurbishment means to bring something back to its original good state and if such a process should be deep, it will include a very substantial improvement of the energy use and will bring the building beyond the original energy efficiency. Many possible definitions are reported in Shnapp et al. (2013): (1) deep reduction or deep energy reduction is a term used in the United States for a deep renovation or a deep refurbishment, which aims at more than 75% reduction in energy use in comparison with that prior to the improvement; (2) zero-carbon-renovation: A deep renovation with large-energy consumption reductions, where the energy needed to supply the resisting need is carbon neutral; (3) zero-energy-renovation: A deep renovation with large-energy consumption reductions, where the energy needed to supply the resisting need is supplied as renewable energy on site. Furthermore, other definitions based on relative targets are reported to support the clarification of deep renovation projects and can help to separate the level of ambition in DR projects. They are: Factor Two or Factor 2 Renovation: A renovation with energy consumption reductions of 50% compared to prerenovation performance; Factor Four or Factor 4 Renovation: A deep renovation with energy consumption reductions of 75% compared to prerenovation performance; Factor Six or Factor 6 Renovation: A deep renovation with energy consumption reductions of 84% compared to pre-renovation performance. The most commonly used expressions are: deep renovation, deep retrofit, deep refurbishment, and to a lesser extent, deep reduction. The problem is that these expressions mean different things to different analysts. In the report a "standard renovation" or refurbishment is defined as the one harvesting the minimum possible energy savings, ranging between 20% and 30%. Conversely, by renovating deeply, using state-of-the-art technologies, it is possible to reduce the energy consumption of a building by more than 75%. The primary energy consumption includes energy used for heating, cooling, ventilation, hot water, lighting, installed equipment and appliances. After the deep retrofit the buildings energy reduction is 50% or more compared to the status of the existing building/s the retrofit. (GBPN/definition mainly used in the United States).

a renovation that captures the full economic energy efficiency potential of improvement works, with a main focus on the building shell, of existing buildings that leads to a very high-energy performance. The renovated buildings energy reductions are 75% or more compared to the status of the existing building/s before the renovation. The primary energy consumption after renovation, which includes, *inter alia*, energy used for heating, cooling, ventilation, hot water, and lighting after the deep renovation of an existing building is less than 60 kWh/m^2/year (GBPN/definition often used in Europe).

Recalling the EU EPBD introduced in Chapter 1, a new "nearly zero energy" building[31] is assumed as a building that has a "very high energy performance," with a nearly zero or very low amount of energy required to be covered by energy from renewable sources. Following this assumption, the basic principle inspiring retrofitting solutions toward nearly zero energy appears to consist of a threefold direction, which in turn follows three specific, but concurring, objectives:

1. The reduction of energy requirement for heating and cooling through passive interventions on the building envelope
2. The use of renewable energy sources to cover consumption and to feed plant systems
3. The reduction of consumption by improving the efficiency of the plant systems

The order of these listed actions (1, 2, 3) is not a secondary element if we consider the common building practice. As a matter of fact, because of a shorter life cycle time compared with other architectural and constructive components or solutions[32] and lower payback time,[33] plant systems are commonly seen as the first option to be considered in the retrofitting of existing

[31] Article 2(1a) gives a qualitative definition of what a "nearly zero energy building" is: "A 'nearly zero energy building' is a building that has a very high-energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources (RES), including energy from RES produced on-site or nearby."

[32] While architectural and technological solutions may have a life-cycle time close to 30–50 years, plant systems' life is commonly assumed to be close to 10 years. Thus, after this time they are usually considered obsoleted. Furthermore, generally mechanical plant systems are part of an industrial production sector affected by faster and shorter renovation processes compared to typical industrial components of the building sector market, which usually suffer from more inertia toward changing.

[33] Economic aspects and consequent economic feasibility of solutions is discussed in the Chapter 3.

buildings. Thus, taking into account these practical considerations, in a possible step-by step renovation, a more probable order could be the following: 3, 2, 1 (namely: 3. reduction of consumption by improving the efficiency of the plant systems; 2. the use of renewable energy sources to cover consumption and to feed plant systems; 1. reduction of energy requirement for heating and cooling through passive interventions on the building envelope). Nonetheless, considering our final mission to achieve nearly ZEB in urban settings, this last hypothesis would lead to the unavoidable oversized dimensioning of the plant systems. In the present work, preference has been given to the technical consistency and efficiency of a one-step renovation (or a step-by step renovation based on logical, technically-based, follow-on steps) regardless of other practical-based aspects. We do believe that this approach is the most consistent with respect to the final mission of progressing toward nearly zero energy built environment.

Thus, to evaluate the technical feasibility of the possible energy retrofitting options in our urban settings, a series of transformation – gradually increasing, from the sectorial single intervention up to the far-reaching and combined scenarios – have been considered on the different building types. These transformations produce the following possible scenarios:

Scenario 1: Wall insulation (external walls, ground floor, and lower floors on “pilotis” when applicable)

Scenario 2: Window replacement with high-performing glazing components

Scenario 3: (3 = 1 + 2): Combined scenario

Scenario 4: Roof insulation[34]

Scenario 5: Roof insulation and green roof[35]

Scenario 6: (6 = 3 + 5): Combined retrofitted scenario

Scenario 7: New plants and energy generation by renewable energy sources

Scenario 8: (8 = 6 + 7): Complete retrofitted scenario

We will limit our investigation to the scenario number 6, thus considering the technological modifications applied at the building shell level. New

[34] This is generally achieved using layers of polystyrene to avoid additional loading on the existing structures.

[35] The retrofitting operation consist in the positioning of: (1) a layer of anti-root membrane, (2) a drainage layer and a filter layer, and (3) the moist soil that can be planted with grass or small shrubs, with underground watering system. Table 2.14 shows the change in building performance through indexes EPh and EPc and the resulting changes in terms of consumption and consumer spending, in reference to the apartment type for the whole year.

plant systems associated with the renewable sources to set to zero the energy balance of existing buildings are described next.

Notwithstanding slight and negligible differences depending on the specificity of building types and geometry, in all the case studies, simulations performed have suggested that architectural and technological components are the building sections where the possible energy retrofitting operations should be concentrated, namely, the roof level, the windows, the facades, and the ground floor.

In a Mediterranean climate like Athens, the passive solutions selected have to be able to address both insulation requirements and the building's need for thermal inertia. Hypothesized solutions for opaque envelope components (wall, ground floors, and roofs) should therefore consist of retrofitting both dense and highly massive coating materials to achieve the improved thermal performance in both hot summer seasons and cold winter periods.

To evaluate the effectiveness of the proposed solution, a simulation of the building before and after the intervention was carried out annually, and indexes of primary energy for heating in winter (EPh) and for summer air conditioning (EPc) were calculated and used as a benchmark for assessing the effectiveness of the intervention. These interventions also have been evaluated from an economic point of view, considering the amortization time of the investment (see Chapter 3).

For all these evaluations, no changes in the systems or in the user profiles have been introduced to properly and equally compare the consequences of the variable design choices as assumed in the design retrofitting operations. Before proceeding with the choice of the insulation and window frames, some tests were performed to determine the appropriate thickness. Finally, the option of a heat-proofing, 10-cm thick insulation system for the external vertical walls and on the roof has been selected. Higher performing windows with 4-mm thick double glass and an air layer of 12 mm were considered.

Two different options also have been considered for the insulation of opaque elements (walls and floors): polyurethane foam panels on the one side and, on the other side, more dense autoclaved aerated concrete (AAC) and mineral-based, nonfibrous panels, ideal for the thermal insulation of external walls in the winter and summer seasons. These panels also present more stability and fire resistance; they are more transpiring, thus avoiding the risk of mold growth by internal humidity. The choice of these kinds of panels is mainly due to the improved thermal behavior in summer conditions with respect to the polyurethane foam expanded panels, which, on their side, present some advantages in cold winter conditions. This is illustrated by the fact that the chosen insulation panels have a high density, which increases the mass of the opaque envelopes. Thus, the resulting construction will increase its performance in summer by restraining the effects of oscillation of external surface temperature caused by solar radiation and external air temperatures.

In existing buildings, while for vertical walls denser and highly thermal-resistant materials (like AAC panels) are preferable, for flat-top roofs, polystyrene panels that avoid additional loading on the existing structures are the more desirable option. A detailed stratigraphic description of the building envelopes' components applied for the different retrofit options is reported in the Appendix.

2.3.2.1 Aghia Varvara: Energy Retrofitting Scenarios

As a result of the simulations performed in the analysis phase, building B has been identified as the worst in terms of orientation and layout of the surrounding buildings, and therefore it has been used for further investigation of the energy retrofitting options. Following the unit-oriented energy analysis adopted for the energy analysis of the as-built state in the case study of Aghia Varvara, with the units consisting of single apartment, to investigate the energy saving of each retrofitted option, we should have referred to the different type of apartments.

Nonetheless, although some retrofitting operations may be done in the single apartments, the majority of them (namely the new building coatings for the opaque envelopes, the insulation of roofs, or green roofs, etc.) have to be considered as interventions to be applied on whole buildings.

For all the proposed intervention, a table showing the indices EPh and EPc (summer and winter consumptions before and after the intervention and the cost for consumption) has been reported. As shown in the energy analysis, for the case study of Aghia Varvara, the major critical surfaces are the external flat roofs; they receive the larger amount of solar radiation during summer period and are responsible for the majority of heat loss during winter. Thus, in this case, the proper insulation of the roof has been proposed as a step assessed individually, because of: (1) the simple technical implementation of the material operation; (2) the small economic entity involved; and (3) the great potential to lead to great advantages in terms of energy savings.

As an alternative to the choice previously selected, a further simulation has been performed to assess whether a green roof could yield better performance, by being able to decrease the thermal transmittance both by decreasing the thermal capacity and increasing the mass. It has been found that intervention leads to an improved building performance in both winter and summer conditions and leads to the consequent decrease of energy costs. However, the energy performance improvement appears to be similar to that obtained by the roof insulation, although some benefits of this solution, both to the heat island reduction as well as the environmental benefit, have been disregarded by the performed calculations expressly related to the building's energy demand. Different costs between the two options are discussed in Chapter 3.

An optimized solution could be to contemplate using a combination of insulating polystyrene panels and a green roof. Of course no single retrofitting operation is able to achieve a substantial energy improvement. Thus, the combination of multiple interventions on the building envelopes has to be investigated.

Since thermal dispersions/gains through the transparent surfaces are very relevant and comparable to those through the roof, a further scenario has been hypothesized that considers the replacement of the existing aluminum frames with single glass, along with the new window components described in the previous paragraph. The replacement of windows, together with the roof insulation, has been also investigated.

The last retrofitting scenario consists of the combination of thermal insulation on vertical surfaces, roof insulation, and window replacement; the retrofitting operation is based on the construction of a thermal insulation made by external panels of stone wool, with settlement of the ground floor, and including the subsequent restoration of the exterior plaster and window thresholds.

EPh and EPc indexes (kWh/m^2 year) for summer and winter consumptions before and after each retrofitting intervention are reported in Table 2.14.

2.3.2.2 Peristeri Energy Retrofitting Scenarios

Similar investigations have been performed for the possible energy retrofitting scenarios of existing buildings in the Peristeri urban compound. In this case, consistent with the building-type oriented energy analysis adopted for the as-built state in the specific case study, to investigate the energy savings of each retrofitted option, we referred mainly to the different building types. Results of performed simulations are synthetized in Figs. 2.49–2.51.

In Peristeri, the three different building types have been analyzed with different levels of simulations quantifying all the encountered variants in

Table 2.14 Total energy demand in the different urban contexts

Urban setting	Aghia Varvara	Peristeri	Evripidou
Number of buildings	15	12	11
Total square meters (m^2)	18,396	27,368	12,233
EPh (heating) (kWh/m^2 year)	78	88	44
EPc (cooling) (kWh/m^2 year)	55	99	36
Thermal energy consumption (winter) (kWh year)	1,677,282	2,817,456	533,043
Electric energy consumption (winter)	0	0	0
Electric energy consumption (summer)	600,348	1,651,705	438,063
Total thermal energy consumption	1,677,282	2,817,456	533,043
Total electric energy consumption	600,348	1,651,705	438,063

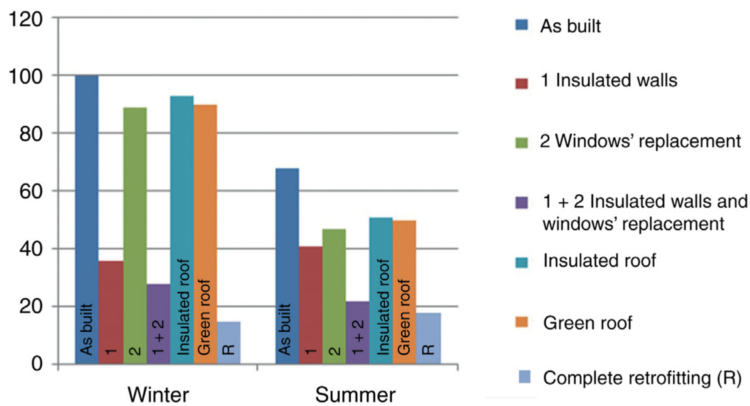


Figure 2.49 ***Possible energy retrofitting options in the tower building and correspondent savings in terms of energy performance indexes (kWh/m^2 y).***

buildings and apartment types, in order to identify the most appropriate retrofitting actions to achieve reduction of energy consumption up to nZEB in existing building blocks; the detailed diagnosis of the individual residential units, similar to the previous case study in Aghia Varvara, have shown that, in some cases, it is possible to reach an average energy performance (EP) of up to 20–15 kWh/m^2 y by insulating opaque surfaces – roof and walls – and replacing existing windows.

2.3.2.3 Evripidou: Energy Retrofitting Scenarios

As for the previous case studies, for Evripidou the single retrofit options also have been selected and combined in an attempt to find the best compromise

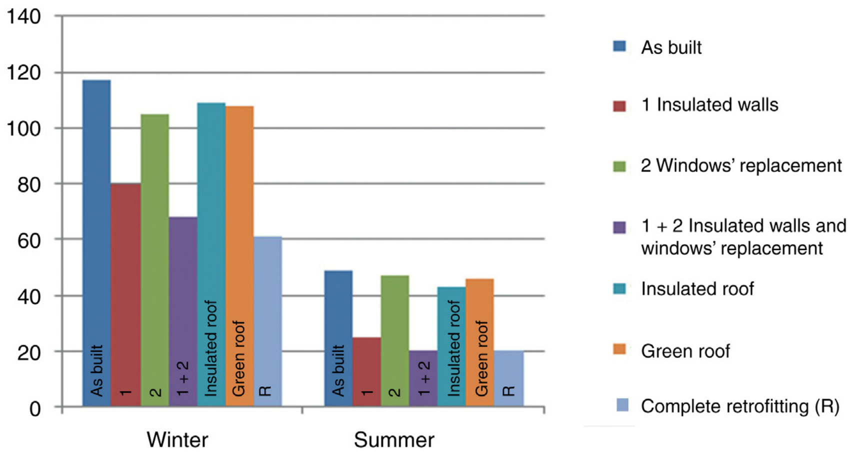


Figure 2.50 ***Possible energy retrofitting options in the double block and correspondent savings in terms of energy performance indexes (kWh/m² y).***

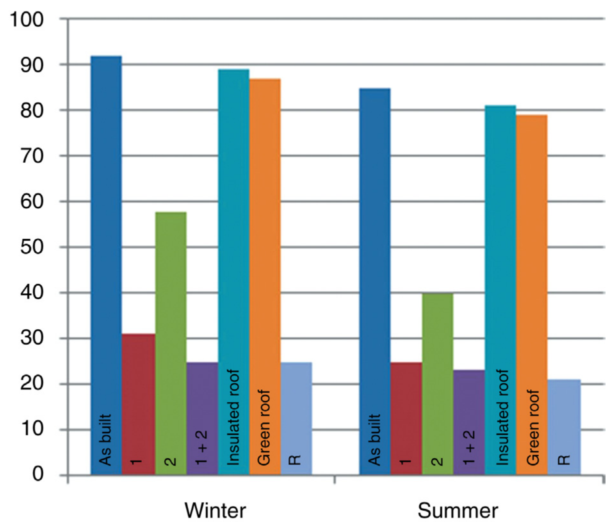


Figure 2.51 ***Possible energy retrofitting options in building block (T7) and correspondent savings in terms of energy performance indexes (kWh/m² y).***

between the different (and often conflicting) winter and summer demands, with existing constraints limiting the possible retrofitting actions in the existing buildings.[36]

High performing windows with 4 mm double glass and an air layer of 12 mm have been hypothesized in the Evripidou case study.

[36] In example, the polyurethane insulation on the roof while having characteristics of low thermal inertia has been considered preferable for the reduced weight with respect autoclaved aerated concrete (AAC).

Before proceeding with a simulation including all the designed retrofitting options, the same options have been analyzed separately, in order to understand and select the highest performing solutions. A detailed analysis for each scenario has been performed for all 11 buildings in the selected area, thus obtaining, for each building, the energy requirements in both the summer and winter periods. Furthermore, an economical analysis taking into account the cost of operations and retrofitting options has been developed with reference to each building (see Chapter 3). The tables mentioned later report the performed calculations for building 1.

The same calculations have been performed for all 11 buildings in the selected urban courtyard in Evripidou. From the mutual comparison between the tables, the following conclusions can be drawn:

- The insulation of the vertical walls through external coatings is more or less convenient depending on the orientation of the individual buildings. It does not present the greatest advantage during the hot summer season.
- The roof insulation always represents an excellent intervention.
- The green-insulated roof produces a slight disadvantage in winter.

Among the interventions, combination number 3 produces the greatest benefits: compared to the insulated roof, or the isolated green roof, consumption is much lower and savings are increased by up to three times as much.

2.3.2.4 Comparing Energy Retrofitting Scenarios

In all the case studies considered, the calculations have shown that it is possible to reach an average EP of up to 15 kWh/m^2 y by insulating opaque surfaces – roofs and walls –- and replacing existing windows (Tables 2.15–2.19).

A complete and comprehensive calculation has been performed for obtaining the global energy demands in the urban complexes considered as case studies in the Athens area.

Table 2.20 illustrates the different components of energy consumption in the scenario as built and after the complete renovation of all the buildings given by the retrofitting scenario number 6 (6 = 3 + 5), the combined scenario consisting of wall insulation, window replacement with high performing glazing components, and the insulated and green roof. A reduction in energy consumption that varies between 33 and 31% is the result. It shows how a huge potential for energy savings can be realized by renovating the existing building stock.

Table 2.15 The indices EPh and EPc (summer and winter consumptions before and after each retrofitting intervention)

Building type 1 in Aghia Varvara: gross surface 928 m²				
	WINTER		SUMMER	
Retrofitting option	Q (kWh/y)	EPh (kWh/ m² year)	Q (kWh/y)	EPc (kWh/y)
As built	78,880	85	62,176	67
1. Insulated walls	64,029	69	55,632	60
2. Windows' replacement	68,680	74	52,352	56
3. 1 + 2	53,829	58	45,808	49
4. Insulated roof	72,379	78	57,855	62
5. Insulated green roof	73,318	79	57,857	62
6. (6 = 3 + 5)	48,266	52	41,488	45

Table 2.16 Retrofitting options in the tower building (T11) and corresponding energy savings

Building type: tower (T11): gross surface 3560 m²				
	WINTER		SUMMER	
Retrofitting option	Q (kWh/y)	Epw (kWh/ m² year)	Q (kWh/y)	Ep (kWh/ m² year)
As built	302,600	100	205,768	68
1. Insulated walls	108,936	36	124,066	41
2. Window's replacement	269,314	89	142,222	47
3. 1 + 2	84,728	28	66,572	22
4. Insulated roof	281,418	93	154,326	51
5. Insulated green roof	272,340	90	151,300	50
6. (6 = 3 + 5)	45,390	15	54,468	18

The calculations illustrated in Table 2.20 result in the global annual electric energy demand, which is the total amount of energy considered for the energy generation to be provided to achieve the zero energy balance of all the buildings in the considered urban settings.

2.3.3 Energy Generation by Renewable Energy Sources

Given the existing constraints of the built environment in the majority of the Mediterranean cities, we have to consider the unavoidable need to

Table 2.17 Retrofitting options in the double building block (B6) and corresponding energy savings

Building type: double building block (B6): gross surface 6200 m²				
	WINTER		SUMMER	
Retrofitting option	**Q (kWh/y)**	**Ep (kWh/ m² year)**	**Q (kWh/y)**	**Ep (kWh/ m² year)**
As built	354,042	117	148,274	49
1. Insulated walls	242,080	80	75,650	25
2. Window's replacement	317,730	105	142,222	47
3. 1 + 2	205,768	68	60,520	20
4. Insulated roof	329,834	109	130,118	43
5. Insulated green roof	326,808	108	139,196	46
6. (6 = 3 + 5)	184,585	61	60,520	20

Table 2.18 Retrofitting options in the building block (T7) and correspondent energy savings

Building type: building block (T7): gross surface 3560 m²				
	WINTER		SUMMER	
Retrofitting option	**Q (kWh/y)**	**Ep (kWh/ m² year)**	**Q (kWh/y)**	**Ep (kWh/ m² year)**
As built	278,392	92	257,210	85
1. Insulated walls	93,806	31	75,650	25
2. Windows' replacement	175,508	58	121,040	40
3. 1 + 2	75,650	25	69,598	23
4. Insulated roof	269,314	89	245,106	81
5. Insulated green roof	263,262	87	239,054	79
6. (6 = 3 + 5)	75,650	25	63,546	21

Table 2.19 Different retrofit options calculated for building 1 in the Evripidou urban courtyard

Building type 1 in the Evripidou courtyard: gross surface 930 m²				
	WINTER		SUMMER	
Retrofitting option	**Q (kWh/y)**	**EPh (kWh/ m² year)**	**Q (kWh/y)**	**EPc (kWh/y)**
As built	46,442	47	41,353	41
1. Insulated walls	42,727	43	38,045	38
2. Windows' replacement	43,191	43	38,458	39
3. 1 + 2	39,940	40	35,564	36
4. Insulated roof	36,689	37	32,669	33
5. Insulated green roof	37,154	37	33,083	33
6. (6 = 3 + 5)	27,865	28	24,812	25

Table 2.20 Comparison of total energy consumption in the as-built scenario and after the complete energy renovation (scenario 6) in the three urban settings

		Urban settings	Aghia Varvara	Peristeri	Evripidou	
		Number of buildings	15	12	11	AS BUILT
		Total Square metres	18,396	27,368	12,233	
		Qh (winter)	1,563,660	3,219,845	442,425	
		Qc (summer)	1,232,532	1,833,656	731,565	
A		Thermal energy consumption (cold season)	1,839,600	3,788,053	533,043	
B		Electric energy consumption (cold season)	0	0	0	
C		Thermal energy consumption (hot season)	0	0	0	
D		Electric energy consumption (hot season)	738,043	1,097,998	438,063	
E	A + C	Total thermal energy consumption	1,839,600	3,788,053	533,043	
F	B + D	Total electric energy consumption	738,043	1,097,998	438.,063	
G		Thermal energy reduction (cold season)	714,198	3,219.,765	306,644	RETROFIT SCENARIO 6
H		Electric energy reduction (cold season)	0	0	0	
I		Thermal energy reduction (hot season)	0	0	0	
L		Electric energy reduction (hot season)	242,343	360,537	166,464	
M	E − G − I	Final thermal energy demand	1,125,402	568,288	226,399	
N	F − H − L	Final electric energy demand	495,701	737,461	271,599	
O		Percentage of reduction of thermal energy	−39	−85	−70	
P		Percentage of reduction of electric energy	−33	−33	−38	
Q		Electric energy supply for heat pump system (cold season)	673,894	340,292	183,619	
R	N + Q	Annual energy demand for heating and cooling	1,169,594	1,077,754	455,218	
S		Electric consumption for domestic appliances	643,860	957,880	393,715	
T	R + S	Global annual electric energy demand	1,813,454	2,035,634	848,933	

actively supply energy in order to meet heating and cooling requirements and reach the ambitious goal of nZEBs. Obviously, simply reducing the requirements obtained with passive systems cannot be sufficient, thus the energy source feeding the heating and cooling residual requirements that still exists after renovation must be addressed. In Mediterranean climates, the most immediately available renewable source is certainly the sun. Thus, in the evaluation of retrofitting operations, it is necessary to consider possible absorbing surfaces or space that might be needed to cover the building's energy consumption.

The relationship between the entities involved in response to external environmental conditions requires a certain amount of energy in order to establish and maintain the comfort conditions expected in indoor environments. The equipment needed to produce this amount of energy requires a power source. Therefore, the interventions on the final consumption or on systems may not change the overall energy requirement balance of the building, but should aim to change the way in which the requirements are met. As has been already stated, to minimize energy consumption, careful bioclimatic analysis and consistent design are of strategic importance; if wisely used, they can lead to the construction of totally passive buildings.

The technical feasibility of nZEBs in new building construction can be partially achieved by using passive techniques in the Mediterranean climate, as examples of traditional architecture have shown; but existing buildings, and especially the buildings of the 1960s and 1970s, do not respect the rules of the bioclimatic design, for example, with regard to the choice of the site and the orientation and arrangement of the blocks, and also with regard to the construction characteristics and materials. Thus, we need to understand and evaluate how to reduce consumption and transform existing buildings into nZEBs. More specifically, we are attempting to answer whether adopting the previously proposed passive solutions will produce small enough energy consumptions to cover the energy requirement via the sole use of renewable energy.

Therefore, we considered combining passive retrofitting interventions with the goal of realizing thermal insulation on vertical surfaces, together with the insulation of the roof and replacement of windows. The combination of these passive solutions allows a substantial reduction of the energy requirements (reduction varies between 22 and 85% in terms kWh/m^2/year in winter and summer, respectively).

To evaluate the feasibility of nZEBs in the selected buildings, the installation of a photovoltaic system has been assumed, considering it as the renewable source for the production of electrical energy to supply the HVAC plant systems, which consist of (1) the cooling system made up by air conditioning units, (2) the heating system with heat pump, and (3) the electricity for other domestic uses. Given the objective of achieving nearly zero energy in the selected RUEs, the need to compare different situations and building components and to avoid excessive fragmentation of data in the calculations, we assumed the use of PV plants to supply energy in the heat pump system for all domestic uses, including the production of domestic hot water (DHW). The thermal requirements currently produced through a central heating system using gas/oil to meet the electricity demand have been turned into electrical requirements through the conversion multiplicative factor of 0.46 to transform kWh_t into kWh_e.

Photovoltaic and solar thermal systems on the flat roofs of buildings have been hypothesized, considering the possible construction of a grid-connected plant, that is, an installation connected to the public network. A single panel of 1.6 m^2, in polycrystalline silicon, with a peak power of 315 W, has been chosen in order to assess the feasibility of net zero energy buildings. We have assumed a photovoltaic and solar system as part of the complete retrofitted option, namely the installation of thermal insulation on the vertical surfaces, roof insulation combined with a green roof, and the replacement of regular windows with high-performing double-glazed windows.

The installation of a photovoltaic system for the production of electricity has been assumed to power the following: the cooling system with AC units, the heating system with heat pump, and electricity for other domestic uses. Furthermore, the evaluation of costs and payback times has been conducted; once again, it showed that although the nZEB goal is technically achievable, it remains ambitious due to the high cost of technology for the photovoltaic system. Thus, it needs to be tackled in conjunction with the "passive" retrofit interventions aimed at reducing as much energy consumption as possible.

The following steps illustrate the calculation of the photovoltaic (PV) and solar systems to balance the energy requirements in the different urban compounds. The calculation of the PV system that would be necessary to cover the total electrical consumption in the different urban settings has been developed considering the following data:

- Athens average total global annual radiation on a horizontal surface: 1800 kWh/m^2 year
- Estimated performance of the PV system = 19.53%

Given the previous data, the total power required in the case of Aghia Varvara is as follows:

			Aghia Varvara
T	R + S	Global annual electric energy demand	1,813,454

Needed power required (peak power) = 1,813,454/1800 = 1007.47 kW_p

Given the estimated performance of the PV system = 19.53%,

the consequent total area of PV system surface needed to produce 1007.47 kW_p is as follows:

$$1007.47 / 0.1953 = 5158.34\,m^2$$

A photovoltaic pergola (providing an additional shading over the green roof surface) on the building blocks in Aghia Varvara, covering the total roof's surface of each building has been hypothesized. In this case study, the roof surface area available for PV panel installation on the flat-top roof is about 330 m^2. Thus, by covering the existing roof, we almost completely cover the total building energy demand. Additional overhangs could be hypothesized to cover the remaining 20 m^2. Fig. 2.52 is a schematic representation of the energy balance of the buildings.

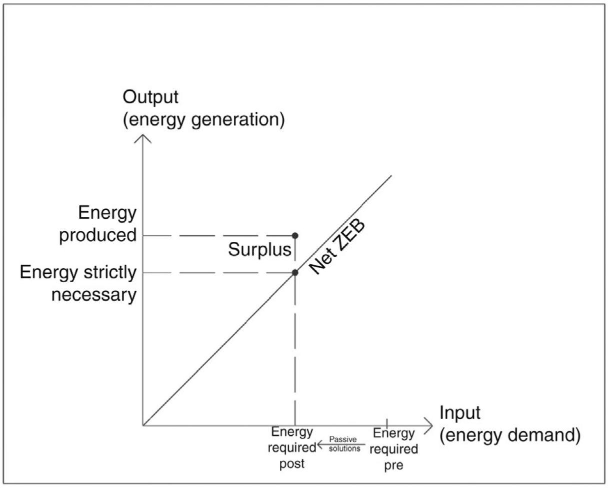


Figure 2.52 ***The PV system adopted by the retrofitting scenario could cover the energy demand in Aghia Varvara.***

As for the previous case of Aghia Varvara, a simple calculation has been made for the urban setting of Peristeri. Given the previous data, the total power required in this case is as follows:

			Peristeri
T	R + S	Global annual electric energy demand	2,035,634

Needed power required (peak power) = 2,035,634/1800 = 1130.91 kW_p

Given the estimated performance of the PV system = 19.53%,

the consequent total area of PV system surface needed to produce 1130.91 kW_p is as follows:

$$1130.91 / 0.1953 = 5790.32\,m^2$$

The photovoltaic pergola hypothesized on the green roofs of building blocks in Peristeri will not necessarily cover the entire available surfaces (about 6800 m^2). Thus, by covering just part of the existing roofs, we cover the total building energy demand.

Finally, the same calculation has been made for the urban courtyard in the Evripidou Athens central area.

Given the previous data the total power required in this case is as follows:

			Evripidou
T	R + S	Global annual electric energy demand	848,933

Needed power required (peak power) = 848,933/1800 = 471.62 kW_p

Given the estimated performance of the PV system = 19.53%, the consequent total area of PV system surface needed to produce 1130.91 kW_p is as follows:

$$471.62 / 0.1953 = 2414.90\,m^2$$

In the case of Evripidou, the photovoltaic pergola (providing an additional shading over the green roof surface) will cover all roof surfaces. In fact, in this case study, the roof surface area available for PV panel' installation on the flat-top roofs of the urban courtyard is about 2.100 m^2; thus, by covering the existing roofs and adding shading devices equipped with PV on the last floors of the buildings, we might cover the total buildings' energy demand.

We may conclude that nearly zero energy in the selected existing buildings of Athens has been proven to be a technically feasible goal even for high energy-consuming and energy-inefficient housing stock. In Chapter 3 we will analyze the costs associated with these goals.

2.3.4 The Energy-Saving Potential of Greenery and Passive Techniques in the Selected Urban Environments

As shown in Chapter 1, the radical transformation of vegetated landscapes as they are replaced by constructed cityscapes, accelerated by increased industrialization and urbanization in recent years, has dramatically affected the urban environment and its atmosphere, causing the thermal degradation of urban climate and hindering the environmental efficiency of buildings.[37] The resulting evolution of urban areas created cities that are getting progressively hotter than the surrounding areas. From the beginning of this century, the average annual temperatures in many cities have increased by as much as 2.8°C.

Denuded landscapes, impermeable surfaces, massive buildings, heat generating cars, and air pollutants have all helped to increase the well known urban heat island effect with higher summer temperatures in urban areas than in the rural surroundings. Morphological and spatial geometry of buildings, together with the thermal properties of surface coatings and, most of all, green surfaces have a strong potential to improve the energy performance and bring about a reduction in cooling demand in urban areas. Thus, planning strategies to reduce the cooling demand in Mediterranean cities should include greenery and natural components as the main tools for improving climatic conditions.

At the territorial and urban scale, it has been largely demonstrated that plants have a strong effect on climate: trees and green spaces can help cool our cities (Santamouris, 2001) and save energy (Environmental Protection Agency, 1992). Trees also help mitigate the greenhouse effect, filter pollutants, mask noise, and prevent erosion (Ferrante and Mihalakakou, 2001). Results of computer simulations aimed at studying the combined effect of shading and evaporative transpiration of vegetation on the energy use of several typical one-story buildings in US cities have showed that by adding

[37] As Zinzi (2010) has pointed out, there are two main challenges concerning the building sector: (1) reducing the energy consumption in European countries and (2) preventing less developed countries from following the same development patterns of the most developed ones, as is happening in recent years. These tasks are not easy to achieve in the Mediterranean region, especially for inland locations, with highly variable conditions throughout the year. Here the buildings have to respond to such variations and be flexible both in hard winters and oppressive heat in the summer.

one tree per house, the cooling energy savings varied from 12 to 24%, while adding three trees per house can reduce the cooling load from 17 to 57%. According to this study, the direct effects of shading account for only 10 to 35% of the total cooling energy savings (Santamouris, 2001; Gaitani et al., 2007). Other prominent studies (Akbari et al., 2001) have verified that the density of the tree crown would reduce the air temperature under the tree between 2 and 4°C.[38] Therefore, considering vegetation in urban areas can help alleviate the greenhouse effect. In the Mediterranean hot climate, vegetation planted around buildings can alter the energy balance as well as provide cooling energy benefits to buildings by sheltering windows, walls, and rooftops from strong solar radiation and radiation reflected from the surroundings. Beyond energy considerations, the redesign of outdoor spaces (streets, squares, and courtyards) is very important for cities (Tapias and Schmitt, 2014), as these provide daily pedestrian traffic and different outdoor activities contributing to urban livability and vitality (Chen and Ng, 2011).[39] Also, it has been found that increased urban temperatures[40] affect the concentration and distribution of urban pollution because heat accelerates the chemical reactions in the atmosphere leading to high ozone

[38] Besides energy consideration, high temperatures could increase health risks and atmospheric pollution, as it is known that the greenhouse effect contributes towards global warming, higher energy demand and emission. Hence, the urban green areas and infrastructure should be maintained in tropical hot and humid cities to guarantee the well-being of the urban communities (Mansor et al., 2010). Trees could help reduce the CO_2 level, increase O_2 and the quality of life (Borhan et al., 2013).

[39] Promoting the use of streets and outdoor spaces by pedestrians will benefit cities from physical, environmental, economical, and social aspects. In this way, ensuring that people are comfortable in outdoor spaces is essential to a better quality of urban life. Over the past few decades, making outdoor spaces attractive to people, and ultimately used by them, has been increasingly recognized as a goal in urban planning and design. The complexity of the physical phenomena in the urban layouts derives from interactions among urban geometry and climatic physical phenomena: the layouts of existing buildings and volumes act as ground obstacles and therefore they usually generate turbulence, thermal airflow instability, shade for solar access, vertical air movements. For example, narrow passageways, comers of buildings close together, expose pedestrians to gusting air movements. Furthermore, interactions among the above mentioned physical effects and current negative urban conditions such noise and pollution should to be considered.

[40] M. Santamouris, *POLIStudies – a Multimedia Educational Structure on The Energy Efficiency of Buildings in Urban Areas*, Department of Applied Physics-laboratory of Meteorology of Athens, 1997. In this frame it should also be considered that higher urban temperatures increase the electricity demand and the consequent production of carbon dioxide and other pollutants, in turn increasing pollutants' concentration (CO_2, NO_2).

concentrations. Moreover, if pollutants land in sheltered areas such as street canyons, they may reside longer than they normally would in a windy environment. The roughness of buildings and urban structures may therefore increase pollutant concentration (CO_2 NO_2).

However, the urban microclimate represents the key indicator among the many factors that determine the quality of outdoor spaces. Pedestrians are directly exposed to their immediate environment in terms of variations of air temperature, relative humidity, wind speed, and solar radiation. Therefore, people's sensation of thermal comfort is greatly affected by the local microclimate (Chen and Ng, 2011).[41] The microclimatic conditions have significant impact on urban dwellers, as the higher temperatures in cities will result in increased energy use for indoor and cooling and higher water demand for landscape mitigation. The high humidity in cities, combined with higher air temperature, create discomfort and undermine the function of outdoor places. As a result, the demand for a better microclimate condition is more pronounced today than decades ago.

The ability to understand and especially to be able to predict and manipulate urban microclimates may help improve aspects on pedestrian activity in urban spaces, and also may improve the performance of buildings, especially with respect to energy conservation (Erell et al., 2011; Kolokotroni et al., 2006; Santamouris, 2006).

Realization and awareness of the climate conditions, seasonal variations, and climate change bring additional demands on the planning and design of urban developments. In this context, an urban "climate-sensitive" design may be defined as a process that considers the fundamental elements of microclimates (eg, sun, wind, temperature) for design purposes (Grimmond et al., 2010). This concept is applied to benefit from the positivity of natural sources in urban microclimate conditions and to mitigate, decrease, and counterbalance the negative effects of urban disfunctionality through appropriate design and planning options.

[41] The outdoor thermal condition is impacted by various elements in the built environment such as: anthropogenic heat (Ichinose et al., 1999) ground surface covering (Lin et al., 2007) evaporation and evapotranspiration of plants (Robitu et al., 2006) and shading mainly level, which is affected by the canopy layer heat island (CLHI). As shade can block incident solar radiation, some studies have discussed mainly the shading effect on thermal environments. For example, street orientation and the height/width (H/W) ratio have been measured to assess the shading levels in some studies (Emmanuel et al., 2007; Johansson 2006). In the context of urban planning, how outdoor thermal conditions influence thermal sensations of people and their behavior (use of outdoor spaces) is of great interest for designing urban spaces.

Nowadays urban planners who intend to create comfortable microclimates can take advantage of easy methods of assessment of the thermal component of climate (Höppe, 1999). The degree of impact of the outdoor thermal environment on thermal comfort varies with the thermal requirements of people in different climatic regions.[42]

Improvement of the ambient microclimate in the urban environment requires the use of more appropriate materials, increased use of green areas, use of cool sinks for heat dissipation, appropriate layout of urban canopies, and the like, all of which help to counterbalance the effects of increased energy consumption in the urban areas. Construction of new generating plants may help generate the needed energy to achieve nZEBs, but it cannot be the sole option to solve outdoor climatic issues. Thus, the adoption of measures to decrease the energy demand in the urban areas, like the aforementioned use of more appropriate materials, increased plantation, use of sinks, and so on, seems to be a much more reasonable option.[43] In this framework, the Athens central region has to be considered a very special pilot study. Measurements developed by the group Building Environmental Studies have shown dramatically higher temperatures in the central Athens area than in the suburban areas (by around 10–15°C). In the same research context, work developed by the research project POLIS in Athens (Ferrante et al., 1998) has shown some effective uses of natural components – such as green roofs and pedestrian permeable surfaces in the streets – within urban canyons. It is evident that microclimatic enhancements in urban scale involving water systems, planting of trees, and lightening of colors in urban surfaces may decrease pollution loads and save huge amounts of energy, consequently improving both indoor and outdoor comfort conditions. Unfortunately though, open spaces among buildings or free courtyards are not always available; therefore the use of passive natural elements can be reduced in dense urban environments. Therefore, an urban energy concept has to address these problems; it must investigate, on a

[42] A number of biometeorological indices have been developed to describe human thermal comfort level by linking local microclimatic condition and human thermal sensation (Chen and Ng, 2011). A major group of such indices are the so-called "steady-state" models. These models are based on the assumption that people's exposure to an ambient climatic environment has, over time, enabled them to reach thermal equilibrium, and they provide numerical solutions to the energy balance equations governing thermoregulation.

[43] Such a strategy, adopted by the Sacramento Municipal Utility District, (SMUD), has proved to be very effective and economically profitable, (Flavin and Lenssen, 1995). It has been calculated that a megawatt of capacity is actually eight times more expensive to produce than to save it. This is because energy saving measures have low capital and no running cost, while construction of new power plants involves high capital and running costs.

smaller scale, the building envelope and the energy-saving potential of selected passive techniques such as building materials and components, shading devices (including green ones such as pergola), and low albedo surfaces, in order to minimize thermal discomfort both in the open spaces and inside the buildings.

The design of outdoor spaces – even if reduced to the envelope of the buildings because of existing urban constraints within thickly built urban areas – as well as the use of natural components have been regarded as key means to improve urban conditions in relation to both microclimate and reduction of pollutants. By "making up" the building's surfaces and elevation facades with green components or shading devices, different scenarios have been proposed in different case studies in downtown Athens. Experimental software research models have been used to quantify the positive effects of these selected passive techniques. Obtained results clearly indicated that alternatively designed outer surfaces act as a prior microclimate modifier and deeply improve outdoor air climate and quality (up to 2/3°C reduction in ambient temperature) (Santamouris, 2001).[44]

2.3.4.1 Previous Studies on Heat Island's Mitigation

Extended analyses on urban layout and passive cooling in the Athens area have been carried out throughout more than 20 years' worth of research studies by Santamouris et al. (2014).[45] The optical characteristics of materials used in urban environments and especially the albedo-to-solar radiation and emissivity-to-long-wave radiation have a very important impact to the urban

[44] Other significant physical factors in the thermal performance of urban environments are wind flows and air circulation, (Ricciardelli et al., 2006) as well as air stratification within urban canyons. In particular, the heat island effect and the microclimatic conditions typical of urban canyons (Bitan, 1992) appear to be strongly influenced by thermal properties of the materials and components used in the buildings and on the streets. Comparative research studies demonstrated that the use of cool colored materials (Synnefa et al., 2007) and thermo-chromic building coatings can contribute to energy savings in buildings, providing a thermally comfortable indoor environment, and, at the same time, highly improve the urban microclimatic conditions (Karlessi et al., 2009).

[45] M. Santamouris, *Passive Cooling and Urban Layout*, Physics Department, University of Athens, 1997. Physical and mathematical definition of the air space above the city, as well as equations defining wind distribution, the urban temperature field and the impact of the main design parameters such as the role of the surface albedo, of green spaces, of anthropogenic heating systems have been described in his work. His work describes the mean features by which the urban climate differs from the climatic conditions of the surrounding rural areas, defining specific parameters and conditions with a physical and climatic approach. Nonetheless, studies on urban temperature have been conducted by many authors in literature, starting form the last three decades, like Oke (1976) and Johnson et al. (1991).

energy balance. Yap (1975) has reported that systematic urban–rural differences of surface emissivity have the potential to cause a portion of the heat island. Using high albedo materials reduces the amount of solar radiation absorbed through building envelopes and urban structures and keeps their surfaces cooler. Materials with high emissivity are good emitters of long-wave energy and readily release the energy that has been absorbed as short-wave radiation. Lower surface temperatures contribute to decreasing the temperature of the ambient air, as heat convection intensity from a cooler surface is lower. Such temperature reductions can have significant impacts on cooling energy consumption in urban areas, a fact of particular importance in hot climate cities (Lin, 2009). Trees and green spaces contribute significantly to cool our cities and save energy (Shahidan et al., 2012). Trees can provide solar protection to individual houses during the summer period while evapotranspiration from trees can reduce urban temperatures.

The causes and effects of urban climates and heat islands are diverse and their interactive are complex, as discussed previously. Urban design, and thus energy consumption in urban spaces, can be influenced if the impact of the main urban design factors is well understood. The optical characteristics of materials used in urban environments and especially the albedo-to-solar radiation and emissivity-to-long-wave radiation have a very important impact on the urban energy balance.

The albedo of a surface is defined as its hemispherical and wavelength integrated reflectivity. Use of high albedo materials reduces the amount of solar radiation absorbed through building envelopes and urban structures and keeps their surfaces cooler. Asaeda and Ca (2000), has experimentally tested the impact of various pavement materials used commonly in urban environments during the summer period. They found that the surface temperature, heat storage, and its subsequent emission to the atmosphere were significantly greater for asphalt than for concrete and bare soil.[46]

[46] At the maximum, asphalt pavement emitted an additional 150 W/m^2 in infrared radiation and 200 W/m^2 in sensible transport compared to a bare soil surface. They also found that the rate of infrared absorption by the lower atmosphere over asphalt pavement was greater by 60 W/m^2 than that over the soil surface or concrete pavement.

Albedo and emissivity for selected surfaces have been classified by Bretz and colleagues (1992). Concrete: albedo 0.3; Emissivity 0.94; Red Brick: 0.3, 0.90; Building Brick: emissivity 0.45; Concrete Tiles: emissivity 0.63; Wood (freshly planted): 0.4, 0.90; White paper: 0.75, 0.95; Tar paper: 0.05, 0.93; White Plaster: 0.93, 0.91; Bright Galvanized Iron: 0.35, 0.13; Bright Aluminum foil: 0.85, 0.04; White pigment: 0.85, 0.96; Grey Pigment: 0.03, 0.87; Green Pigment: 0.73, 0.95; White Paint on Aluminum: 0.80, 0.91; Black paint on Aluminum: 0.04, 0.88; Aluminum paint: 0.80, 0.27–0.67; Gravel: 0.72, 0.28; Sand: 0.24, 0.76.

Increasing the surface albedo has a direct impact on the energy balance of a building. Large-scale changes on urban albedo may have important direct and indirect effects on the city scale.[47] Various studies have been performed that examine the relationship between the canyon layout and especially the sky view factor, with the heat island intensity as well as with surface temperatures.[48]

Other studies have been developed in relation to anthropogenic heat in urban areas, mainly related to transportation systems, power generation, and other heat sources (Johnson et al., 1991).[49]

In this framework, we should point out that plants and vegetation also play a key role in CO_2 absorption. For example, Steemers (1993) has shown high levels of CO_2 absorption by plants in relation the rate of woody growth.[50]

2.3.4.1.1 Mitigations on Urban Canyons in Athens

Among previous studies and experiments on urban mitigation, it is worthwhile to report experiments on urban canyons developed in Athens, which investigated the effect of urban canyons' characteristics on the temperature

[47] Using computer simulations and actual measurements, Bretz et al. (1992) report that roof albedo increase strongly reduces the cooling demand. Other studies have demonstrated how trees and green spaces can significantly contribute to cool cities and save energy. Trees provide solar protection during the summer period, mitigate the greenhouse effect, filter pollutants, mask noise, prevent erosion and calm their human observers; evapotranspiration from trees further reduces urban temperatures. As pointed out by Akbari (1992), "the effectiveness of vegetation depends on its intensity, shape, dimensions and placement. But in general, any tree (...) can have a noticeable impact on energy use." Numerical studies trying to simulate the effect of vegetation have been performed by various researchers. Huang et al. (1986) report that computer simulations predict that increasing the tree cover by 25% in Sacramento and Phoenix, USA, would decrease air temperatures at 2:00 pm in Jul. by 6.0°F to 10.0°F.

[48] Yamashita et al. report a clear correlation of urban air temperature and sky view factor for some Japanese cities. Bärring et al. (1985) has studied the relationship between the street surface temperature and the sky view factor in Malmoe, Sweden. They report a correlation of the surface temperature pattern on the street geometry and the highest the sky view factor the lowest the surface temperature. Higher surface temperatures are recorded in low sky view factor canyons also outside the city.

[49] In different kind of street canyon geometry it has been found that heat island intensity is much higher at low ambient temperatures and can reach values between 2 and 8°C. (Source: Johnson et al., 1991.)

[50] This study refers to the rate of absorption per square meter of planted area. Results can be used to determine plants required to absorb certain amounts of CO_2, in an aim to ensure sustainability of urban developments. The CO_2 absorption ($kg/m^2/year$) for different plant's types are: Trees (average): 1.0; Hawthorn (*Crataegus macrocarpa*): 1.9; Blackthorn (*Prunus spinosa*): 1.4; Field Maple (*Acer campestre*): 1.2; Beech (*Fagus sylvatica*): 0.4.

distribution in the urban environment[51] and proposed mitigations to improve microclimate conditions.[52] Experiments in the Athens central area have been performed in ten different canyons presenting dissimilar layout, orientation, anthropogenic heat, and vegetation. These measurements have been performed taking into account the surface temperature,[53] air temperature,[54] and wind speed.[55]

The distribution of the surface ground temperature of pavements and roads have been measured in seven different canyons on an hourly basis time-lapse and for the period of a whole summer in 1997.[56] Asphalt temperatures during the day period reach peak temperatures of up to 57°C, while the corresponding maximum temperature for white and dark slab pavements are close to 45 and 52°C, respectively. The mean temperature of all the materials during the night period is about 23–25°C. The orientation

[51] M. Santamouris, POLIStudies – a Multimedia Educational Structure on the Energy Efficiency of Buildings in Urban Areas –, 1997. EU Project.

[52] Ferrante, A., 1997–1999. Water, Green, and Selected Passive Techniques to improve microclimate and reduce pollution in the urban contexts. Research project developed during the 24 months of PostDoctoral Research Activity in the University of Athens, Department of Applied Physics. Programme work selected and funded in the framework of EU TMR Research Programme. Directorate G. XII, Science, Research and Development.

[53] Surfaces receive short wave radiation as a function of absorptivity and exposure to solar radiation, receive and emit long wave radiation as a function of their temperature, emissivity and view factor, transfer heat to or from the surrounding air and exchange heat via conduction procedures with the lower material layers. Surface temperature measurements performed from the bottom to the top of both facades of the canyon using a step of 3–3.5 m. Additional measurements have been performed in some cross sections of the canyon where different materials are used. All measurements have been performed from the street level. Temperatures of pavement, road and 5 additional points along the width of the canyon were measured.

[54] It is worthwhile remembering that temperature of the external materials in a canyon is governed by its thermal balance. The thermal balance of a surface in a canyon can be expressed as follows: $Q^\star = Q_H + Q_G$; Where $Q^\star$ is the net radiation, Q_H represents the convective heat exchanges and Q_G are the conductive heat exchanges with the substrate.

[55] Wind speed measurements by means of a three-axis anemometer to measure the three components of the wind speed inside the urban canyons.

[56] Existing knowledge on the temperature distribution of materials used for pavements and roads has been implemented by Asaeda and Ca (2000), texting experimentally the impact of various pavement materials during the summer period used commonly in urban environments. They found that the surface temperature, heat storage and its subsequent emission to the atmosphere were significantly greater for asphalt than for concrete and bare soil. At the maximum, asphalt pavement emitted an additional 150 W per square meter in infrared radiation and 200 W/m^2 in sensible transport compared to a bare soil surface. They also found that the rate of infrared absorption by the lower atmosphere over asphalt pavement was greater by 60 W/m^2 than that over the soil surface or concrete pavement.

of the streets, the H/W ratio,[57] as well as the type of used materials define the surface temperature of the materials.

The impact of the absorbed solar radiation on the temperature increase of the materials used in pavements and roads has been found to be very important. It has been shown that for white and dark slab pavements, the instantaneous temperature difference across the street varies from 10 to 22°C as a function of street layout and orientation; for asphalt, the instantaneous temperature difference goes up to 27°C. The effect of the street orientation on the temperature of the street and pavement materials can be understood if the daily peak temperatures of same materials across the canyon are compared. Usually the southern pavement slabs present a higher daily peak temperature, to about 8–15°C, compared to the peak daily temperature of the northern pavements. Similar values are observed for asphalt streets between the southern and northern part of the road across the same section of the street. To understand the impact of thermal and visual characteristics of the various materials used in a road on their surface temperature, the temperature differences of these materials across a street have been compared.

Surface temperatures of the buildings' envelope have been measured for seven canyons. Temperatures vary as a function of all parameters defining their thermal balance, but mainly as a function of the received solar and emitted infrared radiation.[58] As expected, in a canyon, the south-oriented or almost south-oriented surfaces present much higher temperatures than the opposite surfaces. The maximum daily simultaneous temperature difference between two opposite panels was close to 19°C. The highest recorded difference of the daily maximum temperature of two opposite surfaces was 14°C. In almost all canyons, there was a period during the day at which each of the two facades presented a higher temperature than the opposite

[57] Urban canyons are characterized by three main parameters: H, the mean height of the buildings in the canyon, W, the canyon width, and L the canyon length. Given these parameters, the geometrical descriptors are limited to three simple measures. These are the ratio L/H and the building density J=Ar/A1 where Ar is the plan of roof area of the average building and A1 is the "lot" area or unit ground area occupied by each building.

[58] Minimum observed surface temperatures during the night period varies between 18 to 27°C, while the maximum temperature during the day period varies between 25 to 50°C. To evaluate the impact of the building's orientation and relative position in the canyon, on its surface temperature, the temperature of building panels facing each other, from the ground up to the upper height, have been compared for the day and the night period. Taking into account that the received solar radiation by a surface varies mainly as a function of its orientation and its relative height in the canyon, that defines the degree of shading from the adjacent buildings. The study has been concentrated on two specific parameters.

surface. This time period is a certainly a function of the canyon orientation, layout, and characteristics of the material.[59]

Since distribution of the ambient air in a canyon greatly influences the energy consumption of the buildings, important deductions can be derived from these experimental activities. It is important to specify that the orientation of streets determine the amount of solar radiation received by the canyon surfaces; in other words, measurements taken at the southwest facade present a higher peak temperature during the day period, up to 2°C, compared with the corresponding northeast-oriented facades.

During the night period, all temperatures were almost similar. The orientations of the streets do not influence the bulk air temperature in the canyon; however, orientation has a rather strong influence on the air film developed in the proximity of the facades; close to the facade of the buildings, an air film is governed by the temperature of the building surface and the vertical air transport is developed.[60] Measured air temperature differences between the two facades vary as a function of the canyon layout and surface characteristics: as expected, south, southwest, or southeast facades presented higher air temperatures. In all cases, during the night, higher temperatures were measured at the ground level, and temperatures were found to decrease as a function of height. During the night, the temperature of the air in the middle of the canyon was found to be higher than that of the air film close to the facades of the canyon.

The daytime intensity of the heat island for all canyons and measuring points at the ground level varies between 4 and 15°C. The highest heat island intensities have been found for the very central canyons characterized by high circulation and high H/W values. In particular the Solonos, Ippokratous, and Mavromichalis, located at the very central Athens area, presented a heat island intensity between 10 to 15°C. The highest intensity, close to 15°C, has been found on Solonos Street, a south-southwest-oriented canyon having a very high concentration of cars. Also in the Valaoritou canyon, a pedestrian street located at the central area of the city and in the neighborhood of high-concentration main roads, the absolute heat island

[59] In northeast-southwest and southeast-northwest-oriented canyons, where the solar surfaces are of southeast or southwest orientation, the simultaneous temperature difference between opposite surfaces during the day is lower at the ground level and increases as a function of canyon height: as a matter of fact, in this type of canyon, the lower height surfaces of the southeast-southwest facades receive much less radiation than the upper level ones and thus the upper southwest-southeast floors present higher surface temperatures.

[60] Obviously, it has been found that the middle canyon temperature is very different from the mid temperature of the air film temperature close to the facade of the buildings (in most of the cases, temperature at the middle of the canyon is lower than the corresponding film air temperature).

intensity was high (11°C), similar to the intensity found in other high-concentration canyons. In the south-southwest-southeast-oriented facades and during the day period, the temperature gradient varied between 0 and 14°C, while the ground floor presents the lower surface temperature, because of the lower incident solar radiation. Intermediate floors presented the highest temperatures, because they received almost the same solar radiation as the upper floors, as well as the infrared radiation from the opposite buildings, while convective fluxes were lower because of the lower wind speed at this level. In the north-northeast-northwest-oriented facades and during the day period, the temperature gradient varied between 2 and 8°C.[61]

To evaluate the energy-saving potential of greenery and passive techniques in these urban environments considering the specific restrictions encountered in the AMA, two different rehabilitation procedures have been considered:

1. Passive technological measures related to the envelope of the buildings in existing dense thickly built urban areas close to central high circulation streets.
2. Passive technological measures related to the envelope of the buildings added to (alternative) use of outdoor green spaces, courtyards, and pedestrian streets like places able to improve microclimate in existing urban areas, where a relative amount of open space was available.

A climatic conscious design of outdoor spaces as well as an appropriate use of natural components are key elements to reducing the effect of unsound evolution of urban areas where impermeable surfaces, denuded landscapes, and air pollutants determine higher summer temperatures and unhealthy life conditions.

Courtyards, streets, and outdoor spaces (even if reduced to the shell and envelope of the buildings within existing thickly built urban areas) can be redesigned by using natural elements (water, green) to improve urban conditions in relation to both microclimate and reduction of pollutants (Nikolopoulou et al., 2001).

[61] However, comparison of simultaneous measurements with the high circulation Solonos street, taken at the northern facade of the streets, clearly shows that this pedestrian street has to about 2°C lower temperature. Taken into account that both streets are parallel, have the same layout and almost same H/W ratio, it can be concluded that higher recorded temperatures are mainly due to the anthropogenic heat and the use of more absorbing street materials like asphalt. Lower heat island intensities, from 4°C to 8°C, have been found in canyons located in the surroundings of Athens characterised by much lower circulation and lower H/W ratios. Heat island intensity during the day period is mainly a function of the thermal balance of the urban area. In particular, in Solonos canyon it is found that mean daily heat intensity is close to 5.7°C.

The architectural rehabilitation design, by making use of passive cooling techniques like water, appropriate plantings, and vegetation, proposes alternative scenarios in the main canyons to improve thermal comfort conditions and decrease pollution loads in the high temperatures of the central Athens areas. The proposals are based on the following strategic objectives:

1. Promotion of all forms of passive natural devices according to the potential effects on minimizing the localized pollution problems and to enhance the urban microclimate. The first step to avoiding the problem of poor air quality is to reduce pollution at the source by improving efficiency and extracting pollutants. The next step is to ensure that unavoidable pollutants are dispersed safely. A planning strategy to minimize pollution impact is to provide spatial separation of environmentally incompatible activities. Where open spaces and buildings are naturally ventilated, ensure that ventilation air is drawn from a source that is clear and green.
2. Maximum increase of permeable surfaces in the outdoor spaces.
3. Improvement of natural cooling, reducing solar heat gains both in the open spaces and on building facades (allowing protection for southeast and southwest facades by means of shading devices and "natural filters"). The evaporative and transpiration cooling effects of plants are used to precool ventilation air, both for the buildings and the open spaces. Furthermore, dense vegetation helps to filter particles from the air.
4. Ensure CO_2 absorption by plants and urban pollutant dispersion by natural ventilation and night cooling.

To reach these strategic objectives, the study has theoretically envisaged the possible redesign of these urban contexts, trying to use and consider as much as possible the existing constraints of the as-built scenarios. Thus, different scenarios have been designed by using new materials and green components onto building surfaces and elevation facades, and in the street layouts.

In the redesign of the urban canyons, shaded, under-planted roof gardens have been regarded as a common feature.[62] In fact, the technical tool of

[62] Planted green roof on the bare roofs of the buildings may greatly reduce the high thermal load, both from the single buildings and from the city as a whole. The factors behind temperature reduction are evaporative cooling and shading of the ground, whereas temperature increase during night is the result of the reduced sky factor within the canopy. Results of the simulations show that a vegetative cover of 30% could produce a noontime oasis of up to 6°C, in favorable conditions and a nighttime heat island of 2°C. Other simulations indicated that the net effect of the increased urban vegetation is a decrease in ozone concentrations. Hader (1970) summarizes the conclusions of different studies on the distribution of dust in and out of urban green areas. He found that inside the green area, a diminution of dust is

(*Continued*)

an additional pergola over the roof garden represents a simple but effective architectural measure. Hence, in all the flat surfaces of the roofs, an additional pergola layer has been combined with the planted roof layer. By using this device, the hypothesized results suggest that the air temperature in the roof garden should be even lower than the shade temperature simply provided by trees. This solution could also represent a key element to address the static problems derived from the additional soil weight. In fact, it is estimated that a 0.8–1.00 m depth layer of soil is able to support the growth of medium-high vegetative plants. Thus, a garden with a wide variety of plants, including bushes of up to 1.5 m in height, would imply a considerable soil weight, with consequent additional load bearing on existing buildings.[63]

Shaded roof gardens under-planted with shade-tolerant plants are an architectural measure that has been widely employed throughout all the studied urban canyons. This is a sustainable solution that contributes to a thermal load reduction of the building's shell and to the improvement of microclimatic conditions of densely built urban centers with no natural environment.[64]

During the rehabilitation process for four different canyons, specific proposals for canyons with different geometrical features, orientation, and types of buildings have been hypothesized. In brief, the following strategies were proposed:

1. Provide spatial separation between polluted areas and open public spaces by means of green pedestrian streets (proposed for Mavromihali, existing in Valaoritou). These main streets, rehabilitated by trees, permeable pavements, and watercourses, will provide evaporative cooling and ensure clearer air free of noise and cars.

noticeable, while he describes the processes of filtration of dust by vegetation. The processes of heat transfer into the planted roof has quantitatively and qualitative differences in comparison with the normal processes in bare roofs. The solar radiation, the external temperature and the relative humidity are reduced as they pass through the foliage coverings the roof. The plants, because of the biological functions of photosynthesis, respiration, transpiration, and evaporation, absorb a significant proportion of the solar radiation. Therefore the creation of gardens on the roofs of buildings could represent one of the key steps to be considered for the environmental and climatic improvements in the city of Athens. Offering large surfaces with vegetation, a garden blocks the infiltration of solar radiation by creating a protective layer, reducing range of temperature in winter and summer.

[63] Additional technical tools to contain the soil thickness, involving the external facades of the buildings and extra economic costs are also implied by using soil and greenery.

[64] In this contribute, the role of planted roofs in the improvement of the thermal performance of the buildings has been deeply investigated (Eumorfopoulos and Aravantinos, 1995).

2. Position openings from internal courtyards (where a higher portion of fresher and cleaner air is available) toward open spaces and building facades.
3. As much as possible, increase permeable surfaces on the pavements.
4. Provide shadow and filter for building facades (especially the southwest and southeast-oriented ones) by means of selected passive techniques such as pergolas and winter gardens.
5. Create planted roof gardens on the bare roofs of the buildings and shaded roof gardens planted with shade-tolerant plants.

In canyon Hyppokratous, the increase of permeable surfaces has been obtained by removing one car gangway in front of the southeast-oriented blocks of buildings to allow filtered and shadowed areas for pedestrians, as shown in the figures mentioned later. In Mavromihali, a multi-story green building has been proposed in the existing open area to provide a green "oasis" between the existing buildings along the canyons. Finally, since canyon Valaoritou is the only existing pedestrian street, the alternative scenario is to consider adding shading devices between the buildings (to shade the southwest-oriented facades of the canyons and the open spaces). Fig. 2.53 shows a map of the central Athens area, giving the position of the three

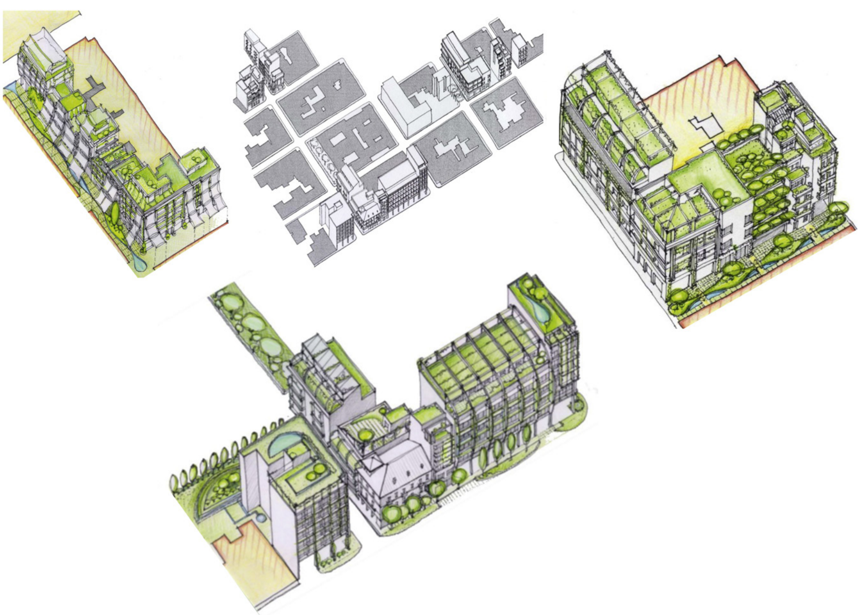


Figure 2.53 ***A schematic 3D model of the central Athens area showing the position of the main canyons (in the center) with the envisaged scenarios (left, right, bottom in the figure).***

(a) (b)

Figure 2.54 ***Canyon Valaoritou (a) and envisaged scenario with greenery and shading devices (b).***

canyons. In the downtown city quarter, the three canyons Hyppocratous, Solonos, Mavromihali are concentrated, while Valaoritou is a pedestrian street.

To assess the microclimatic improvements of the proposed architectural and technological measures, selected software simulation tools have been used,[65] selecting the pedestrian street in canyon Valaoritou Fig. 2.54. In this case, air temperature distribution inside the canyon calculated for 15th July, selected as the reference day. Simulation results are shown in Fig. 2.55.

[65] The cooling potential of the proposed techniques has been investigated for the Canyon Valaoritou, by means of a theoretical software model developed in the MATLAB program. The overall energy exchanges and internal heat flows to be considered in an urban canyon thermal model are: reception, absorption and reflection of short wave radiation, as well as absorption and emission of long wave radiation by involved surfaces and facades. In addition, the heat transfer toward or from the surrounding air via convection and conduction with the lower materials layers has to be fixed. The thermal energy balance for transient conditions at any surface of a canyon can be expressed by the following differential equation: $\rho C \delta T si/\delta T = = hc(T si - T oi) + \lambda/\Delta x(T si - T mi) + \Sigma Fij\sigma(T sj4 - T si4) + asqs + Fi/sky\ (\varepsilon c\sigma Tc4 - \varepsilon\ i\sigma Tsi4)$; (1) where: $hc(T si - T oi)$ is the heat rate transferred by convection between the surface at temperature $T si$ and the adjacent air layer. In this case the convective exchange coefficient hc is considered to be a function of the air velocity near the building facade and it is expressed by: $hc = 4.1\,V + 5.8\ W/m^2K$. $\lambda/\Delta x(T si - T mi)$ is the heat rate transferred by conduction into the wall or the ground. The temperature $T mi$ is defined as the temperature inside the wall at a distance Δx from the surface; λ is the conductivity constant and Δx has been set up by the operator; $\Sigma Fij\sigma(T sj4 - T si4)$ represents the rate heat exchange by long wave radiation between a surface i and the n surrounding surfaces ($j=1:n$). The view factors between every element of surface i and the surrounding elements are calculated by the equation: $Fij=\cos(\theta)\sin(\theta)/r^2$ where θ is the angle between the line connecting the centers of the two segments at distance r and the normal line to the plane containing the segment; asqs represents the short wave solar irradiance absorbed by the surface element, as is the absorption coefficient, while qs is made up of the direct solar radiation, and the diffused irradiance from the sky and the surrounding surfaces. It has been calculated for each segment as a function of their partial shaded area (PSA).

(*Continued*)

For the basic equation describing thermal energy balance for transient conditions of a canyon, to investigate the proposed alternative scenarios, a series of transformations have been considered.

First, regarding the scenario that includes shading devices, an additional energy balance between the proposed curtains and the ground has been assumed, which will simulate the new thermal performance of a theoretical first scenario modified by the curtains in the canyon. Second, to assess microclimate modifications brought about by the use of greenery, the mean energy and vapor balance has been inserted into the MATLAB equation. Finally, in order to assess the microclimate modifications brought about by

The total solar radiation (direct, diffuse, and reflected) incident on each segment by the following equation:
$I(t)=I\mathrm{dir}\ (t)(1-\mathrm{PSA}(t))+I\mathrm{dif}(t)\mathrm{SVF}+\Sigma \mathrm{I}\ \mathrm{dir+dif}(t)i\ (1-\mathrm{mi})\mathrm{FiA}$, Where: PSA= partial shaded area of the segment; $I(t)$ is the mean hourly total solar radiation incident on the segment (W/m^2); Idir(t) is the hourly mean unobstructed direct solar radiation (W/m^2); Idif(t) is the hourly mean unobstructed diffuse solar radiation on a horizontal plane, (W/m^2); Idir+dif(t) is the hourly mean direct and diffuse solar radiation; F=view factor for two segments; m= surface absorptivity; SVF= sky view factor for the segment. Subscript i is the ith surface type; the direct radiation is corrected for specific solar zenith angle; the incoming diffuse radiation is assumed to be isotropic and the first reflection is only included as it is very difficult to model multiple reflections. Direct and diffuse radiations are derived from observed values at the meteorological site and assumed specifically in the urban site. Fi/sky εcσTc4 represents the diffused atmospheric long wave heat contribution; it is the long wave irradiance emitted by the atmosphere and received by the surface element i. εcσTc4 corresponds to the diffuse flow emitted by the atmosphere where Tc is the sky temperature given as: Tc =To - 6; Fi/sky ε iσTsi4 represents the heat rate as long wave radiation exchanged between the surface and the sky. The general form of equation (1) works the same for any segment on the ground as well as on the walls except for qs, which is considered as the solar total irradiance on a horizontal plane. The surface temperature of each urban unit cell is used as the boundary condition in the determination of the ambient air temperature. This equation has been inserted in the MATLAB, and different simulation of initial scenario have been performed, as showed in the following graphs. Respectively the ambient air distribution, calculated at the height of 2 meters, the air temperature distribution and the surface distribution on SW Facade have been simulated.

The main output matrixes describing the variation of temperature distribution inside the canyon are: Tout = air temperature inside the canyon; Tout1 = air film temperature on the right wall (south-west oriented); Tout2 = air film temperature on the left wall (north-west oriented); TM = surface temperature in the middle of every segment of the left wall; TMR = surface temperature in the middle of every segment of the right wall; TMW = surface temperature in the middle of every segment of the ground; As a reference temperature for the air temperature inside the canyon the whole fifth column of the matrixes has been considered for the main parameters above mentioned. As far as it concerns the air temperature distribution inside the canyon the fifth row of the fifth column has been considered. The fifth element of the fifth column of Tout has been selected as the representative value of the temperature in the middle of the canyon for the pedestrians (at the height of 2 m).

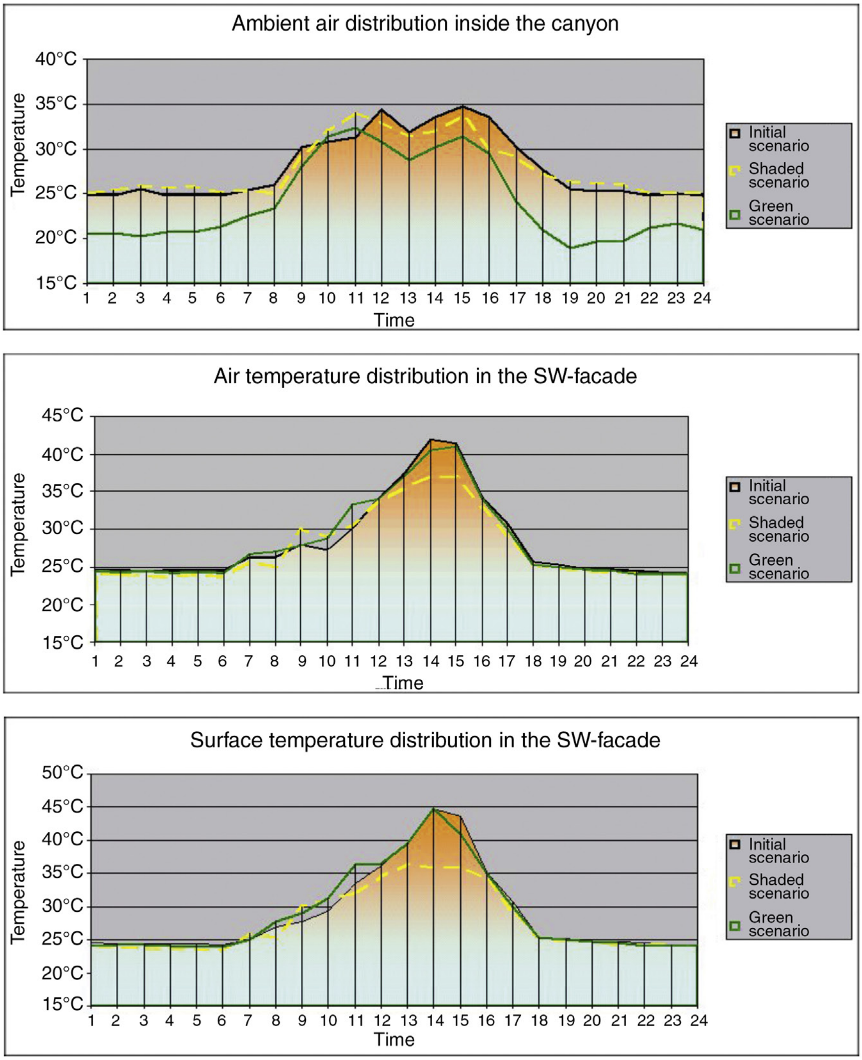


Figure 2.55 ***Ambient air distribution in the urban canyon; air temperature distribution and surface temperature distribution for the southwest facade.*** The dark gray refers to the green areas that have been inserted in place of street in the urban context.

the use of permeable surfaces and greenery (in place of existing stone slabs) in the pedestrian street, equations representing the macroscopic or "mean" energy and vapor balance in a canopy have been considered.[66]

[66] $(\rho c)\rho$ d LAI $dTp/dt = \varphi$ rad.sol $+ \varphi$ rad, TIR. $+ \varphi$ conv, $\rho - a + \varphi$ trans, $\rho - a$; $(\rho c)_a$ H $dT_a/dt = \varphi_{conv,a\text{-}\rho} + \varphi_{conv,a\text{-}g}. + \varphi_{conv,a\text{-}\infty}$ ρa H $d\theta_a/dt = \varphi_{vap,a\text{-}\rho} + \varphi_{vap,a\text{-}g}. + \varphi_{vap,a\text{-}\infty;}$ where: T_p= Leaves temperature (average in control volume), (°C); T_a= Air temperature (average

(*Continued*)

Fig. 2.55 describes the ambient air distribution in the urban canyon, the air temperature distribution, and the surface temperature distribution for the southwest facade. The air temperature distribution refers to the variation of the temperature calculated in the middle of the urban canyon, while the air temperature distribution and surface temperature distribution refer to the southwest facade (namely, the air film of the southwest-oriented facade and the surface temperature on the same facade). As expected, air film and surface temperatures are much higher than the air temperature in the middle of the urban canyon, with the surface temperatures in turn higher with respect to the air film temperature. Results also show that the proposed shading devices do not affect the air temperature inside the canyon, while strong temperature reductions can be observed for film air and the surface temperature on southwest-facing facades.

Conversely, the proposed greenery on the ground level of the urban canyon does not seem to affect the film air and the surface temperature on the southwest facades, while a strong air temperature reduction can be observed for the air temperature inside the urban canyon (the air canyon temperature for the initial scenario fluctuated between 25–35°C; for the greenery scenario, the air temperature inside the canyon varied between 20–31.5°C). Therefore, the green scenario contributes significantly to the temperature reduction, especially during nighttime, because of the increased long-wave heat losses from the planted surfaces. This can be associated by the different times when maximum is observed at the two canyon's walls.

Regarding the air temperature distribution and the surface temperature distribution for the southwest facade, the most improved situation is the theoretical shaded scenario where the air temperature profile varied between 24 and 42°C, while the surface temperature distribution fluctuated between 24 and 45.5°C.

in control volume), (°C); θ_a= Air specific humidity (average in control volume), (kg.kg^{-1}); d= Average leaves thickness, (m); $(\rho c)_\rho$, $(\rho c)_a$ = Leaves and Air, respectively, specific thermal capacity, (J/m^3/K); ρ_a = Air density (kg. m^{-3}); H = Canopy layer thickness (m); $\varphi_{rad,sol}$,$\varphi_{rad,TIR}$ = Solar radiation absorbed by leaves and Net thermal radiation flux on leaves, respectively, (W.m^{-2}); In addition the equations describing: – the convective heat transfer between leaves and air ($\varphi_{conv,\rho-a}$), - the heat and vapor transport between the air within the canopy and the outdoor air ($\varphi_{conv,a-\infty}$ and $\varphi_{vap,a-\infty}$), – the transpiration flux, the energy flux consumed to let water evaporate in leaves (φtrans,ρ-a), – the heat and vapor flux between the ground surface and the air ($\varphi_{conv,a-g}$) have been introduced in the software model developed in POLISTUDIES Multimedia Tool.

To sum up, the obtained results and the relative mutual comparison clearly indicate that:

- The air temperature inside the canyon is much lower than the film air temperature and the surface temperature on the southwest-oriented facades.
- The air temperature in the middle of the canyon is strictly influenced, governed, and improved by the presence of greenery (which acts as the microclimate modifier), while the proposed shading devices do not seem to importantly affect the air temperature inside the canyon.
- The air film temperature on the southwest facade as well as the surface temperature distribution are much lower in the theoretical shaded scenario (see broken line in Fig. 2.55) than in the initial one, while, as expected, the presence of green does not influence the surface temperature distribution on the facades of the building.

As a whole, the research study has demonstrated that the redesign of urban surfaces (both in relation to the building envelope and the ground level – streets, courtyards, squares, etc.) acts as the prior microclimate transformer of urban conditions and can deeply improve outdoor air climate and quality. Nonetheless, the positive effects of each different scenario, as simulated so far, seem to address specifically and differently the various climatic parameters inside the canyon. But, as a matter of fact, the energy potential of proposed architectural measures cannot be analyzed separately from an overall comprehensive investigation that addresses the combination of the building with the surrounding urban boundary conditions.

This deduction, together with the encouraging results, led us to other exploratory exercises aimed at:

- Investigating the potential of these alternative scenarios from the outdoor urban spaces to the indoor thermal performance of the urban buildings
- Assessing the energy potential of combined scenarios by integrating the green component with the shading devices in the different urban environments.

2.3.4.2 Modeling the Urban Microclimate (Annarita Ferrante and Anastasia Fotopoulou)

It is well known that modeling a built environment project may help to visualize its future impact and is an important part of responsible design decision-making (Erell et al., 2011; Kanton and Unger, 2010). There are three types of modeling methods used in urban climatology; physical scale models, integrated open-air models, and mathematical models. Computer programs simulate the physical environment and produce knowledge that may say something about real-world behavior. However, all types of models need validation, and because of the deficiency of well-documented, high-quality data from field studies, this remains a major problem for most urban climate models (Erell et al., 2011). In terms of outdoor thermal comfort, there is the need for a predicting tool by means of urban climate models and tools. Although people's subjective perceptions and responses to the urban environment are various and not yet well understood, simulation and scenario-testing tools are always of particular importance in an assessment framework because they provide a platform for the integration of knowledge from various perspectives and comparisons of various design scenarios (Chen and Ng, 2011). These "predicting tools" can support the research on how changes in design details influence outdoor thermal comfort. The statement applies with equal force to the more general context of research in this area, which is how urban design can influence the microclimate of an urban environment and people's outdoor thermal comfort and, in turn, how people's thermal comfort can influence their use of outdoor urban spaces. Design regulations and guidelines in this respect require comprehensive assessment before they are adopted. City planners and decision makers, when faced with the task of designing urban spaces that are desirable and thus used rather than abandoned, will be better informed with a predicting tool that allows various design alternatives to be compared and tested in terms of attractiveness and effectiveness. In particular, a testing tool is needed that can provide both quantitative and qualitative understanding of the relationships among microclimatic environment, subjective thermal assessment, and social behavior. Such a tool should have the ability to process detailed environmental information according to time and location variations and to generate analytical results to reveal the relationship.

To simulate the cooling potential of greenery in the urban setting of Peristeri, ENVI-met,[67] an environment and micro-climatic simulation

[67] The ENVI-met software uses input values for buildings, vegetation, ground surfaces, climatic conditions, soils, and then simulates the modifications from the proposed building form, additional shading, alternative orientations, etc. ENVI-met is a three-dimensional computer model, which analyzes micro-scale thermal interactions within urban environments. The software uses both the calculation of fluid dynamics characteristics, such as air flow and turbulence, as well as the thermodynamic processes taking place at the ground surface, at walls, at roofs and at plants. It calculates the dynamics of microclimate during a diurnal cycle [24–48 h]. Main prognostic variables of the program are wind speed and

(*Continued*)

software, has been used. The main goal here is the investigation of microclimatic variations linked to modified parameters and their impact on buildings. The focus of the analysis is, in particular, on the possible replacement of parking areas with green parks and pedestrian streets, of standard roofs with green ones, of vertical walls to green ones, and of the creation of roof shading systems with the use of a photovoltaic system.

A packet of simulations has been modeled for this elaboration, based on reliable standards from the urban compound of the Peristeri area. Variations in the models concern the replacement of standard roofs with green ones (from 0 to 100%) and the reorganization of the car circulation in order to leave open asphalt areas that become, in a second step, permeable and planted green surfaces. In addition, one of the most important steps for the simulation of the new scenario is the creation of

direction, air temperature and humidity, turbulence, radiative fluxes, bioclimatology and gas and particle dispersion. The basic data structure of ENVI-met is described by Ozkeresteci et al. (2003). ENVI-met takes into account all types of solar radiation (direct, reflected, and diffused) and calculates the mean radiant temperature. The calculation of radiative fluxes includes the plant shading, absorption and shielding of radiation as well as the reradiation from other plant layers. ENVI-met has two basic steps before the simulation is run. The first is editing the input of the urban area to be tested. For this task, one needs the horizontal and vertical dimensions of the architectural environment along with any specific design features such as open breezeways, overhangs, horizontal surface materials, ground cover, vegetation size and coverage, and so forth. The input is designed in a 3D setting where the buildings, trees/vegetation, and the various surfaces are placed. These elements are represented by various size grid cells. The smaller the cell is, the finer the resolution (as small as 0.5 m). The cell area can be designated at any dimension from 0.5 to 10 m. For example, a 100×100 m^2 area can be represented in a 100×100 grid cells of 1×1 m^2 each, or it can be represented by a 20×20 grid cells of 5×5 m^2 each, depending on the size of the test area and the desired resolution. This stage can be quite complex depending on the environmental domain that is chosen to work. The high-resolution aspects of the program enable the user to go into finer details in smaller scale. The second step is editing the configuration file, where the information about the site location, temperature, wind speed, humidity, PMV parameters, and databases for soil types and vegetation are entered. The simulation is then processed using both the input and configuration files. The output data then has to be imported and visualized in LEONARDO 3.0. ENVI-met outputs binary files (.EDI/.EDT) which have to be imported into a visualization program – LEONARDO 3.0. Each output file has a multitude of information, which has to be translated into different layers in Leonardo. The following main layers are typically used to visualize the output data: Data layer: Displays continuous data (eg, temperatures); Special: Displays singular data (eg, buildings, plants); Vector: Displays vectors such as wind. Visualization is then configured to display the urban environment with the desired section of data cut horizontally (plan view), vertically (section view), or in a 3-D axonometric view. ENVI-met however has certain limitations. The building blocks have no thermal mass.

roof shading (from 0 to 100%). Investigations are focused on the thermal variation resulting at the scale of the urban contest. Introducing parks instead of asphalt areas leads to fresher air (temperature decreases generally in a range set from 0.25 to 1.5°C, locally the difference can be 3°C). The replacement of standard roofs with green ones does not lead to significant variations in temperatures; the maximum decrease is of 0.7°C). These conclusions focus attention on the interactions between green area and air temperature, but also look at the impacts of these variations on project choices at and the urban building level.

2.3.4.2.1 Peristeri Urban Setting: Measured Climatic Data and Simulation on the Scenario as Built (Annarita Ferrante and Anastasia Fotopoulou)

Peristeri is located in the western part of Athens, as this area along with the center presents the highest heat island (HI) intensity of the whole city. The blocks are typical social housing from the 1960s constructed by pillars and beams, and the basic structure material, concrete, was used. Its parts consist of: the three tower buildings, the three double block buildings south-north oriented, and four east-west oriented blocks. Focusing on urban areas, the proposed research considers the buildings and the related space as a whole. The urban compound extension is 37,820 m^2, of which 25,713 (68%) is occupied by building construction and impermeable surfaces (parking areas and streets); the remaining (32%) is a green space, or open area. The built area represents the 29% (7,504 m^2) of the total impermeable surfaces.

In order to achieve the goal of zero energy, a strategy of five basic steps has been followed:

- Selection, analysis, and simulation with ENVI-met of a characteristic urban compound
- Selection of different urban sustainable design scenarios, with new simulations
- A comparison of the results and selection of the best possible scenario for the improvement of the HI effect and the microclimate in the urban compound
- Simulation with "Energy Building" to check how much influence the improvement of the microclimate has on the existing buildings
- Analysis and collection of the buildings' energy-performance results after the redesign of the urban compound and the improvement of the microclimate

For the simulations, the area of interest has been transformed into a model grid with the dimensions 130 × 120 × 30, with a resolution of

Figure 2.56 ***The Peristeri urban compound in the ENVI-met 2D and 3D interpretation in the as-built and alternative scenario.*** (a) Existing situation (b) Proposal (c) 3D map.

2 m × 2 m × 3 m, resulting in a total area of 260 × 240 m in the horizontal extension (see Fig. 2.56).[68]

These databases (soils, plants, buildings, surface materials) are used as generic types in the first stage, so a comparative match to the closest resemblances are chosen for soil, plant, and building characteristics. These data can also be localized and additional plants, soils, and source information can be added to the model. The outputs are basic 3D information on atmosphere, surface, and fluxes and soils. The meteorological input for a one-year period (2014) recorded by the urban climate station in Peristeri plus measurements performed by the University of Athens Department of Physics (Santamouris, 2014) was applied. For the simulation, the hottest day of the summer of 2014 (9th of July) was selected, with a mean temperature of 30°C, while the maximum was 35.7°C. The wind was in a westerly direction with an average speed of 3.1 m/s. From the previous analysis, the simulation results showed drastic measurements and the need for action. The lack of green spaces, lack of parking, lack of pedestrian streets, the high temperatures measured at the ground surface as well the high air temperature, plus the indication of uncomfortable thermal sensation are some of the problematic issues that the urban planners must consider.

The next proposed step is the analysis and simulation of alternative sustainable scenarios that could help improve the existing situation and come a step closer to the goal of this research, which is zero-energy urban settings. In brief, these actions are:

- Addition of trees and green surfaces on the ground level
- Green roof and green walls
- Shading system with photovoltaic elements on the rooftops

[68] The digital map data for the area was obtained by Google earth but additional surveying took place to correct changes. ENVI-met uses its own graphic interface to plot the layout of the area, and its own configuration editor for the climatic data plus the plants, soils, and sources databases. Therefore all cartographic information had to be gathered on a digital map and redrawn in ENVI-met graphic editor for the modeling language.

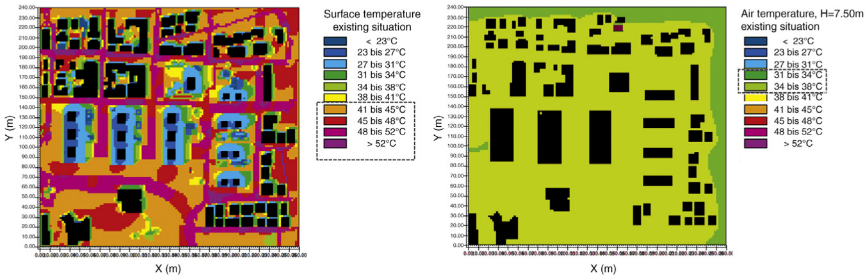


Figure 2.57 ***Comparison between ENVI-met output of surface ground temperature (on the left) and the air temperature at 7.5 m height in the existing situation at 14.00 pm.***

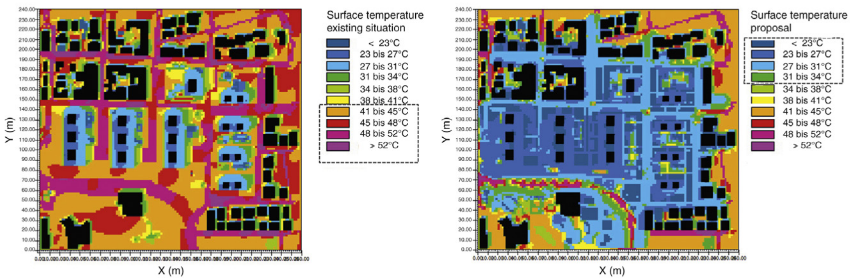


Figure 2.58 ***ENVI-met output of surface ground temperature in the existing situation (on the left) and for the designed scenario at 14.00 pm.***

- Reorganization of the parking and creation of pedestrian permeable streets
- Linear park (green roof) on the existing roof of the market

The research conducted consisted of two brief studies of the area. Figs. 2.57–2.61 visualize the model of the area in different conditions.[69] This stage is used to explore calculation and visualization potentials of the model plus it also helped the researcher to hypothesize on certain factors of the model itself and on certain characteristics of the urban compound.[70]

[69] Data of external temperature in the model of the as it is condition have been verified with measured data by the team GRBES (Prof Santamouris).
[70] The processes of working with the models in the research are described by Ozkeresteci et al. (2003). These are summarized as follows.•Model shows a fine detail in the analysis of the atmospheric data form the user's point of view.Model shows a fine detail in the analysis of the atmospheric data form the user's point of view.•It provides area-based information about critical areas in the study domain like very hot sports, problematic areas.•It plots in 3D and 4D the path and the direction of the wind movement and particle diffusion around the landscape elements therefore critical areas of polluted spots in the study domain.•The previous inferences are critical design and planning data either from an urban designer's point of view preparing a development project in the area or from the point of a planner's working in the city reviewing and communicating the development in different stages.

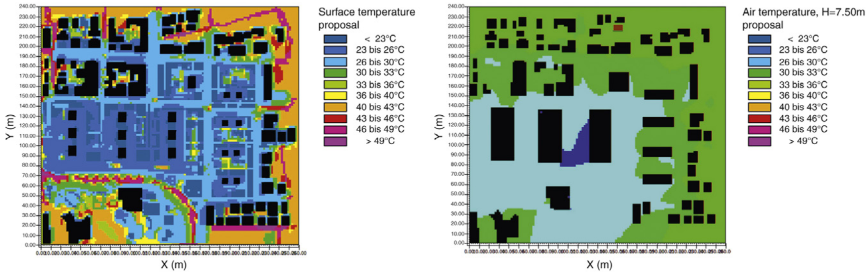


Figure 2.59 *ENVI-met output of surface ground temperature (on the left) and the air temperature in the proposed scenario at 14.00 pm.*

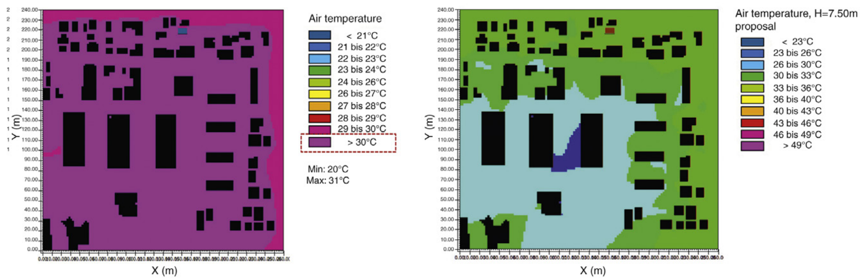


Figure 2.60 *ENVI-met output of air temperature in the as-it-is scenario (on the left) and the air temperature in the proposed scenario at 14.00 pm.*

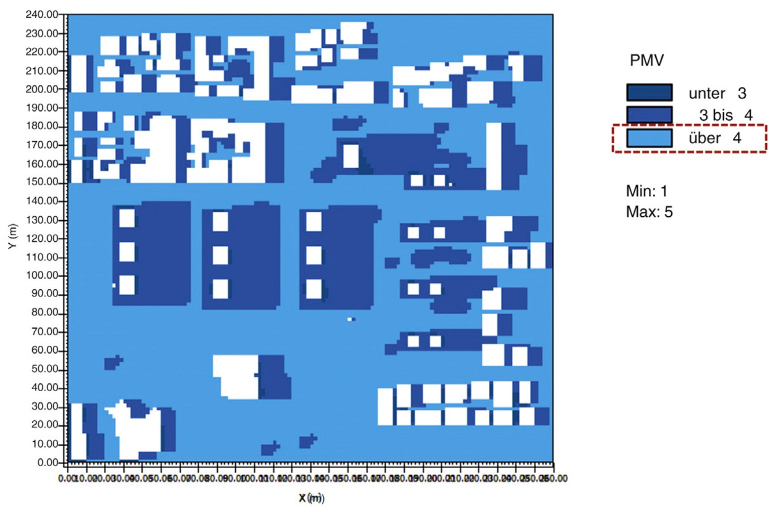


Figure 2.61 *Thermal comfort interpretation in the existing area at 16.00 pm.*

For the environmental simulation with ENVI-met, the same climatic data and maps were taken into account. To compare and discuss in further detail here, the results of the simulations are provided for four of the five scenarios: green elements and trees, green walls and roofs, pedestrian streets, and design of a linear park on the roof level of the market. Variations imply a different microclimatic behavior in the models. Introducing parks and pedestrian streets in place of asphalted areas led to fresher air (temperature decreases generally in a range from 0.25 to 1.5°C; locally, the difference can be as much as 4°C). Results show consistencies with the previous studies discussed at the beginning of this section (Figs. 2.62).

Selection of trees and vegetation should be made according to the warm, dry climate of Athens. Plantings with big crowns provide adequate shade while requiring less water. The replacement of standard roofs with green roofs does not seem to lead to significant variations in temperatures, as maximum decrease is only equal to 0.7°C; conversely, measurements performed locally, close to one of the buildings, with a shading system on the rooftop in place, show a significant decrease (about 2.5°C).

Furthermore, by using the simulation tool it is also possible to define the best area of thermal comfort.[71] A method of describing thermal comfort

[71] According to the ANSI/ASHRAE Standard 55-2010, thermal comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation." Also known as human comfort, thermal comfort is the occupants' satisfaction with the surrounding thermal conditions and is essential to consider when designing a structure that will be occupied by people. A cold sensation will be pleasing when the body is overheated, but unpleasant when the core is already cold. At the same time, the temperature of the skin is not uniform on all areas of the body. There are variations in different parts of the body, which reflect the variations in blood flow and subcutaneous fat. The isolation potential and quality of clothing also has a marked effect on the level and distribution of skin temperature. Thus, sensation from any particular part of the skin will depend on time, location and clothing, as well as the temperature of the surroundings.

There are six factors to take into consideration when designing for thermal comfort. Its determining factors include the following: Metabolic rate (met): The energy generated from the human body; Clothing insulation (clo): The amount of thermal insulation the person is wearing; Air temperature: Temperature of the air surrounding the occupant; Radiant temperature: The weighted average of all the temperatures from surfaces surrounding an occupant; Air velocity: Rate of air movement given distance over time; Relative humidity: Percentage of water vapor in the air. The environmental factors include temperature, radiant temperature, relative humidity, and air velocity. The personal factors are activity level (metabolic rate) and clothing. Thermal comfort is calculated as a heat transfer energy balance. Heat transfer through radiation, convection, and conduction are balanced against the occupant's metabolic rate. The heat transfer occurs between the environment and the human body, which has an area of 19 $ft.^2$. If the heat leaving the occupant is greater than the heat entering the occupant, the thermal perception is "cold." If the heat entering the occupant is greater than the heat leaving the occupant, the thermal perception is "warm" or "hot."

Figure 2.62 ***The urban compound in the existing situation and in the proposed alternative scenario.***

was developed by Ole Fanger and is referred to as predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD). The PMV refers to a thermal scale that runs from cold (−3) to hot (+3), originally developed by Fanger and later adopted as an ISO standard (Table 2.21).[72] Figs. 2.63 and 2.64, show the comparison between the temperatures and PMV of the existing situation versus the transformed scenario.

Actually, in the current as-it-is scenario, shade is indeed provided by existing trees in the center of the courtyards between the buildings. The presence of the trees is assumed to be increased and enhanced by the redesign of

[72] The original data was collected by subjecting a large number of people (reputedly many thousands of Israeli soldiers) to different conditions within a climate chamber and having them select a position on the scale the best described their comfort sensation. A mathematical model of the relationship between all the environmental and physiological factors considered was then derived from the data. The result relates the size thermal comfort factors to each other through heat balance principles and produces the following sensation scale.

Table 2.21 Predicted mean vote sensation scale

Value	Sensation
−3	Cold
−2	Cool
−1	Slightly cool
0	Neutral
+1	Slightly warm
+2	Warm
+3	Hot

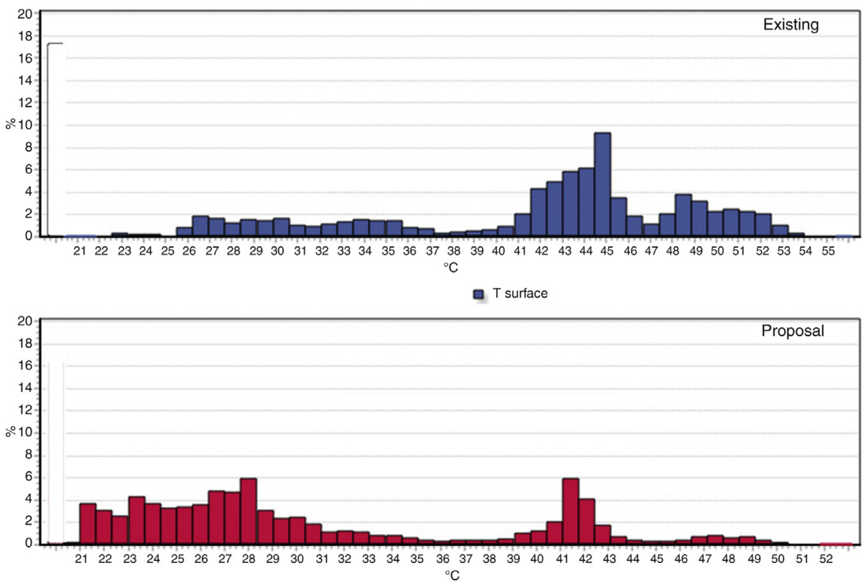


Figure 2.63 ***Temperature comparison of the existing situation and the alternative scenario.***

external surfaces, increasing the permeable surfaces and reducing the asphalt area as much as possible. A great impact in local decrease in temperature is brought about by the linear park and the shading of the new plantings in that area. There is a significant temperature reduction on the surface of the ground level due to the use of new materials and the shading provided by the vegetation. According to the measurements around the central building, the resulting air temperature reduction is between 0.5 and 2.9°C, while a lower reduction is observed to the west and south.

A further step is needed in the effort to understand the potential effects of modifying external conditions and what improvements that will make

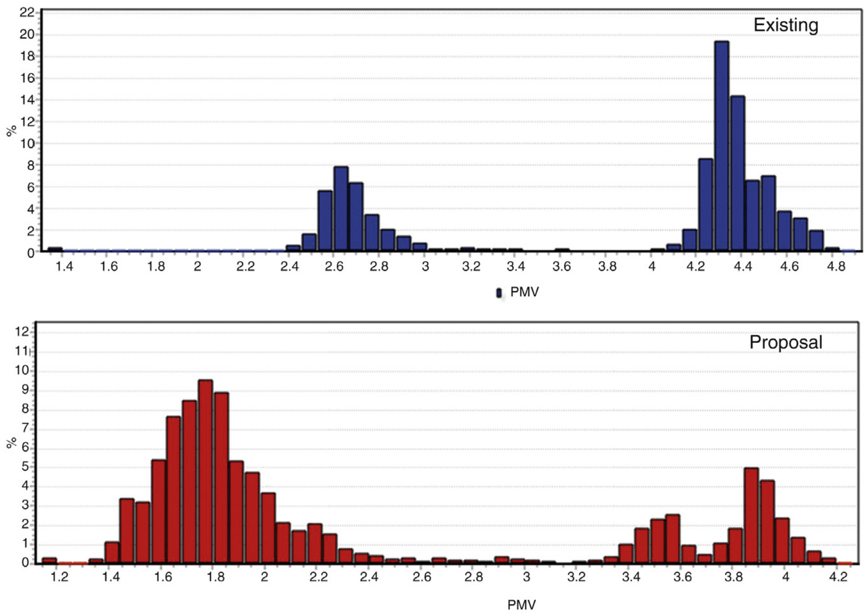


Figure 2.64 ***PMV comparison of the existing situation and the alternative scenario.***

on the energy performance of existing buildings. To provide an idea of the potential energy performance improvements in this urban compound, taking into account the mutual interactions between buildings and open areas, further simulations have been run.

The new climatic data of the area simulated by ENVI-met have been used in conjunction with the simulation by Design Builder (IWEC climatic data file), allowing new input for the re-calculation of the energy performance of the building. Fig. 2.65 shows an area of 4 × 4 × 4 m around the main central double block building. A vertical division in five critical points was also performed (ground level, pilotis level, first floor, middle floor, and

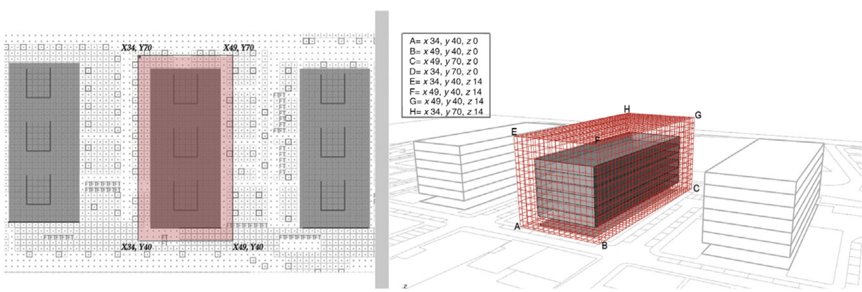


Figure 2.65 ***The defined area around the double block building for the new climatic data.***

last floor including 4 m above the rooftop) so as to subtract results from all the points referred to in these elevations.

The air temperature of these points has been used for the simulation of the corresponding apartments. South-oriented residential apartments at the first, third, and last floors of the double building block B6 of Peristeri have been used as reference units. Simulations have been performed for the summer period, from Jun. 1 until Aug. 31.

The standard climatic data used by Design Builder have been modified in two different and opposite ways. On the one hand, they have been decreased according to the corresponding value of the external temperatures from the ENVI-met calculations; on the other hand, the same data have been increased as a function of measured data in the corresponding meteorological station of Peristeri (Giannopoulou et al., 2011). Results of the energy demand for cooling (kWh) these apartments for the whole summer period are reported in Fig. 2.66. As shown, these results are highly variable as a function of external temperatures (Table 2.22).

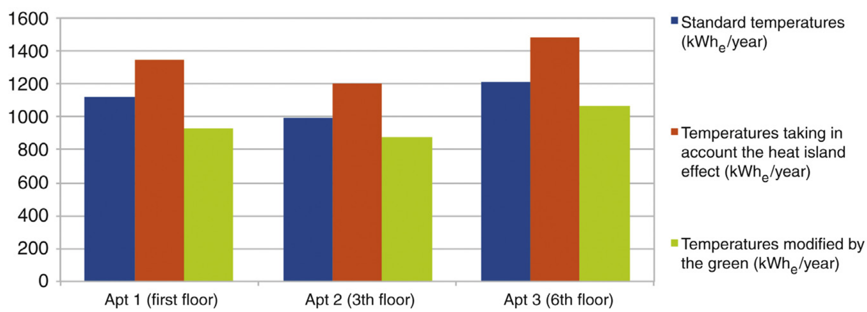


Figure 2.66 ***Cooling demand in three reference apartments of the building block B6 in Peristeri.***

Table 2.22 Cooling demand values in three reference apartments of the building block B6 in Peristeri

	Energy demand for cooling (kWh) (standard air temperatures) (kWh_e/y)	**Energy demand for cooling (kWh) (air temperatures HI effect) (kWh_e/y)**	**Energy demand for cooling (kWh) (temperatures modified by green) (kWh_e/y)**
Apt 1 (first floor)	1122.55	1348.37	926.54
Apt 2 (3th floor)	990.98	1202.45	874.06
Apt 3 (6th floor)	1211.22	1483.49	1067.35

As it can be observed, values of energy demand for cooling the selected apartment on the first floor vary between 1348.37 kWh, which is the worst condition (due to the HI effect), to 1122.55 kWh, which is the best scenario. Note that air temperatures are presumed to be "under standard condition"; the reduction to 926.54 kWh in the improved scenario is due to the cooling effect of the greenery.

Corresponding values of energy demand for cooling the apartment on the intermediate floor vary between 1202.45 kWh (worst condition, a result of the HI effect) to 990.98 kWh (best condition). Again, air temperatures are presumed to be "under standard condition"; the reduction to 874.06 kWh in the improved scenario is due to the cooling effect of the greenery.

Corresponding values of energy demand for cooling the apartment on the top floor vary between 1483.49 kWh (worst condition, a result of the HI effect) to 1211.22 kWh (best condition). As per the previous two examples, the same assumption about air temperatures holds; the reduction to 1067.35 kWh in the improved scenario is due to the cooling effect of the greenery.

A 20% decrease among each of the three scenarios can be seen. Globally, approximately a 40% reduction in energy consumption can be observed, demonstrating the huge potential of environmental modification at the urban scale on the energy performance of existing buildings. A very significant, twofold impact on HI reduction at the urban scale and energy consumption at the building scale can be seen. We have deduced that this is the direct result of shading and greenery in the model.

Results of these simulations are highly consistent with data and corresponding values reported by Santamouris (2014). In fact, as illustrated by Santamouris and colleagues and already reported in Chapter 1, the energy penalty of ambient overheating is quite high and depends mainly on the characteristics of the building stock, the climate zone, the urban form (and its boundary conditions), as well as the type of the energy services provided. A significant increase in the energy consumption of buildings caused by the ambient temperature intensification in metropolitan areas was calculated for the period 1970–2010. In particular, for the Athens case study, a percentage increase of the base electricity load per degree of temperature increase equal to 4.1% was found. In particular, in Athens, Santamouris (2014) found that the cooling load increased from 99.5 kWh/m^2/y in 1970 to 124.8 kWh/m^2/y in 2010, while the corresponding heating load decreased from 39.4 kWh/m^2/y in 1970 to 31.7 kWh/m^2/y in 2010.

The urban HI effect and global warming increase the temperature of metropolitan cities like Athens and exacerbate the energy demand of buildings. In particular, Santamouris (2014) found that energy increase is very significant in cooling dominated zones, where summer energy needs are much higher than the possible decrease of heating needs in winter, as can be observed by the figures reported. Although the available studies comparing the energy consumption of similar buildings located in urban and rural zones are quite limited, existing data reveal that the average increase of the cooling load, because of the HI effect, is statistically significant and averages about 13%. So far, limited studies are available regarding the global energy penalty induced by urban warming on the total building stock of a city.[73]

It can be concluded that in order to reduce the specific impact of urban HI and global overheating on electricity consumption, buildings and urban structures have to be adapted to the specific climatic conditions, taking into consideration the built environment in its different scales, and conceiving the retrofitting options in the building block and in its urban boundary conditions. In fact, energy demand and energy retrofitting options should be observed, quantified, and designed not only with reference to the building blocks and urban textures that are considered to be the "solid" part of the city, but also with regard to the open street environments, thus considering the buildings and the related open spaces as a whole; in fact, energy investigation should be conducted taking into account the cumulative effects between the buildings and the open areas.

The development of low energy or close-to-zero energy buildings may significantly reduce the energy needs and thus the resulting stress to the

[73] As shown by Santamouris (2014), calculations performed for a set of different cities around the world have demonstrated that the global energy impact of higher urban temperatures is very important. The average global energy penalty per unit of city surface is significant (2.4 kWh/m^2), while the average global energy penalty per unit of surface and degree of UHI intensity is close to 0.74 kWh/m^2/K. In parallel, the average global energy penalty per person is close to 237 kWh/p and the global energy penalty per person and per degree of the UHI intensity is around to 70 kWh/p/K. These figures consist of preliminary information may change when more data are available. Based on a significant number of studies, it is calculated that the average increase of the cooling demand of representative buildings during that period 1970–2010 was close to 23%. In parallel, the corresponding average reduction of the heating load is around to 19%, while during the same period, the average total energy load of representative buildings spent for heating and cooling purposes increased by 11%. The specific studies and analysis make clear that urban warming has a very significant impact on the global energy consumption of buildings.

utilities and the consumers would also be lessened. In parallel, the development and use of advanced urban adaptation and mitigation techniques and technologies with the potential to decrease the ambient temperatures in the built environments may also considerably reduce urban temperatures.

2.4 ON THE TECHNICAL FEASIBILITY OF NEARLY ZEUS

Achieving a nearly zero energy building in these three urban compounds has been proven to be a technically feasible goal; in particular, a large set of possible solutions from the best available products and components is technically applicable to achieve nZEBs, even in buildings that presently consume a lot of energy. In all the considered cases, to reach zero energy, passive retrofitting interventions and the production of energy from renewable sources are both necessary.

The effective reduction of energy consumption remains a necessary objective that should be combined with alternative uses of open spaces, where water, greenery, and selected passive techniques may foster and accelerate the significant reduction of energy consumption. This is especially important in the Mediterranean urban areas, where the dramatic combination of HI phenomena and global overheating is severe. This chapter has discussed and demonstrated the technical feasibility of these goals, using examples from the urban setting of Athens.

Nonetheless, so far, as reported by several prominent studies, only about 1.2% of European existing buildings are renovated every year.[74] This means that a series of barriers must be overcome to facilitate the adoption of measures to reach the target number of nZEBs. Chapter 3 will discuss these barriers as well as the estimated costs that must be taken into account when proposing energy retrofitting options. It will also address the two following important questions:

- Is technical feasibility associated with economic feasibility when retrofitting existing buildings toward becoming nZEBs?
- To what extent is deep renovation and high transformation of buildings toward becoming nZEBs competitive with conventional retrofitting?

[74] The demolition rate is about 0.1% per year and highly energy efficient new-build reach 1% additions/year. JWG: Toward assisting EU member states on developing long-term strategies for mobilizing investments in building energy renovation (EU EED Article 4), see the Composite Document of the Joint WG of CA EED, CA EPBD and CA RES, Nov. 2013 (http://www.ca-eed.eu/reports/art-4-guidance-document/eed-article-4-assistance-document).

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CHAPTER 3

Understanding Economic Constraints to Achieve Nearly ZEUS

3.1 OVERCOMING EXISTING CONSTRAINTS TOWARD ZEUS

To reach the ambitious target of nZEBs (EPBD recast 2010/31/EU), the technical feasibility in general is not sufficient to widely spread nZEB into building current practice, especially considering the quality and the amount of existing building stock, which represents a huge potential in terms of carbon reduction. As a matter of fact, the representative case studies selected for this work appear to be consistent with the quality of the existing building stock at the European level, made up in the larger majority, from about 60% of buildings built after World War II and between the 1960s and the 1980s[1] (see Fig. 3.1). In fact, the current age of existing building stock derives from the political and social events that occurred just after the WW II.[2] This percentage further increases (about 70–75%) if we confine the analysis within

[1] In fact, a high number of quite drastic measures have been undertaken to vastly and quickly combat the great post-war housing shortage in the EU countries. These measures were mainly conceived through standardization of plans and building elements, as well as setting up of a central organization for the distribution of building material and labor and the creation of a building industry connected to the industrialization. This happened identically even if with different technologies and industries involved, between the two wars and after 1945. In particular, the social housing stock has been conceived everywhere in Europe according to the modernist idea of the minimal residential units. This solution has been then applied – with few considerations on the context – all over Europe, often resulting in housing complexes that are now facing very similar problems: small dwellings, mono-functional districts, concentration of weak minorities and immigrants, low quality of public spaces. This monotony of endless rows of identical houses is threatening the identity of urban dwellers and inhabitants. On the other side, the industrialized system applied for rapid building edification was without any doubt effective and has proven its potential, rapidity, and capacity of serving the purpose of providing a shelter for everyone throughout the decades until the present time.

[2] This was not only a problem related to the post-war reconstruction but also to the emergency caused by the phenomena of internal migration. In many Mediterranean countries

(*Continued*)

Towards Nearly Zero Energy
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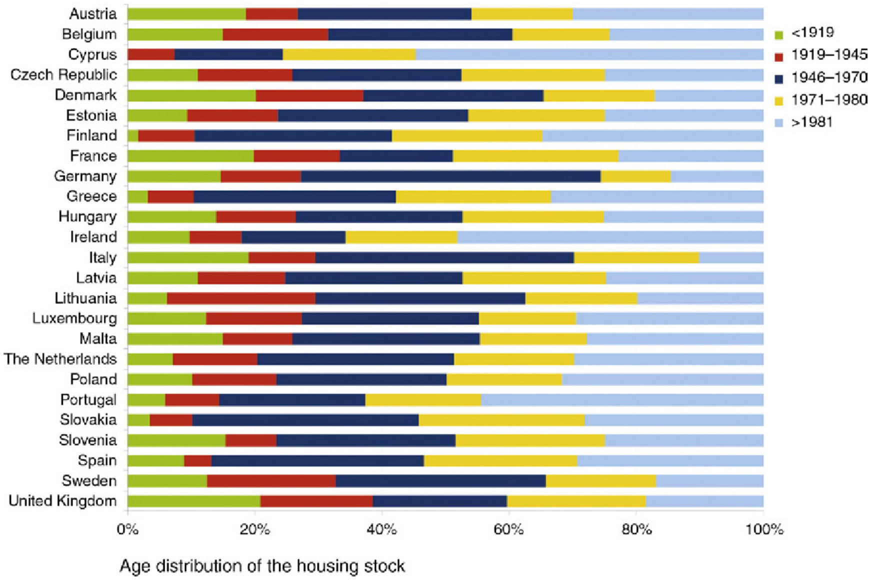


Figure 3.1 ***The age distribution of EU existing building stock shows that the larger majority of buildings (about the 60%) have been constructed after World War II (1960s and 1980s).*** Housing Statistics in the European Union, 2010. *(Source: Boverket and MMR, 2005).*

the boundaries of the Mediterranean European countries (Greece, Cyprus, Spain, Portugal, etc.) and slightly increases for Italy, as well (about 65%).

This means that the majority of existing buildings in the European Union (EU) have been built well before the design and application of

of the current European Union like Italy, France, and Spain the extent of the migration from the south to the north, the return of a large number of citizens from the colonies and the migration from the countryside to the cities, resulted in a consistent request for housing which became national issues in these countries, causing legislation answers, dedicated urban plans and several special measures (ie, Fanfani Plan, Gescal, Casa Plan, etc.). The objective of those actions was to combine the interests of developers and construction companies to generate cheap and fast-to-build dwellings that could be rented or sold to the inhabitants or allocated upon social conditions. In the Eastern Europe countries the situation was similar: the organization of socialist states after the defeat of the Axis powers, centralization of planning and powers according to the soviet model lead to the idea that housing, as social good, is a good of collective consumption and the Institutions had to provide for their construction, favoring multifamily homes organized in large settlements. Architects and urban planners tried to find the solution to the housing emergency, reinterpreting the principles of the modern movement and its results from the experiences carried between the two wars. The increase in the Housing production created a vast and fairly uniform patrimony of buildings that are now facing similar conditions.

regulatory measures on energy consumption reduction, because the energy requirements applicable to housing before 1995 were absent or very limited; as a result, the existing building stock across EU presents very low standard energy performance (Housing Statistics in the European Union, 2010). In fact, an awareness regarding energy consumption related to buildings' performances arose only after the energy and oil crises in the 1970s: these buildings that were once built to answer to the housing emergency represent now the largest energetic emergency. In fact, from illustrated figures, almost two-thirds of the buildings that make up the European real estate assets have been designed in total absence of specific regulations and with very few considerations on energy efficiency. As a result, the existing buildings' stock is responsible for over 40% of the total European energy consumption, of which residential use represents two-thirds of the total building sector's consumption; this data is not surprising looking at the percentage of elements, within the building envelope, lacking insulation, and or the necessary requirements.

Furthermore, housing in the EU represents a huge part of the building stock. EU dwelling stock accounts for about 200 million units, representing around 27% of energy consumption in the EU: the potential reduction in CO_2 emissions that energy-efficient housing would provide cannot be underestimated. But, of Europe's existing buildings, only about 1.2% per year are renovated.[3]Nonetheless, research studies and analysis performed in different EU contexts have shown wide margins of energy efficiency (EE) in retrofitting through standard technical interventions such as renewal of plants or U-value reduction of building components (Ferrante et al., 2011).

Within the frame of social housing sector, many experiences have highlighted the coincidence between low-quality and high-energy management costs, often associated with the deterioration of both buildings and urban

[3] JWG: Towards assisting EU Member States on developing long term strategies for mobilising investment in building energy renovation (per EU Energy Efficiency Directive Article 4), Composite Document of the Joint Working Group of CA EED, CA EPBD, and CA RES, Nov. 2013 (http://www.ca-eed.eu/reports/art-4-guidance-document/eed-article-4-assistance-document). A survey of social housing providers across EU (Cecodhas, 2013) has identified five key categories of barriers (economic, technical, credibility, social, legislative) in delivering new construction and retrofit to nZEB standards; in particular, among others, the lack of access to available and affordable finance to retrofit existing stock toward nZEBs is one of the major barriers.

contexts (Santamouris et al., 2007). Thus, promoting energy improvement measures for the housing stock is an urgent and challenging objective.

3.1.1 Is Technical Feasibility Associated with the Economic Feasibility in ZEUS? Important Economic Barriers for ZEUS

To respond to this important question, cost analyses and simple payback times in the different cases have been calculated. Generally, the basic costs to be considered in a preliminary analysis of the economical feasibility of retrofitting actions are:

- Current prices of energy for heating and cooling demand
- Current prices for electric appliances
- Costs of designed retrofitting interventions

In this work, to avoid excessive fragmentation of data and achieve comparable results, consumptions are assessed under the same plant systems' conditions and the cost for consumption was estimated applying the average energy tariffs in force in Greece for domestic residential users, currently 0,102 €/kWh for gas and 0,145 €/kWh for electricity. The electrical equipment in the buildings is assumed close to 35 kWh/m^2 per year.[4] A summary evaluation of the costs of the various interventions has been calculated for each case study in order to be able to compare the cost of the refurbishment with the savings and payback time of the initial investment.[5]

General assumptions have been made for costs for the retrofitting options in the possible scenarios:

Scenario 1: Wall insulation

Scenario 2: Windows' replacement with high performing glazing components

Scenario 3: (3= 1 + 2): Combined scenario

Scenario 4: Roof insulation

Scenario 5: Roof insulation and green roof

[4] While the electrical need to meet thermal demand can be reduced, there are still other demands to account for and the electrical equipment in the building could easily double the electrical demand. An equipment demand of 35 kWh/m^2 of floor area per annum is not unusual (Dunster et al., 2009). This estimation is consistent with other studies' evaluations reporting an annual consumption of about 4000 kWh for a family consisting of four persons.

[5] In all performed calculation simple payback period in capital budgeting refers to the period of time required to recoup the funds expended in an investment, or to reach the break-even point. The time value of money is not taken into account.

Table 3.1 Mean costs assumed for each retrofitting option

Retrofitting options	Cost per unit EUR
Wall insulation (per square meters)	50.00 – 110.00
Windows' replacement with high performing glazing components, including costs for removal (each window)	250.00
Roof insulation and waterproofing (per square meters)	60.00
Insulated green roof (per square meters)	125.00
New plants (per square meters of net residential floor surface)	30.00
Energy generation by PV panels per kW_p	1,800.00

Scenario 6: (6= 3 + 5): Combined retrofitted scenario
Scenario 7: New plant system associated with scenario 6
Scenario 8: Energy generation by RES based on scenario 7
Scenario 9: Complete retrofitting scenario to nZEB

To identify the economical feasibility of the energy retrofit scenarios, the cost-benefit analysis was conducted by means of a market survey, determining, for each different design option, the evaluation in terms of energy performance improvement and the related cost estimations.

The general assumptions are summed up in Table 3.1

3.1.1.1 Cost-Benefit Analysis in Aghia Varvara

Considering these assumptions, for each proposed intervention for the Aghia Varvara case study, the relative cost and the consequent savings have been reported.

Table 3.2 shows the different retrofitting options in the Aghia Varvara urban setting. Results show that a significant decrease in terms of cost of energy may be achieved.[6] The increasing progression of hypothetical retrofit options show that some interventions, if taken alone, do not significantly affect the energy savings and the consequent energy costs. This is the case, for example, of the insulated green roof. Here, the benefits to the contribution of this solution to the heat island (HI) reduction and its overall environmental benefits have been disregarded by the performed calculations, expressly related to the building's energy demand; in this calculation, the energy performance improvement appears to be similar

[6] The calculated consumption does not include the consumption for domestic appliances, but only the one for electric energy for cooling and for gasoil for heating.

Table 3.2 Costs and simple payback time for the different retrofitting options in the Aghia Varvara urban setting

		Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	9,465	5,391	14,864	–
1	Wall insulation	47,122	7,683	4,830	12,513	20.0
2	New windows	24,280	8,241	4,545	12,787	11.7
3	1 + 2	71,402	6,459	3,977	10,436	16.1
4	Roof insulation	9,150	8,685	5,023	13,708	7.9
5	Insulated green roof	18,471	8,798	5,023	13,821	17.7
6	1 + 2 + 5	89,873	5,791	3,602	9,394	16.4
7	Plants systems	27,840	0	4,190	4,190	2.6
8	Renewable plants (PV)	122,400	0	0	0	8.2
9	nZEB-nZEUS = 6+7+8	240113	0	0	0	16.2

to that obtained by the roof insulation. The cost of the green roof is higher when compared to the cost of the simple insulation; therefore, the payback time in the green roof option is longer. Nonetheless, since the extension of roof surfaces in building blocks and in densely built urban compounds is usually limited with respect to the amount of surfaces of other building components like walls or windows, the up-front costs remain acceptable in absolute value.

Performed evaluations on cost analysis in Aghia Varvara essentially show a long payback time of the different retrofitting scenarios: the cost-benefit assessments of these interventions vary from 8 to up to 20 years. New plant systems associated with renewable energy systems (RES) given by the photovoltaic installations have been evaluated as the consequent options of the complete retrofit scenario modification. In particular, results show the high costs for photovoltaic (PV) panels to set to zero the energy balance of the building. Nonetheless, by coupling the RES in a complete retrofitting scenario, the payback time becomes shorter, while achieving almost null costs for the total energy consumption.

In this, as in all the urban settings, results are oriented at achieving net ZEB, net zero energy building (Net ZEB), conceived as a grid-connected

Table 3.3 Costs and simple payback time for the different retrofitting options in Peristeri urban setting

		Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	371,849	192,284	564,133	
1	Wall insulation	2,893,434	221,512	111,039	332,551	12.5
2	New windows	998,295	337,066	180,935	518,001	21.6
3	1 + 2	4,091,910	196,929	95,000	291,930	15.0
4	Roof insulation	393,129	342,857	179,951	522,808	9.5
5	Green roof	625,263	341,002	179,281	520,283	14.3
6	1 + 2 + 5	4,474,764	170,719	80,657	251,376	14.3
7	Plants systems	1,089,360	0	167,550	167,550	2.7
8	Renewable plants (PV)	2,635,034	0	0	0	4.7
9	nZEB (6 + 7 + 8)	8.199.158	0	0	0	14.5

building or groups of buildings in the whole urban settings that generates as much energy as it uses over a year. The "net zero" balance is attained by applying energy conservation and efficiency measures and by incorporating RES.[7]

3.1.1.2 *Cost-Benefit Analysis in Peristeri*

Similar cost-effective analyses have been developed for the whole urban setting in Peristeri (Table 3.3). Furthermore, they have also been developed for each building type and for each different scenario in the urban context of Peristeri (Tables 3.4–3.6). Simple payback time of the investments has been put in relation using the synthetic results of these calculations in Fig. 3.2.

Generally, the double building block and the tower building type present the higher payback times in all the retrofitting options; in the tower building, the sole exception to this rule is embodied in the intervention

[7] While based on annual balances, a complete description of a net ZEB should require the detailed analysis of the system at smaller time-scales, evaluating, in example, the relationship between power generation and building loads to evaluate the resulting interaction with the power grid. These detailed aspects are disregarded in the present work, whose aim is a simplified, yet effective, comparison among different contexts and different building types in the aim of ZEUS.

Table 3.4 Costs and simple payback time for the different retrofitting options in the tower building in Peristeri

	Tower Building T11	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	30,865	15,186	46,051	
1	Wall insulation	236,736	20,062	12,060	32,122	17.0
2	New windows	111,636	25,309	13,400	38,709	15.2
3	1 + 2	348,373	17,902	8,710	26,612	17.9
4	Roof insulation	23,455	27,161	14,070	41,231	4.9
5	Green roof	37,299	26,853	13,846	40,699	7.0
6	1 + 2 + 5	371,595	14,815	6,923	21,738	15.3

Table 3.5 Costs and simple payback time for the different retrofitting options in the double building block B6 in Peristeri

	Double block B6	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	36,112	10,943	47,055	
1	Wall insulation	318,394	24,692	5,583	30,275	19.0
2	New windows	135,769	32,408	10,496	42,905	32.7
3	1 + 2	454,163	20,988	5,136	26,125	21.7
4	Roof insulation	65,700	33,643	10,273	43,916	20.9
5	Green roof	104,396	33,334	10,273	43,607	30.3
6	1 + 2 + 5	558,559	18,828	4,467	23,294	23.5

Table 3.6 Costs and simple payback time for the different retrofitting options in the building block T7 in Peristeri

	Block T7	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	28,396	18,983	47,379	
1	Wall insulation	204,674	14,488	9,685	24,173	8.8
2	New windows	42,680	27,237	18,208	45,445	22.1
3	1 + 2	280,717	13,329	8,910	22,239	11.2
4	Roof insulation	20,944	26,657	17,821	44,478	7.2
5	Green roof	33,363	26,657	17,821	44,478	11.5
6	1 + 2 + 5	280,717	11,590	7,748	19,338	10.0

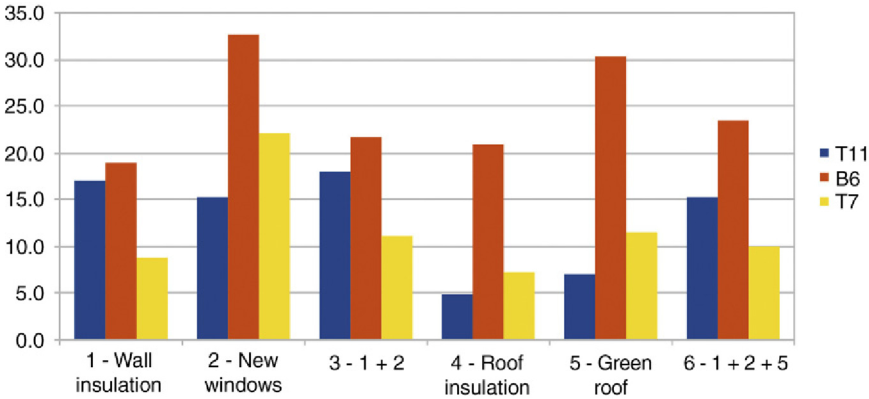


Figure 3.2 ***Payback times of the investments range widely: a variation between 30 and 4 years can be observed as a function of the different hypothesized scenarios in the different building types (B6 = double building block T6= single building block).***

of the roof (scenarios 4 and 5 of the roof insulation and green roof), given the limited extension of the roof surface in this building type. All performed evaluations on cost-benefit assessments of these interventions generally show excessive payback times (from 5 up to 32 years). As shown, variations essentially depend on building type and on the number of glazed surfaces, since window replacement is by far the most expensive retrofitting option.

The costs in Tables 3.4–3.6 do not yet include the installation of RES plant and the plant interventions that are in any case necessary to set to zero the energy balance of the selected buildings. They have been incorporated in Table 3.3, hypothesizing only one PV system network serving the whole urban setting. However, costs and simple payback time calculated in the different retrofitting options of the whole urban compounds in Peristeri and Aghia Varvara (Table 3.3) show how the hypothesis of the complete retrofit scenario equipped by new plant systems and PV sources to set to zero the energy balance can imply a significant reduction in payback times with respect to single retrofitting options and are similar to the complete retrofit scenario 6 while providing null costs for total energy consumption. Nonetheless, the option nZEB (6 + 7 + 8 = 9) requires very high up-front costs. Thus, as for the Aghia Varvara case study, the energy retrofitting in the existing building of Peristeri urban compound is proved to be a technically feasible goal, but it is necessary to face the problem of very high up-front costs, due to the need to apply both active and passive interventions to achieve nZEBs; these high costs are amortized

Table 3.7 Different retrofit options and relative payback time calculated for building 1

	Building 1	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	6,300	11,206	17,506	
1	Wall insulation	87,218	5,796	10,309	16,106	62.3
2	New windows	61,531	5,859	10,421	16,281	50.2
3	1 + 2	148,749	5,418	9,637	15,055	60.7
4	Roof insulation	34,727	4,977	8,852	13,830	9.4
5	Green roof	40,370	5,040	8,964	14,005	11.5
6	1 + 2 + 5	189,119	3,780	6,723	10,504	27.0

Table 3.8 Different retrofit options and relative payback time calculated for building 2

	Building 2	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	6,489	11,411	17,899	
1	Wall insulation	101,074	5,970	10,498	16,467	70.6
2	New windows	87,631	6,035	10,612	16,646	69.9
3	1 + 2	188,705	5,580	9,813	15,393	75.3
4	Roof insulation	12,337	5,126	9,014	14,141	3.3
5	Green roof	14,342	5,191	9,129	14,320	4.0
6	1 + 2 + 5	203,046	3,893	6,846	10,740	28.4

over a relatively long time, generally comparable with the life of the systems of energy production from RES.

3.1.1.3 Cost-Benefit Analysis in Evripidou

A detailed analysis for each scenario has been performed for all 11 buildings in the selected area of the urban courtyard in Evripidou, thus obtaining, for each building, the energy requirements in both the summer and the winter periods. Furthermore, an economical analysis taking into account the cost of operations and retrofitting options has been developed with reference to each building. Thanks to this analysis, the annual savings and simple payback times can be assessed. Tables 3.7–3.18 show the performed calculations for all 11 buildings.

Table 3.9 Different retrofit options and relative payback time calculated for building 3

	Building 3	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	5,907	11,821	17,728	
1	Wall insulation	82,100	5,434	10,875	16,310	57.9
2	New windows	111,230	5,493	10,993	16,487	89.6
3	1 + 2	193,330	5,080	10,166	15,246	77.9
4	Roof insulation	18,277	4,667	9,339	14,005	4.9
5	Green roof	21,247	4,726	9,457	14,182	6.0
6	1 + 2 + 5	214,577	3,544	7,093	10,637	30.3

Table 3.10 Different retrofit options and relative payback time calculated for building 4

	Building 4	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	3,028	5,282	8,310	
1	Wall insulation	39,960	2,786	4,859	7,645	60.1
2	New windows	15,533	2,816	4,912	7,728	26.7
3	1 + 2	55,493	2,604	4,542	7,146	47.7
4	Roof insulation	9,139	2,392	4,172	6,565	5.2
5	Green roof	10,624	2,422	4,225	6,648	6.4
6	1 + 2 + 5	66,116	1,817	3,169	4,986	19.9

Table 3.11 Different retrofit options and relative payback time calculated for building 5

	Building 5	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	4,737	8,678	13,415	
1	Wall insulation	69,966	4,358	7,984	12,342	65.2
2	New windows	106,997	4,405	8,071	12,476	113.9
3	1 + 2	176,963	4,074	7,463	11,537	94.2
4	Roof insulation	10,509	3,742	6,856	10,598	3.7
5	Green roof	12,217	3,790	6,943	10,732	4.6
6	1 + 2 + 5	189,180	2,842	5,207	8,049	35.3

Table 3.12 Different retrofit options and relative payback time calculated for building 6

	Building 6	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	10,769	20,106	30,875	
1	Wall insulation	152,372	9,907	18,498	28,405	61.7
2	New windows	168,229	10,015	18,699	28,714	77.8
3	1 + 2	320,600	9,261	17,292	26,553	74.2
4	Roof insulation	41,581	8,507	15,884	24,391	6.4
5	Green roof	48,337	8,615	16,085	24,700	7.8
6	1 + 2 + 5	368,938	6,461	12,064	18,525	29.9

Table 3.13 Different retrofit options and relative payback time calculated for building 7

	Building 7	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	1,811	3,069	4,881	
1	Wall insulation	16,166	1,667	2,824	4,490	41.4
2	New windows	17,033	1,685	2,855	4,539	49.9
3	1 + 2	33,199	1,558	2,640	4,198	48.6
4	Roof insulation	13,251	1,431	2,425	3,856	12.9
5	Green roof	15,404	1,449	2,455	3,905	15.8
6	1 + 2 + 5	48,603	1,087	1,842	2,928	24.9

Table 3.14 Different retrofit options and relative payback time calculated for building 8

	Building 8	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	2,890	5,157	8,047	
1	Wall insulation	41,972	2,659	4,745	7,404	65.2
2	New windows	23,132	2,688	4,796	7,484	41.1
3	1 + 2	65,104	2,485	4,435	6,921	57.8
4	Roof insulation	10,966	2,283	4,074	6,357	6.5
5	Green roof	12,748	2,312	4,126	6,438	7.9
6	1 + 2 + 5	77,852	1,734	3,094	4,828	24.2

Table 3.15 Different retrofit options and relative payback time calculated for building 9

	Building 9	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	2,866	5,043	7,909	
1	Wall insulation	33,579	2,637	4,639	7,276	53.1
2	New windows	24,332	2,666	4,690	7,355	44.0
3	1 + 2	57,911	2,465	4,337	6,802	52.3
4	Roof insulation	11,423	2,264	3,984	6,248	6.9
5	Green roof	13,280	2,293	4,034	6,327	8.4
6	1 + 2 + 5	71,191	1,720	3,026	4,745	22.5

Table 3.16 Different retrofit options and relative payback time calculated for building 10

	Building 10	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	4,555	8,320	12,874	
1	Wall insulation	54,886	4,190	7,654	11,844	53.3
2	New windows	106,163	4,236	7,737	11,973	117.8
3	1 + 2	161,050	3,917	7,155	11,072	89.4
4	Roof insulation	11,880	3,598	6,572	10,171	4.4
5	Green roof	13,811	3,644	6,656	10,299	5.4
6	1 + 2 + 5	174,860	2,733	4,992	7,724	34.0

Table 3.17 Different retrofit options and relative payback time calculated for building 11

	Building 11	Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	5,018	9,364	14,382	
1	Wall insulation	81,159	4,617	8,615	13,232	70.5
2	New windows	84,264	4,667	8,709	13,376	83.7
3	1 + 2	165,423	4,316	8,053	12,369	82.2
4	Roof insulation	15,079	3,965	7,398	11,362	5.0
5	Green roof	17,529	4,015	7,491	11,506	6.1
6	1 + 2 + 5	182,952	3,011	5,618	8,629	31.8

Table 3.18 Costs, savings, and payback time for the urban courtyard in Evripidou

		Retrofitting option cost (EUR)	Annual cost of thermal energy (EUR)	Annual cost of electric energy (EUR)	Total annual cost for total energy consumption (EUR)	Payback time (years)
	As built	0	54,370	99,456	153,827	
1	Wall insulation	760,452	50,021	91,500	141,521	61.8
2	New windows	806,075	50,564	92,494	143,059	74.9
3	1 + 2	1,566,527	46,758	85,532	132,291	72.7
4	Roof insulation	189,169	42,953	78,571	121,523	5.9
5	Green roof	219,909	43,496	79,565	123,061	7.1
6	1 + 2 + 5	1,786,434	32,622	59,674	92,296	29.0
7	Plants systems	387,016	0	82,722	82,722	5.4
8	Renewable plants (PV)	633,888	0	0	0	4.1
9	nZEB (6 + 7 + 8)	2,807,338	0	0	0	14.5

The same calculations have been performed for all 11 buildings in the selected courtyard. From the mutual comparison between the tables, the following conclusions can be drawn:

- The insulation of the vertical walls through external coatings is more or less convenient depending on the orientation of the individual buildings. It does not present the greatest advantage during the hot summer season.
- Given the very high payback time of the high performing triple-glazed windows, the double-glazed windows are always convenient in winter; conversely, during the summer period, in particular for the additional costs of the shading devices, they present very high payback time (especially in those buildings with large windows).
- The roof insulation always represents an excellent intervention.
- The green insulated roof produces a slight disadvantage in winter, but the costs still appear balanced.

Among the combined interventions, combination number 3 produces the greatest benefits: although the payback times are higher compared to the insulated roof or the insulated green roof, consumption is much lower and the resulting savings increase up to three times as much. The overall cost assessment of the whole set of buildings is reported in the Table 3.18.

Fig. 3.3 shows how payback times vary in a wide range. In particular, the very high payback time due to the wall insulation and the window

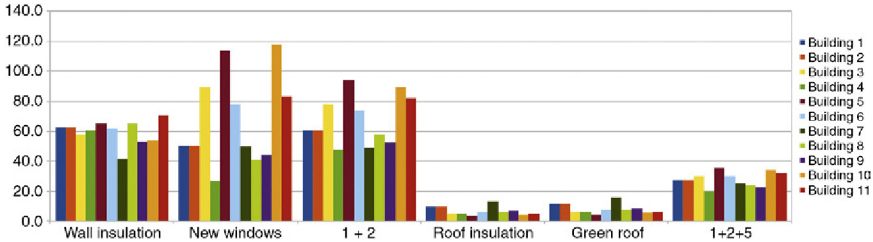


Figure 3.3 ***Payback times of the investments in Evripidou show a variation between 75 and 4 years can be observed as a function of the different hypothesized scenarios in the different building types of the urban courtyard.***

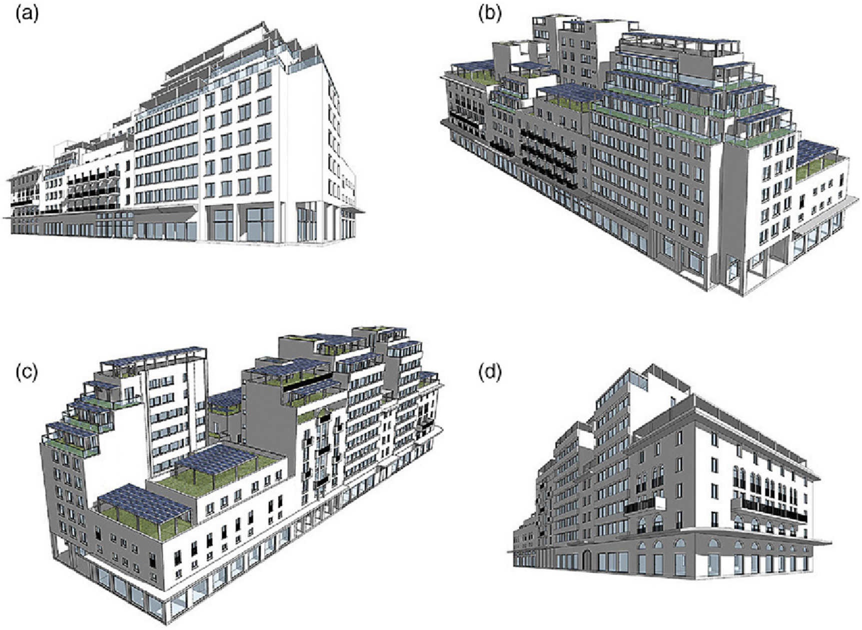


Figure 3.4 Existing buildings retrofit in Evripidou: energy retrofitting up to nearly zero buildings can be hardly visible at the urban scale, especially from the street level perception (a–d).

replacement is shown. This is particularly true for those buildings with large glazing surfaces. As can be observed in Fig. 3.4, also in this phase the volumes do not undergo visible changes in the architectural and urban form.

3.1.1.4 Conclusions on Energy Costs

To assess the technical and economical feasibility of retrofitting actions, different urban settings in Athens have been investigated, calculating and comparing costs and energy savings connected with different retrofitting actions. To identify the economical feasibility, a cost-benefit analysis was conducted by means of a market survey, determining, for each different design option, the evaluation in terms of energy performance improvement and the related cost estimations. The same options have been analyzed both individually and in combination, according to an increasing degree of transformation up to nZEBs in existing building blocks.

So far, our work has been focused on quantifying different variants in retrofitting actions of existing housing; simulations showed that it is possible to reach an average energy performance (EP) of up to 35–50 kWh/m^2 year, by the insulation of opaque surfaces and the replacement of existing windows. This energy index may decrease to 15 kWh/m^2 year in the complete retrofit scenario. However, the cost-benefit assessments always show excessive payback times (from 35 up to 70 years) for these interventions.

The set of all considerations emerged by the retrofitting options as developed so far lead us to the conclusion that, although it is possible to transform highly consuming existing buildings to achieve nZEB, the transformation requires necessarily high up-front costs, resulting in very long paypack times.[8] These high costs are due to the high cost of the technology for the renewable energy sources to be realized jointly with other costs occurring by the passive retrofitting operations to reduce energy consumption. Furthermore, both passive and active solutions require maintenance costs and present a certain decrease in performance over time; in particular, the PV system presents the higher management fees and is subject to a decrease in performance over time.

Thus, nearly zero energy in the existing buildings of these urban settings have been proven to be a technically feasible goal, but it is necessary to face the problem of very high up-front costs due to the need to operate both active and passive interventions, which are amortized over a relatively long time, generally comparable with the life of the systems of energy production from RES.

As a preliminary conclusion, we may state that the nZEB goal remains highly ambitious and exceptionally challenging, especially in the Mediterranean urban areas, considering the context of economic crisis, fuel poverty, unemployment, poverty, and social exclusion that these areas of the world are currently experiencing. Nonetheless, the effective reduction of energy consumption toward zero energy buildings and districts is and remains an

[8] Both passive retrofitting interventions and the production of energy from renewable sources are necessary to achieve nZEBs in the retrofitting of highly energy consuming building stock.

unavoidable objective, just right in the Mediterranean areas, where the dramatic combination of the HI phenomena and global overheating is severely threatening humans and the environment.

The reflection on the estimated costs of proposed energy-retrofitting options clearly indicate the need for additional tools and measures to be developed to counterbalance the large payback times of energy retrofitting measures aimed at achieving nZEBs in existing urban buildings. In particular, it is necessary to activate new forms of incentives in order to attract potential investors in the uptake of deep renovation toward nZEBs and ZEUS. This process should also be set by considering the users' and urban dwellers' contributions in the energy retrofitting of their urban environments.[9]

3.1.2 Why Do We Believe in the Economic Feasibility of nZEBs in Existing Urban Environments? Energy and No-Energy Related Issues in the Energy Retrofitting as Possible Incentives toward ZEUS

Housing represents a huge part[10] of the building stock in the European Union and the potential reduction in CO_2 emissions that energy-efficient housing would provide cannot be underestimated.

[9] According to these partial results and to the general objective of comparing various urban contexts analysis and design scenarios, in the project *Urban Recreation*, the larger and more densely built area of the workers' houses in Peristeri has been selected for further investigations with regards to social aspects; in this context we studied the energy demand/potential of real urban environments in a socio-oriented perspective by designing – in different steps – retrofitted scenarios in order to achieve both zero energy, and socially inclusive solutions, by means of an interdisciplinary research approach. We aimed at: (1) developing, performing and evaluating different possible solutions to achieve a sustainable and spatially localized distribution of energy, by means of technologies to be diffusely integrated in the urban buildings and open areas by means of a similar process with respect to the Aghia Varvara complex; and (2) promoting further actions to contribute to fill the knowledge gap existing among low carbon passive techniques and the adoption of these technological solutions at social and community city level. In particular, *Urban Recreation* has moved to envision the activation of new forms of incentives in order to attract potential investors as well as dynamically involve the social participation to motivate urban dwellers in the energy retrofitting of their urban environments. In this context, energy retrofitting should focus its attention on the roles of energy and environmental re-qualification of existing buildings, by a more appropriate use of technological options in architecture and urban/spatial planning. The functionally oriented approach and the mono perspective use of architectural buildings have to be considered a past attitude. In this effort, we also considered the necessity to find possible solutions by suggesting a multi-fold approach to stimulate the process of renewal also according to a nonenergy-related use of technology in urban environments.

[10] Dwelling stock accounts for about 200 millions units, representing around 27% of energy consumption in the EU.

Three quarters of the buildings standing today, including the residential stock, are expected to remain in use in 2050 (COM, 2012). But, so far, only about 1.2% of Europe's existing buildings are renovated every year.[11] In fact, most improvements in building energy performance are modest – usually in the range of 10–20% for specific energy efficiency interventions. Until recently, those improvements have generally been considered as enough. However, if the energy and climate goals of achieving almost nearly zero energy have to be achieved by 2050, we have no choice but to dramatically upscale the energy performance target of the existing building stock. The implementation of single measures, such as application of insulation layer, replacement of windows, improved operation and maintenance, lighting upgrades, or roof space insulation, constitutes only the first level of intervention. The combination of single measures (which can be termed standard renovation) involves the simultaneous and integrated implementation of a few individual energy-saving measures. Deep renovation or deep energy renovation refers to renovations that capture the full economic EE potential of improvements. A renovation or refurbishment will often harvest the minimum possible energy savings, ranging between 20 and 30%, sometimes even less. However, by renovating deeply as is shown by using state-of-the-art technologies, it is possible to reduce the energy consumption of a building by 75%. This typically includes actions on the building envelope; on the contrary, the definition of a retrofit focuses mainly on the building's mechanical systems.[12]

However, these considerations regarding the urgency of moving toward a "deeper" approach are related merely to the energetic aspect of the problem. Given the various characters of the existing barriers illustrated previously, it has emerged that the multiobjective and integrated character of the intervention has to face the problematic issues through a more all-inclusive approach. The methodology presented in this section seeks to include in

[11] The demolition rates is about 0.1% per year and highly energy efficient new-build reach 1% additions/yr. JWG: Towards assisting EU Member States on developing long term strategies for mobilising investment in building energy renovation (EU EED Article 4), Composite Document of the Joint WG of CA EED, CA EPBD and CA RES, November 2013 (http://www.ca-eed.eu/reports/art-4-guidance-document/eed-article-4-assistance-document).

[12] As observed, the primary energy consumption after renovation, which includes, inter alia, energy used for heating, cooling, ventilation, hot water, and lighting after the deep renovation of an existing building is less than 60 kWh/m^2/year. However, as the level of achievable savings will vary depending on climate conditions and on the level energy performance of the building prior to renovation.

the deep renovation process additional tools that could help to overcome the existing economical, legislative, technological, and even social barriers. Thus, the energy efficiency challenge in buildings mainly concerns energy efficient refurbishment and investments in its existing building stock (EEFIG, 2015).

The simple payback time of retrofitting interventions examined so far has shown how the economic feasibility of nZEBs in existing urban environments is a very challenging objective.

Given the challenging character of nZEB in existing built environments, how can we still believe in the feasibility of achieving this objective using current building practices? In the next paragraph, we will discuss a possible series of energy and non-energy-related issues in energy retrofitting as possible incentives toward the challenging goal of nearly zero urban settings.

3.1.2.1 Barriers and Opportunities at the Economic and Technical Levels toward Achieving nZEBs

Modeling retrofitting hypotheses through technical interventions such as plants renewal and u-value reduction of building-envelope components (opaque envelope insulation and window replacement) have shown great potential for energy efficiency (EE) achievements in very high energy consuming building blocks.[13] However, the cost-benefit assessments always show excessive payback times (of up to 35–45 years, without considering possible incentives).

Besides our case studies, studies and surveys by housing providers, financial institutions (Cecodhas, 2013) and concerted actions documents (BPIE, 2013) identified key categories of hurdles (economic, technical, social, legislative) in delivering deep energy renovation for buildings.[14] Among them, the high up-front costs and long payback times of retrofitting interventions are indicated as the major barriers. Yet, there is a clear investment gap in the retrofitting of existing buildings and, in particular, in the

[13] Providing the energy redevelopment of an average existing building up to 25 kWh/m^{2}year it could be obtained a reduction of primary energy demand by over 90%; in Bologna, an estimation of 0.23 m^2 of PV panel for each square meter of residential net surface will set to nZEB the energy balance of this reference building.

[14] When referring to deep renovation, most of the EU discussions and the consequent definitions on the subject focus on HVAC and the general understanding is that these deep renovation interventions should lead to an improvement of at least 75% after the building has been renovated, with an absolute target between 15 and 60 kWh/m^2/year (Shnapp et al., 2013).

housing market. This has proven to be due to the fact that high investments are required up front and are characterized by a large degree of risk with potential limited return on investments; furthermore, there is a generalized lack of confidence by both public and private investors (including owners and financial institutions). Therefore, it is necessary to develop harmonized actions that can help unlock the needed public and private finance sources, fill the energy efficiency investment gap, and ultimately contribute to re-launching the construction market.[15] Moreover, these operations do not fully compensate the different EP of the units within the building; this can produce additional barriers toward the adoption of monitoring systems to control energy waste[16] and social conflicts in relation to the sharing of costs and benefits among owners or between them and tenants in multi-owner properties.

In the search for possible encouragements toward our aim, the opportunity given by factors able to reduce energy costs can be found in other non-energy-related factors influencing the renovation and valorization of buildings, which are corresponding key benefits. In fact, operating a mere energy retrofitting on individual residential units or building blocks in urban contexts in severe degradation conditions may imply a devaluation of the potential efficiency of the same retrofitting actions; in fact, building renovation actions are always connected with and intrinsically involve a larger spectrum of quality related aspects. In other words, we can state that energy retrofitting of existing buildings, being connected with technical and architectural modifications of building's components, may imply a strong influence on the overall quality of the built environment and that this quality can not be ignored, since it may be a key added value in terms of technical and economic feasibility.

Multilayered components and stratification of elements within the building envelopes have been presented so far as an effective solution in the energy retrofitting of existing building stocks of urban environments.

[15] In example, EU Plans expect to deliver 2.000.000 jobs, increased industrial competitiveness, annual financial savings/emissions reductions of 740 million tons of CO_2e (BPIE, 2013; EEFIG, 2015; EU Report, 2014, Assistant documents by JWG).

[16] As an example, the adoption of thermostatic valves on radiators in centralized heating plants causes the unbalanced distribution in the energy bill and possible problems of negotiations among the dwellers. In case of a proportional redistribution of the total cost of the energy retrofitting measures, the disadvantaged units would incur significantly higher expenses.

But sustainability in architecture and building construction also implies the achievement of other technical requirements like comfort, safety, aesthetic quality, and user's needs, while using minimal amounts of energy and environmental resources. The possibility of achieving this goal in a building is mainly given by acting on its envelope. In this context, producing light prefabricated elements for the facade composition could become an important goal to implement and foster all the highly advanced existing technologies by simply increasing the efficiency in the production and assembly phases. We should observe that the idea of a multi-task and highly energy performing facade is nothing new: well before the energy efficiency and renovation emergency, the goal of producing an integrated facade system was envisaged by Davis (1981), who formulated the idea of a polyvalent wall. In this wall, several functional layers within a glass element were to provide sun and heat protection, and to regulate the functions automatically according to current conditions. The wall itself was to generate the necessary energy and perform at its best for the different housing needs and climates.[17] Again, the main problem is that for the production of prefabricated panels to be economically justifiable, it is necessary to produce them in a large scale and this is highly related to the different morphology of the facade and the opening types. This is a minor problem in case of a new building but becomes important when trying to apply this technology to the renovation of an existing building: the enormous variability of the existing housing stock makes it impossible to develop a catalog of fixed options since every panel should be customized and produced according to the information of the single surveys. The process would be highly un-economical, especially considering the social housing market and the low economical possibilities of these interventions. A possible way to reduce costs and implement efficiency in the production cycle today is given by the movement to establish a strong relationship between the design and the production phases. In fact, the design and production of the panel can be developed today through computer-aided tools that are based on the definition of precisely those geometrical parameters that can vary and represented the aforementioned problem, allowing the producer to simply set these parameters

[17] This idea, not yet realized today, still acts as a driving force for new facade technologies, and many researchers have been engaged in this topic over the last two decades. The idea was born as highly innovative technology for the façade of the future, but what are the benefits that such technology and system could bring when applied in the energy renovation field?

differently every time and send the 3D model to the computer numerical control, or CNC, printer.[18]

To do so, the starting point consists of analyzing the envelope as an architectural and technological complex system, suggesting a shift in coding the facade and its elements, changing the focus from the cell-scale or the building-scale to the module-scale. The process starts from a discretization and division of the facade in a grid, and finding out the original unit and its variants, which is very easy in buildings like the ones considered in this book, that are generally characterized by repetition and rhythm in the facade division and drawing. The same facade element is often repeated and replicated throughout the facade. The division elements are characterized by the staircases and/or the toilet rooms where the opening of the facade as well as the balconies or loggia disappear to leave space for a different geometry of the openings or a change in material, or again, a volumetric transition. But how shall the facade be divided? The approaches to renew and, as far as possible, to prefabricate energy-efficient new envelopes for existing buildings can be very different. This is not only because buildings themselves are divers. Even for identical buildings, there are various options to achieve practical solutions for retrofitting and to find a way to produce prefabricated modules for facades and roofs. For example, the integration of a ventilation system can be very differently addressed and will strongly influence the whole

[18] To better clarify the high potential of this refurbishment method, it is important to underline the following three aspects: (1) The facade modules are standardized in construction, layers, and joints; (2) The facade modules are flexible in architecture, form, and cladding; (3) The facade modules can be combined with each other with non prefabricated (conventional) retrofit options. The application of this process (typical of the mass industrialization trend), the idea of increasing the customization and the specificity of the final product, could drive the production toward unexplored paths. The production chain remains the same, while the parameter of the product can change and follow the specific geometrical characteristic of each single building and the specific wishes and need of the users, thus shifting toward a mass prefabrication system based on modularity and variability in the preliminary design phase; the tools available today (especially considering the potential of laser scanner, CNC machines and 3D printing systems) allow to set up a unique process to produce multiple designs, hundreds of different types of the same piece of facade. Thanks to the transfer of the customization and prefabrication logics in the field of housing refurbishment, it could be possible to re-interpret the residential artefact, no longer in its dimension of building object with a close and rigid configuration, but in the adaptive nature typical of the housing function, subjected to time transformations and users changes.

Figure 3.5 ***Van Shagen in Amsterdam and Kolpa Architecten in Rotterdam (on the right): examples of volumetric compensation (roof-top extension) and creation of new units in the energy retrofitting of existing buildings.***

planning process. Also, the country specific and well-established process chains should not be bypassed.[19]

3.1.2.1.1 Economic, Financial, and Social Potential of Add-ons

The high investment costs in energy retrofitting have driven some experiences at EU level,[20] as well as pilot cases in Austria and The Netherlands (Fig. 3.5), to focus on the strategy of rooftop extensions as additional volumes whose economic value in the housing real estate market may counterbalance the energy retrofitting costs. Examples of volumetric compensation (rooftop extension) in the energy retrofitting of social housing have been adopted from Van Shagen in Amsterdam and Kolpa Architecten in Rotterdam (Fig. 3.5).

In the following work illustrated for the Athens metropolitan area case studies, we will base our effort on the prior assumption that

[19] They set basic conditions from planning to working on site. Four different approaches have been analyzed according to the IEA ECBCS Annex 50, by national teams from Austria, France, Portugal and Switzerland: The Swiss solution is based on small modules with a high degree of standardization. The prefabricated façade modules concentrate on the window area as the area with the highest concentration of technical details, whereas the plain façade parts are insulated traditionally. Also the façade finish – ventilated cladding or rendering – is done on site. This concept has also been used for the development of roof elements, for flat or sloped roofs. The Austrian solution is based on large glazed façade modules, which are fully prefabricated. They are as high as the building story and up to 12 m long. They have been already tested at various demonstration buildings in Graz. The French development was focused on large vertical façade elements with metal under construction. Special attention was given to the avoidance of thermal bridges. Prototypes were produced and tested. The Portuguese study concentrated also on fully prefabricated but smaller sized modules. They are based on easy mountable metallic and of course insulated façade panels. Considering the entire lifecycle of the building and the sustainability of the intervention as a matter that involves the entire life cycle of the building the suggested proposal is based on the assumption that light prefabricated elements that use wood as main material are the favorable option.

[20] For example, European activities and projects like SuRE-Fit, Reshape, Solar Decathlon 2014, and so forth.

non-energy-related benefits play a key role in the deep renovation of existing buildings. In particular, our work will focus on the following main benefit: the generation of a substantial increase of the real estate value of the buildings through significant energy and architectural transformation (mainly integration of RES systems with new volume additions or new building construction) to go beyond the minimum energy performance and aim at achieving nZEBs. Thus, we will try to explore the potential of energy retrofitting actions contemplating a higher level of transformation in the existing buildings and urban settings. Our efforts will concentrate on the following question: To what extent can a deep renovation through higher transformation be competitive with respect to a more standard retrofit?

3.1.3 Deep Renovation and Volumetric Additions in Energy Retrofitting Actions toward ZEUS

It is well known that current energy policies in the European Union, such as EPBD and EED, contain provisions to increase the energy performance of existing buildings and to encourage member states to convert building stock through the development of a marketplace for cost-effective deep renovation. But deep energy renovation of buildings is a composite process that needs to be explained and made attractive to key financial overseers and decision makers (financial institutions, developers, managers, householders, policy makers, building owners, and associations). In order to do so, there is a need to share knowledge, build capacity, and capitalize on all possible win-win solutions that may arise from the mutual collaboration of architects, urban planners, financial actors, decision makers, and social stakeholders. This is the main path toward grasping the existing obstacles to deep renovation and defining effective solutions to overcoming them.

In the search for possible encouragement toward our ZEUS objectives, we should seek out other technical opportunities that reduce energy costs in other non-energy-related factors influencing the renovation and valorization of buildings. In fact, energy retrofitting in real urban environments (RUEs), being connected with technical and architectural modifications of building's components, may involve other qualities that cannot be ignored, since they may be a key added value in terms of technical and economic feasibility.

We may therefore search for a higher degree of transformation; to move toward this, the levels of adaptability of existing buildings and their connected pluses and minuses need to be explored as well. In this context, the positive benefits of prefabricated facade modules as described in the previous section for energy renovation of existing buildings are given by different aspects involving ecological, architectural, engineering, and plant systems.[21] Here the major aids are given by the economic gain and the longer lifecycle of the entire building. In particular, regarding the economic gain, in the real estate market, the integration of spatial and volumetric additions within the same construction system and intervention time frame may represent an important payback accelerator for the investment in the renovation process.

The possibility of integrating both benefits in one technology (the facade renovation and the extension of surface as a volumetric bonus to the energy renovation) embodies great potential, considering the payback time reduction and the increase of value in the real estate market.

In order to support the construction of a new facade (when this can not rely on the existing structure) or the new facade extension that could be part of the intervention, additional structures have to be envisaged. These structures should be entirely prefabricated and mounted on site. The load transfer scheme is mostly thought to be independent from the original structure in order to avoid the worsening of existing static conditions that would not be possible to evaluate with the necessary accuracy in seismic areas.[22] The proposed methodology will focus on the validation of a multitask and highly energy performing facade and its possible integration of space (volumes and surfaces), in addition to the energy renovation of the existing building, to evaluate the possibility of this process overcoming the existing barriers to the deep renovation in order to create nearly zero energy buildings.

As mentioned previously, the basis for the use of prefabricated retrofit building elements could be given by a frictionless digital workflow from survey, planning, offsite production, and mounting onsite, based on a precise initial 3D scanning measurement. This would allow a high degree of

[21] The underling basic principle of using and recycling a building or a building structure is undoubtedly an ecological-related aspect. Architectural quality can be achieved by the possibility of redesign of the façade and entire building envelope. Under the engineering and structural point of view the system could provide the possibility of improving the structural elements and integrate new prefabricated structure that could cooperate with the existing in case of seismic event, finally the substitution of façade by new envelopes can also provide the integration of the heat ventilation air conditioning (HVAC) directly in the façade and the integration of systems for solar components. As far as it concerns energy efficiency, the increase of the performance of the existing envelope is accomplished by: adding extra insulation; removing existing envelope components that are no longer meeting the standards (window frames, old insulation, cladding); integrating innovative systems such as dynamic façade, ventilated and mechanical systems, and so forth. These are the main benefits. The possibility of volumetric addition and spatial transformation within the same construction system is also a great plus.

[22] Further research on the topic could also demonstrate the positive impact and effect that these systems could have as aid to the existing structure when involved in a seismic event.

precision and correspondence between the new facade modules and the old facade, reducing time waste, errors, and risks in the construction phase.

This type of expansion could involve the increase of one room size, or the entire rooftop level, the underground level, the side, or the in-between space at the urban level as well. Moreover, a combination of building system and space components would help to standardize and minimize the connections between space modules. "Nearly zero energy or energy-plus solutions" introducing space modules that are self-sufficient in energy could be one solution to simplifying the connection of extensions to existing building systems. Town planning measures have been developed to increase the density of existing urban structures, which can be achieved by adding roof floors, neighborhood-specific infill developments, or extension of building spaces in a framework that envisages the refurbishment need as an opportunity for reinterpreting and redesigning the periphery of our cities.[23] Therefore, it is not surprising that the last European edition of the Solar Decathlon (Jun. 2014, Versailles) has identified the five central topics of the competition in relation to the main issues of sustainability in European cities: density, mobility, sobriety, innovation, and affordability. This important discussion on sustainability and architecture reflects a clear shift from the search of a formal application of green active energy systems in figurative architectural connotation, to the urban application of housing prototypes that are capable of answering the energy demand. In one sentence, the project has to be designed in its environment and it develops around, above, and within the built environment. Many of the highly efficient home prototypes presented have been designed to be directly integrated in the urban tissue as volumetric additions, rooftop extensions, and/or infill between existing buildings. The prototypes built in Versailles as well as the preliminary studies and similar research experiences show the possibility of building this addition through the utilization of light and prefabricated systems (wooden panels). This type of construction system will ensure the rapidity of realization, the reversibility of the intervention, and will avoid structural interference with the static condition of the existing building that "hosts" the addition.

[23] In many countries of the European Union, the political parties are already moving toward a more flexible framework for energy renewal interventions. The open discussion on the potential of increasing the volume of existing building is an important occasion to review the current legislative framework in favor of an indispensable liberalization of the normative. The urgency for densification policies that Europe is facing requires a direct engagement from both the research and development sectors and the industrial sector.

Therefore, energy renovation through volumetric additions can be divided into three consequential and incremental steps, each independent of one another, but in order of impact and consistency of the transformation: facade transformation, horizontal extension, and vertical extension.[24]

3.1.3.1 Expandable and Adaptable Architecture: Add-ons and Tailored Solutions to Increase the Techno-Economic Feasibility of ZEUS (Annarita Ferrante and Elena Cattani)

The concept of adaptability refers to the capacity of buildings to accommodate substantial changes (Kobayakawa et al., 2006). Adaptability is broken down into three aspects: flexibility, convertibility, and expandability (IEA, 2001). The possibility and the degree of transformation in a building and, generally, in a built environment, is essentially linked to its degree of adaptability. The main consequent and related quality is the durability of the same built environment. A construction can be divided into a structural part and the envelope part, whose life cycle is about one-third of the forecasted life cycle of the structure. It follows that, if the building presents a certain degree of adaptability, the most convenient renovation strategy lies in the

[24] Level 1: *Façade transformation*: According to the architectural and structural type of the existing building it is possible to apply the new façade in addition to the existing one (this is especially true in case of external load bearing walls or façade whose structure and state is still in good static conditions and cooperate with existing building frame) or façade in substitution of the existing one (in cases where the existing façade has reached the end of its life cycle or can no longer meet the minimum requirements). Moreover, the redesign of the façade offers a possibility to engage a dialog with the inhabitants and involve them directly.

Level 2: *Horizontal extension*: Incorporating volumetric addition, new rooms or transformation of the existing balconies, loggias, and ballatoires. The transformation in surface increases the real estate value of the apartments involved in the transformation and also the degree of participation of the inhabitants called to decide upon the transformation according to their needs.

Level 3, *Vertical extension*: The volumetric addition can involve also the rooftop and generate entire new housing units. The economical payback of the intervention can be reduced and the roof surface can be used for production of solar energy.

The following characteristics have to be met in order to be able to proceed from level 1 to level 2 and 3: Reserves in distance spaces and heights according to the existing building regulations; Reserve in permitted density of buildings according to development plan and need for urban densification of the compound; Existing circulation system adapted for an extension (change of building class, escape routes, and accessibility); Simple building geometry (few setbacks or cantilevers, openings of simple geometry); Load reserves in supporting structure (up to the foundation) would represent a plus by reducing the cost of additional structure; Original building with an anyway need for refurbishment; Ownership favorable for investment and/or inhabitants willing to participate in the initiative.

potential exchange of the envelope and those components that have already reached the end of their life cycle. Being that the built environment is already used and lived in by its inhabitants, any process of adaptation cannot ignore them; on the contrary, transformation should be done according to the current user's needs, but also with a high enough degree of flexibility in order to allow for future transformation in case of a change in use or users of the building.

While traditional construction methods were based on physical requirements, minimal space units, and healthy standards values, today the processes of transformation and adaptability increasingly looks at "differentiation, not uniformity in designing the built environment" (Preiser et al., 1991); for the emphasis is on the customization of the products through mass production rather than standardization.[25] Adaptation is also defined as the means by which we can begin to address the urgent challenges of the contemporary age (not only in the building and construction field) and enter a new era of innovation. In this context, preliminary questions to be answered are:

How can we evaluate and calculate the adaptability degree?

What are the factors that influence it and how can they be improved?

According to several previews of research and literature (Dimitrijevic et al., 2002), there are six assessed spatial, structural, and services design features: (1) site (possibility of expansion, access for pedestrians, access for services); (2) interior layout and design (completeness of brief, flexibility of layout, grouping of functions, average main room size, provisions for disabled); (3) facade (window size, balconies, loggias, "ballatoires"); (4) structure (strength of columns/walls, column density/span, floor-to- ceiling height, floor loading, floor structure, removability of partitions); (5) HVAC system (plant location, plant size space wise, access for people, access for equipment, ducting access); (6) services and elevators (capacity, extra space).[26] By intervening on the aspects connected to the adaptability, the consequent result is an increase in the durability of the listed design features: durability in fact is defined as service life, that is, the actual period during which no

[25] As industry and academic leaders discussed already in the early 1999, during the CERF/CIB Symposium, "sustainable" means being able to meet the multiple requirements of society through the life cycle of a building or structure (Bernstein, 1999).

[26] In order to be able to evaluate levels of adaptability, a scale 1–5 has been developed by (Dimitrijevic et al., 2002): scores from 1 to 2 (Low adaptability: design features are appropriate for minor changes); score 3 (Medium adaptability: design features are appropriate for more complex changes). Scores 4–5 (High adaptability: design features are appropriate for complete change and transformation).

unacceptable expenditure on maintenance or repair is required (Dimitrijevic et al., 2002).

In energy retrofits of existing buildings, the approach to durability practiced usually leads to regulations and discussions about the degree of insulation and the materials that are to be used. Although there is no doubt about the value of these aspects, durable building includes facets that have not received much attention so far (Vreedenburgh and Melet, 2012). Vreedenburgh and Melet (2012) defined durability as the ability of a building to last in time, despite the change in number or needs of the people that live in the building itself. When we interpret durability as making use of the full potential of what has already been built, then the possibility of increasing density within the built environments in contemporary cities by adding space may provide a useful opportunity to increase durability while adapting the cities to current energy and non-energy-related needs.[27]

Thus, the possibility of intervening through the adaptation of the total volume of the building (eg, by increasing the number of storeys, transforming the balconies into closed extra rooms, or adding new space on the side of the building) hides some great potential in terms of durability and overall value of the existing building. The densification strategy through punctual volumetric addition could become a key node to overcome existing economic and social barriers.

Indeed, the practice of adding, transforming, changing, or extending existing buildings in different periods of time is everything but new in our building heritage.[28] Formal and informal versions of this may often coexist. While informal is essentially linked to spontaneous bottom-up processes of

[27] The relationship between the adaptability quality and the durability quality of an existing building is thus a cause-effect relation: by increasing the adaptability of the construction, its life cycle increases and the real estate value can rise of significant figures. The application of construction systems and technologies that incorporate directly the concept of variability among the intrinsic characteristics of the project (for new construction but also and more specifically for renovation) can be able to transform according to the needs the building throughout its lifecycle. This could also guarantee final products and urban compounds with increased efficiency and durability at the building and urban scale, including sociological, environmental, and economic systems; in fact, the contribution of an integrated action would produces an overall benefit in all the spheres involved.

[28] Examples of housing addition on historical tissue can be found in Ponte Vecchio, Florence, in Teatro Marcello, Rome; in the northern countries many traditional houses from the 16th century with 17th have been intertwined with wooden frame additions, and so forth. Furthermore, different forms of spontaneous settlements as well as all types of illegal occupations, invasions, and squatter settlements are generally identified as informal addition.

appropriations by users, "formal" addition is considered to be that which is planned through rational processes and under legal institutional frameworks (Hutchison, 2010). So far, the architecture of the addition has been limited to occasional manifesto experiments or largely and commonly applied to transform and evolve the dwelling environment in informal settlements. This occurred commonly in the history of European architecture, but today, in light of the so-called shanty towns (Klanten and Feireiss, 2007) it has received renewed interest. The informal is synonymous with continuous transformation but also with the potential for variety and adaptability, characteristics that current residential areas often lack.[29] In this perspective, it is possible to integrate much of the hidden knowledge, techniques, and systems typical of the informal processes in the formal process of reconstructing our suburbs. The volumetric addition is a possible bridge between experimental design practice and the self-made practice of the informal architecture (Marini 2008).

Some of the projects presented by the Convertible City exhibition in the German Pavilion (Convertible City, 2006) have demonstrated the possibilities of architectural addition onto existing buildings: superimposition, shifting, and penetration make it possible to extend existing building structures and combine and define them in new ways.[30] According to the type and strength of the interconnection that can be introduced between the new and the pre-existing – in conceptual, formal, and technological terms – different relationships can be found. The architectonic and constructive result of addition is, in fact, given by the system of relationships among the different technological components and layers; thus, this system is closely linked with and can reinterpreted to serve the needs of energy renovation of existing buildings.

A categorization of typology of the addition may be also attempted by basing the increasing subversive level of the possible synergies between the pre-existing and the new-addition element(s): starting from a subdued role

[29] Informal architecture can be assumed as a model for the experiments in the field of addition elements for the existing built environment, since the strategy of high transformation through addition joins and connects different expertise and technologies, at the different scales, of the housing system in the common effort of finding regeneration processes starting from densification as a mean for change.

[30] For the first time, the addition in architecture gained a space and identity of its own, rather then a manifestation of informal practice. As formal and theoretical ground for the architecture of the addition, a selection of the 20th century's most significant precedents has been carried. This led to a categorization of the different relationships that could be created between the addition and the existent building. In fact, by the analysis of the previews significant architectural experience and established connections, it has been possible to also draft theoretical assumptions and considerations upon which the innovation aspects could further be developed.

of the addition, moving to a reflexive role, up until a subversive act. The resulting possibilities for addition are: (1) *Completing* (filling in the existing empty spaces that make the volume "incomplete." In this case the addition does not overcome the boundaries of the original volume's projection); (2) *Adding* (side or front or facade integration of extra new elements. Here the addition stands outside the original perimeter and exceeds the boundaries of the original volume's projection); (3) *Topping*[31] (Addition on the rooftop by adding a volume or new element on top of the existing one); (4) *Translating* (reconfiguration and transformation – through addition, subtraction, and replacement of the original components – of the existing building, with the goal of entirely redefining the original, preexisting space).[32]

Furthermore, adaptability and flexibility are a must for any project that hopes to attain a longer life cycle and subsequently, to attain sustainability. In the same way that doctors do not care only for patients' long life but also for their quality of life, a building should guarantee high-quality comfort for its users during its life cycle. However, requirements constantly change due to new society patterns. Predicting future needs is an exercise in speculation.

[31] The topping should be considered a special typology of addition considering the special attention given both in the practice and in literature to the rooftop extension. The authors believe it could represents a stand-alone category with a specific character of peculiarity and criticalness, also linked to the limited possibility of application in seismic areas or where poor static conditions occur.

[32] The main difference in the architectural outcome of these possibilities stands in the type of relationship that the addition created with the preexistence, whether it creates a fracture and declares its own identity or rather hides behind the preexistent formal composition and integrates with it. In the first case, the addition represents an act of subversive transformation that underlines the moment and space, the upcoming of a new time for the building. In the second case the continuity between past and present is emphasized and the continuity between before and after is preserved. The first strategy is the most largely used, mainly because, until now, the role of the architect has never been consistently discussed and readjusted toward a social-oriented and user-tailored dimension. Still, the architecture of the addition did not come as the answer to a social need but rather as a new way for architects to express their style and vision upon the existing, another act of over-imposed formalism that our society can no longer afford. It is important to define the framework of the addition and the typology of the proposed intervention in order to insert the design proposal – which will focus exclusively on the existing housing stock – in a broader architectural scenario. This analysis underlines also the existing contradiction between the eccentric character of these punctual injections, completions, or additions and the rigid status of the current building blocks. The potential of addition is here analyzed as a subject with its own identity in the architecture scenario, claiming the right of overcoming the marginal boundaries and be legitimate as a densification and renovation element whose specific function is that of answering to an urgent energy revision of the building stock and a necessary return to the final user-oriented dimension of architecture.

The more reliable solution is to enhance flexibility in the building system in order to guarantee adaptability. When the world changes, buildings should be able to change with it (Plagaro and Schwehr, 2008). Thus, applying the typology of the addition should imply the understanding of the existing flexibility or adaptability to the transformation of a given system. Those areas, paths, or options where flexibility and adaptation can occur represent spaces and potential for the extension. As clearly exposed by Habraken (1999) in his definition of *open building*, the built environment can be assumed as the product of an ongoing, never-ending design process in which environment transforms part by part. The question that stands behind this process is: how can architecture anticipate diversity and change and make this part of the renovation? According to Price (2001), this process can be described as "thinking the unthinkable," the unpredictability of human behavior, and finally, the substantial illusion of planning.

The programmatic revision of energy renovation practice should by closely connected to the opportunity for addition and transformation aiming at increasing the flexibility of the structure and of the typology of the existing buildings, with particular reference to those housing structures whose rigidness and fixity represent a critical aspect. Flexibility and adaptability may be conceived and interpreted in the construction process by making use of prefabrication of modular retrofit systems that allow optimized construction and easier replacement of parts. Consideration of such systems and the optimization of the operation process and its relevance for the building cycle and user's cycle allow a harmonized building system that can react flexibly during the whole life cycle of the building. In fact, some building parts age more quickly than others; these differences hinder coordinated maintenance and a damaged building part can lead to faults in the whole building system. Based on concepts described by the Fraunhofer Institute (Fraunhofer, 2002) and supported by typology-based building evaluation (Fischer and Schwehr, 2008; Plagaro and Schwehr, 2008), different building flexibility types have been identified. First of all, we should differentiate the external and inner capacity of a building to assume different configurations.[33]

[33] The external flexibility refers to and involves the capacity of positioning and achieving structural improvement from extensions and retrofit systems. The internal flexibility defines the internal adaptability of the building: in which degree are modifications within an existing structure possible. How does the extension influence the building and the internal layout together is a very challenging and interesting aspect connected with the possible and new relationships between the inside and the envelope.

Extension and internal are building characteristics that enable high-value stability over the entire (renovation) life cycle (Schwehr, 2010) and are intrinsically related to the possibility of having an *autonomous* extension. It is evident that the typology of the addition is a result of the potential in terms of the external and internal flexibility of the existing building. Buildings with *a priori planned flexibility* (Ferrante et al., 2011) have a structure, a mechanical engineering system with joints and space, which has been planned to allow future changes. This allows the development of *integrated additions* (which rely on the existing structure and distribution scheme).

However, even considering the possibility of integrating the extension in the existing building, the new regulations (especially considering the seismic and safety regulations in Mediterranean countries like Greece) make it generally complicated and expensive to proceed down this path. When this flexibility is not found – as happens in the majority of the apartment blocks that were built during the 1950s, 1960s, and 1970s – *ad hoc flexibility* can be integrated into the renovation phase, generating the option of a *semiautonomous addition* (that uses the original distribution and layout scheme but is independent structurally and mechanically). Another way to do this is to create an independent and *autonomous addition* (not connected to the existing building), which is associated to the original building solely by energy, economic, and procedural relationship.[34] In this case, we have assistant building(s). However, energy and economically related aspects are the most important for the purpose of this work and have the full potential of enriching the theoretical strategy of addition with further connotative issues.[35] In fact, the rereading and rewriting processes applied

[34] The main differences between the previous experimental experiences of parasite architecture and the methodology of the addition here suggested for the renovation of building stands in the programmatic character of the proposed strategy and in the direct participation of the inhabitants. As illustrated, the addition is used as an instrument and a tool to incrementally foster the willingness from an economical point of view and to provide the inhabitants with additional spaces or rooms. The intervention of addition and extensions stand here as a need to balance the economical and payback circle of the renovation process together with the need of answering to the technical question of the renovation of the facade. But, the addition can also be used to express and translate the need of the inhabitants directly in the facade, on the external layer of the building and consequently on the urban level.

[35] In example, from the energy point of view we should consider that the higher energy consuming apartment units are the ones located on the last levels, on the side of the building or on the first level due to the higher amount of surfaces directly exposed to the external air temperature (see also Chapter 2 on the energy demand of selected buildings in the Athens areas).

on the renovation practice represents an important opportunity to develop new or renewed technological, constructive, and functional models, shifting toward the simplified application of prefabricated and highly adaptable products that may efficiently produce the open redefinition of the building as a whole. In many cases, the building structure can not be modified in an economically sustainable manner but it is possible to integrate secondary systems, extend the existing structure, and redefine the layouts and functions; thus, retrofitting becomes a smart alternative to total demolition in favor of a metamorphosis that responds to the current and future needs of the users. Theoretical architectural speculations on the reinterpretation and the right of the parasite intervention become secondary and merely formal issues. Nonetheless, they can be used as a basis to understand and even anticipate the formal outcome paradigms of the architecture of addition in the design process.[36]

3.1.3.1.1 Expandable and Adaptable Architecture in Athens: Peristeri Case Study

Starting from these considerations, higher transformation scenarios have been conceived and developed for the energy retrofit toward zero energy of the urban compounds of Peristeri and Evripidou, in order to check the technical and economic viability of these solutions in the retrofitting of existing densely built environments in the Athens area. The necessary integration between the need for retrofitting and the opportunity to assume a wider rehabilitation process scenario have found further pilot experiments in the energy retrofit design of the public residential district in the Peristeri urban compound; within this urban context, different reference buildings have been used to test and compare four possible energy retrofit options according to a socio-oriented approach. The different structures in this case study show numerous possibilities and combinations. The design solutions have not been constrained to a simple prefabricated structure; indeed the need for developing modular and variable solutions has lead to a wide set

[36] It is important to underline here that the freedom of the design should not be thought to be entirely left to the inhabitants; they are expected to select different options while control and supervision of critical formal boundaries should be set by the architect, as the style should be in any case anticipated in a preliminary vision of metadesign. The balance between order and disorder: a controlled balance of the diversity and variation of the addition will be guarantee by the planning team and the computer-aided tools will be used as interface to control the variation.

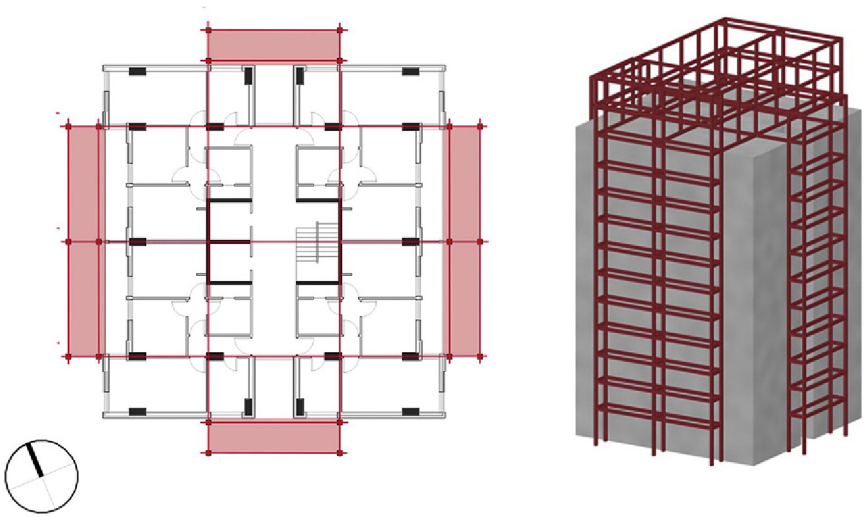


Figure 3.6 ***Structure frame in the Peristeri case study for the tower typology (building T11).*** Technical study of the structural feasibility to combine additions on the top of the buildings realizing new residential units.

of possible urban configurations. The improvement of the interventions in terms of energy performance and structural safety have been investigated and have proven the great potential cost-effectiveness of expandable architecture.

The technical and structural reliability of hypothetical volumetric addition on existing buildings is based on the possibility of considering external structures to be put alongside the existing buildings.

In the majority of illustrated cases, additions have been made on the rooftops of existing buildings: in this case, the risk of exceeding the load bearing of these buildings, which were not conceived for these additional volumes, necessitates a limit of add-ons because adding too much is very dangerous, especially in seismic areas like Athens. This is the main reason why the hypothesized add-ons have been conceived with external support structures[37] in our work. Here, the technical and structural feasibility of potential add-ons relies on the hypothesis of an external supporting frame (Figs. 3.6–3.8). These structures have been

[37] The external structures can be also applied for the purpose of improving the mechanical, static and seismic performance of existing structures, providing an additional element of construction quality and durability.

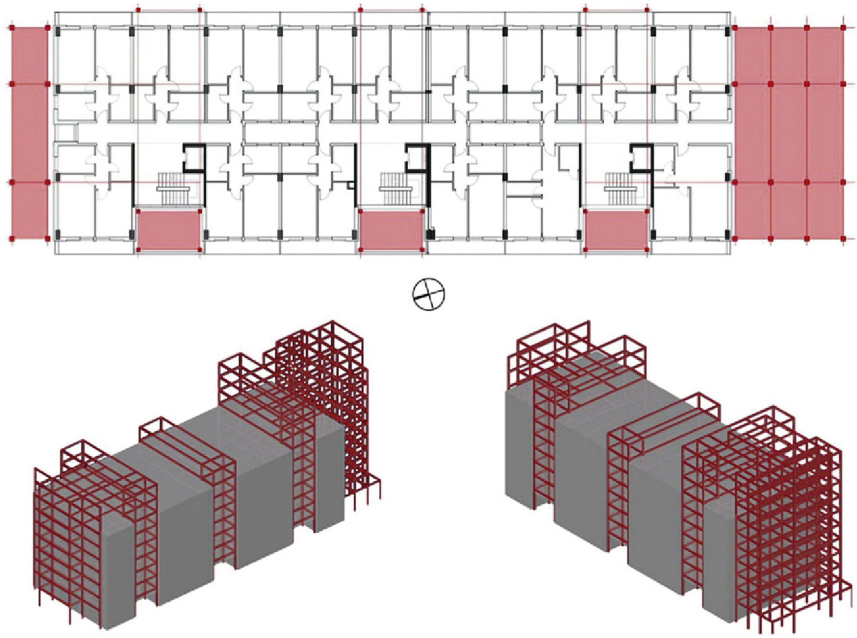


Figure 3.7 ***Structure frame for the B6 block type.*** Technical study of the structural feasibility to combine additions on the top and aside the buildings realizing new residential units.

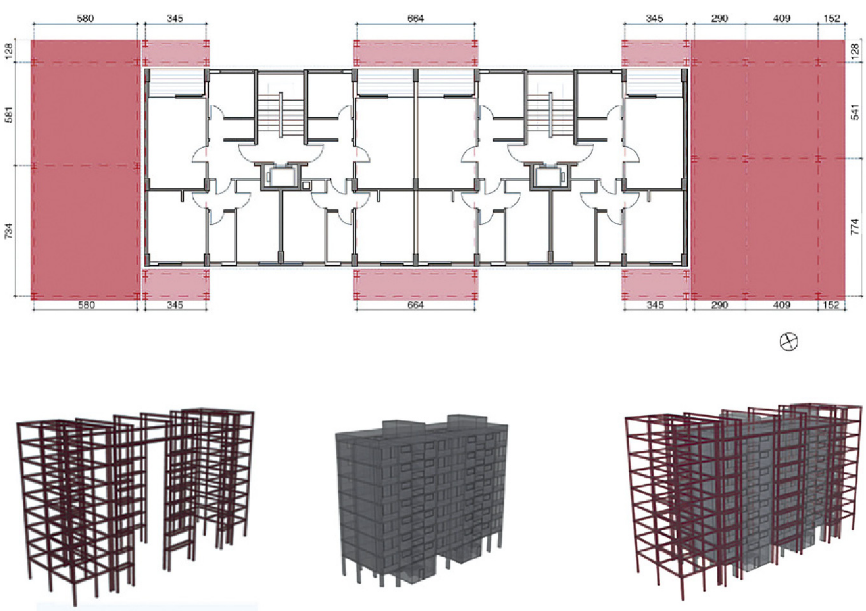


Figure 3.8 ***Structure frame for the T7 block type.*** Technical study of the structural feasibility to combine additions on the top and aside the buildings realizing new residential units.

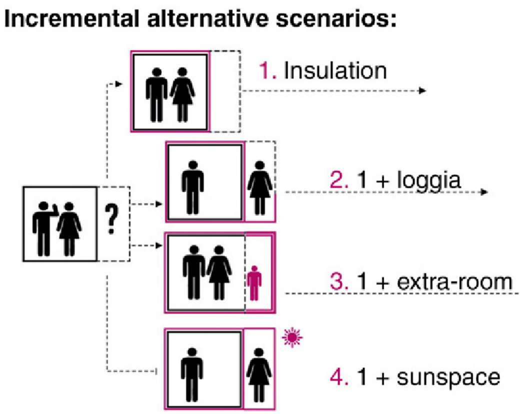


Figure 3.9 ***New volumetric facade solutions for the existing residential units.***

tailored and customized as a function of different constructive elements and architectural types.

In this scenario, the hypothetical structural frame as designed also may be used to combine new residential units with facade additions aimed at improving the quality and the space of existing residential units. So, on existing facades, the possible expansions of the existing envelopes may be thought of as extensions of the existing internal spaces. Whether occupants desire a bigger balcony rather than a loggia or an extension of the existing room, this system could allow people the ability to choose the use of their outside and inside spaces, according to various alternative and incremental hypotheses, as shown in the scheme reported in Fig. 3.9.

Also, the new envelope of these facade solutions may be equipped with a variety of coatings, obscurants, and shadings according to different technical, aesthetic, and socially oriented requirements. Thus, we may create a kind of "abacus" of the possible technological and formal solutions. This abacus can be conceived as the main instrument to give the inhabitants the ability to express their needs within a common order respecting the structure, the functionality, and the guidelines of a renovation strategy involving architectural modifications. Since the "letters" of this alphabet have been studied as a modular system and can be joined together in multiple combinations, the "discourse" that it will produce from inhabitants could have a positive result in terms of aesthetics and functionality.

The suggested technology can be based upon the utilization of prefabricated facade components and extensions that could easily be produced through a CNC machine.[38] The number and size of panels and openings can vary and is a function of horizontal and vertical coordinates (for example, the distance of the openings from the borders of the panel and among each other). By mapping and coding the generic facade panel as per the listed variables, it is possible to define an open geometry through the utilization of software tools.[39]

[38] As previously explained, the possible interventions have been categorized into three different levels, at each level corresponds a different scale of the renovation element. Level 1 is based upon the facade element, level 2 upon the horizontal extensions, and level 3 upon the vertical extensions. In order to group all the possible typological and geometrical variables that can be produced with the same technology the abacus chart can illustrate the range of options. When considering the design and production relationship, it is necessary to exactly and preliminary understand the morphology of the buildings, the most representative types of openings in the facade and define the possible transformation that each facade module could encounter in the design proposal. It is then fundamental to define the different shapes of the panels that could fit within a large number of scenarios and at the same time could be produced in opened forms and configurations so to answer to a vast number of possibilities, as required by the vast housing stock and various user needs. In this terms, the abacus becomes one of the main design tools for planners and professionals involved in the process: it the catalogue of options among which the inhabitant can choose and will enrich the possibilities of synergies between the technical and sociological proposed strategies. In order to do so the starting point is the data collection through the utilization of a 3D scanner enabling the planner to collect all the geometrical information regarding the existing façade. The mere collection of points is anyway not sufficient, it is in fact important to study and map the original façade, the main axes, the possible symmetries and the division of the envelope in parts that can then be separately reproduce, built and mounted. The planner has to define where are the boundaries of the base element and the possible subdivision of the façade in the most efficient and effective base component. The idea is that to figure out which is base element whose dimension can vary in infinite numbers but whose typology stays fixed. Thus, a façade type can be divided into regular modules. Every dimension of the base facade module has then been given a parameter: the height of the floors, the window dimension, the balconies or loggias outline, the ratio between opaque and transparent surfaces, and so forth. The planners can directly introduce the data that come from the survey on the existing building, each and every time different, each panel and each building, but the definition of the module and the production machine will be the same reasoning on the same parameters. This module is generally the one that is then repeated in the original pattern of the façade. It is however true that the façade chosen for the above example is a simplification and can not represent the large number of cases that could be encountered in the housing building stock. Broader can be studied but also open catalogue continuously updating and enlarging considering a broader range of possibilities and façade element typologies might be foreseen. The focus is here once again on the methodology proposed rather than on the completeness of the survey upon existing buildings' elements and their typology.

[39] Rhinoceros (MacNeel) as three-dimensional modeler and the Grasshopper plug-in to govern the parametrical variation of the geometrical dimensions can be the assisting tools of this process. The Grasshopper plug-in is a graphical algorithm editor that allows designers with no formal scripting experience to quickly generate parametric forms. Therefore, each of the panels can be modeled and its parameters (geometrical dimensions) can be left unknown and changed time by time according to each different panel and each different building.

The additions can be thus grouped in an abacus of possibilities that will become one of the main design tools for planners and professionals involved in the process. In fact, the abacus may represent the communication instrument between technicians and inhabitants, which would enrich the possible synergies between the proposed strategies.[40] In this perspective, the potential add-ons can be also considered as a tool to combine the observed ethnographic aspects and end user needs or expectations, thus fostering their potential inclusion.

Up to six modifications of building envelope for each span have been considered in the reference case studies for the Peristeri urban compound. The hypothetical building transformation has been based on the assumption that additional spaces for users and inhabitants would be gained in the current residential units, and the additional units would generate added real estate value.

The technical and structural feasibility of the abacus relies on the hypothesis of an external supporting frame (Figs. 3.6–3.8), and has been tailored and customized as a function of different constructive elements and architectural types; the volumetric additions and options (including the zero-option one = no intervention) have been further combined with different options of materials, according to the construction and types of the different reference buildings.

The current condition of modernist buildings and urban settings of the 1960s and 1980s present clear evidence that the building techniques and the market have not been able to take into account any possible further development and changes, neither in the environment nor in the buildings themselves. The strategy of architectural modification of external envelopes proposes a reverse methodology: by defining the main design principles and

[40] Façade add-ons may be a strategy aimed at delivering forms of customized and variable components of self-expression in operations of energy retrofitting of existing building stock, with respect to urban dwellers and users' expectations. To achieve this, it is important to consider participatory and socio-integrated policies during the abacus definition phase. The research goal of the case studies is to study the possible evolution of the buildings in these specific post-war districts, by envisioning and simulating how inhabitants could take over the architectural role in the future and possibly transform their own houses. In this context, ethnography is not considered as a mere techniques toolbox directly borrowed from social sciences; on the contrary, design rhetoric refers to the ability and the purpose of design thinking to engage and foster transformations. In example, in Peristeri, there is a high percentage of elderly people and a continuously increasing number of young couple becoming part of the community. The traditional approach for multicultural society based on an unsubstantiated and narrow perspective would be ineffective in these urban contexts, therefore inhabitants should be given structural and technological solutions on which they may base their own personal changes and design processes.

parameters according to their variability, it is possible to develop a modular system that incorporates multiple design solutions where the single components can be interwoven, changed, or transformed, while guaranteeing the coherence of the urban configuration in its evolving process.[41] Thus, it becomes important to go back to the initial user analysis, on the collective spaces of the context, and to consider the interrelations between users and architecture without looking for a universal solution, but instead to search for new and dynamic methods and processes that can actively respond to the changeable nature of the surrounding urban, social, and environmental contexts.

Abacuses of modular options as a function of possible energy retrofitting scenarios and users' requirements in the different building types of the Peristeri urban setting have been developed.

Hypothetical incremental scenarios for the existing residential units in the tower building block are summarized in Fig. 3.8 illustrates the first hypothetical retrofit scenario on a residential unit type and the consequent effect produced on the map and the west facade of the buildings. Considering that symmetrical conditions do exist for the east facade of the same building type, hypothesized scenarios may apply to the east facades as well. Fig. 3.10 shows the comparison between the scenario as built (on the left part of the figure) and the first retrofit option (on the right).

As another example, Fig. 3.11 shows the possibility of combining facade insulation and window replacement with additional space for balconies (on

[41] Forecasting the possibility and studying the pattern as a modular system, keeping in mind the development of different combinations, it is possible to let everybody do what they want with their home while still leaving open the possibility for self expression, without clashing with construction codes and regulations, according to a metabolic approach (Macguirk, 2011). Autonomy in the design or production of space means that people involved in designing and building need to have access to knowledge of design and building processes and components in order to discern and enact. But at the same time it means that those processes have to be open enough to increase autonomy and adaptability in time, instead of limiting it or even turning it impossible. Design here is more related to a means for people to experiment different spatial possibilities, so they can evaluate, for example, where to place the openings, the size of the rooms, and so on (Ferrante et al., 2011). Concepts like durability, adaptability, and energy efficiency have been increasingly taken into account in the fields of building and urban research. Especially when considering the high standards and requirements for the retrofitting actions, one of main goals consists of the development of long-lasting building products that can adapt to different needs and environmental conditions throughout their life-cycle and that could guarantee a high level of building envelope energy performance.

Figure 3.10 ***Tower building type and hypothetical retrofit scenario considering wall insulation, window replacement, and structural addition of the external frame.***

Figure 3.11 ***Abacus of modular options as a function of possible energy retrofitting scenarios and users' requirements in the west and east orientation of tower building type in Peristeri.*** (Facade insulation, window replacement combined with additional space for balconies, on the left, or additional space both for the room and for the balcony, on the right).

the left) or additional space both for a room and for the balcony (on the right part of the figure). Each solution is provided with a set of options/details for finishings and coatings. Fig. 3.12 shows the combination of facade insulation and window replacement with additional space for the other room (on the

Figure 3.12 ***Abacus of modular options as a function of possible energy retrofitting scenarios and users' requirements in the west and east orientation of tower building type in Peristeri.***

left side of the figure) or additional space for both rooms, maintaining the same size of the as-built balcony (on the right part of the figure). Again, each solution is provided with a variety of options for finishings and coatings.

Similar abacuses have been hypothesized, assessed, and verified for all the facades in all the different building types of the urban compound in Peristeri.

The general results demonstrate that the abacus can be used as leverage to incentivize inhabitants in their decision to renovate their apartments, since it represents a possible user-driven design scheme to let inhabitants adopt tailored solutions according to their needs and requirements. This overall strategy may signify an innovative and different design approach toward the energy-saving retrofit of existing buildings. By using and combining different options, the outcome is far from being a single solution project; rather, it may represent the projection of a large set of possible projects, all different but similar at the same time, and therefore closer to the inhabitants' desired uses and habits.

The outcome of this strategy is not the design of a model, but the design of a process, as shown in the following different options and envisaged for the different building types in the urban compound (Fig. 3.13). Furthermore, the possibility of combining add-ons on top of and next to the buildings (and thus new residential units) with facade solutions was explored (Figs. 3.14 and 3.15) for the double block building type. Fig. 3.14 illustrates the possibility of combining new residential units on the top floor and in south side (right part of the facade) with new facade solutions in the existing residential units of the block building B6. Fig. 3.15 illustrates the possibility of combining new residential units on the top floor and in the south and north sides (right and left sides of the west facade) with new facade solutions in the existing residential units of the block building B6.

Figure 3.13 ***Combination of additions on the top (new residential units) and on the elevation of the buildings with new façade solutions selected from the abacus for the west façades in the tower building type.***

Figure 3.14 ***Designed scenarios on the west façade of the double building block B6.*** New residential units are combined with add-ons and new façade solutions in the existing residential units.

Figure 3.15 ***Designed scenarios on the west façade of the double building block B6.*** New residential units both on the south and north side of the block building are combined with add-ons and new façade solutions in the existing residential units.

The abacus-tool could be conceived as a "real-time, interactive tool" to engage inhabitants and owners in the selection process of the required solutions, giving life to a creative, variable yet controlled, self-expressed possibilities within the retrofitting process of urban buildings.

Finally, the same strategy has been applied to the building block T7 case study and some of the possible configurations are reported in Figs. 3.16–3.18. As shown, for each building, the first step consists of the definition of the facade element type and geometry. The second step consists of defining the possible variation that each of the panels can have in the energy renovation phase. This is strictly related to the type and level

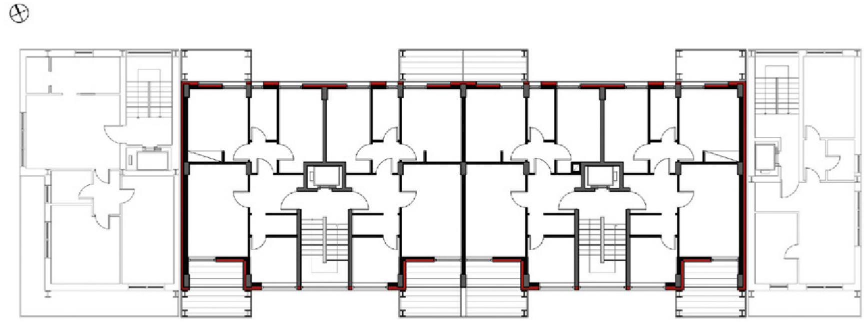


Figure 3.16 ***Plan type of the building block T7.*** Renovation scenario considering wall insulation, window replacement, and addition of the external frame at the west and east side of the building creating new residential units.

Figure 3.17 ***South façade of the block building T7.*** New residential units combined with façade solutions for existing residential units.

of intervention planned. In the hypothesized process, different levels of transformation can be envisaged:

- Level 0 is considered to be the stage where the inhabitant does not want to undertake the facade upgrade and there is no alteration.
- The Level 1 intervention envisioned is the facade transformation; the existing facade component could be switched to a component with identical shape and high-energy performance, with proper insulation. The grade has increased in terms of performance and improvement given to the envelope, calculated on the basis of the envelope performance index.

Figure 3.18 ***North façade of the block building T7.*** New residential units combined with façade solutions for the existing residential units.

- The same can be observed for Level 2, where the horizontal/vertical extension could simply be generated by the extrusion of the existing façade, or rather, the geometry of it could be changed.
- As for level 3, in case of a vertical extension, the prefabricated module that is added on the roof can reproduce the facade of the existing building, continuing the alignment of the facade and the openings, or it can signal an interruption or a break with the existing building. Since Level 3 is the definition of a new prefabricated housing unit module, the typology of the extension has not been grouped in the chart illustrating the levels of increasing upgrades that could be applied to the facade.

Up to six possible modifications for each of base modules have been envisaged, but the number of variations can be increased case by case, according to the planners' desires.

The design process is therefore based upon the idea of developing a collection of possible technological and formal solutions for the new envelope that should give the inhabitants the ability to express their needs within a common order, respecting the guidelines of the project. The three levels of action are characterized by the use of the same technology that could therefore apply to all the incremental stages of the renovation design. The catalog that will be delivered to the inhabitants will show all the possible transformations. For each option, together with the information related to the costs of the intervention, a detailed evaluation of the energy savings and increasing envelope performance will be provided. This information will be illustrated and it will be easy to comprehend the positive impact as it is meant mostly for a nonexpert audience. The details provided are fundamental in order to enable the inhabitant to make the right choice regarding his or her own needs and economic feasibility; the information disseminated should be based upon the conviction that an informed choice is the best one. Together with the performance aspects, it is also important to set the variables related to the aspect of the facade and the personalization degree. Whether the abacus promotes the breaking of the original geometry or maintains the original rigor, or if the main characterizing object of the project is based upon the usage of a special material, (ie, its pattern or the tiling of the façade) must be determined by the planners according to their analysis and their own sensibilities. It is therefore impossible to define a standardized catalog of choices and possibilities that could fit every circumstance, but the suggested method guides the planner in the definition of a case-specific set of elements (facade components, horizontal extensions, and vertical extensions) among which the inhabitants could choose and express their preference.[42]

[42] From a geometrical, typological, and formal point of view, it is important to set the rules for the definition of the new facade outcome. Should the style be defined by the inhabitants, directly giving them a high degree of freedom in the selection of material, colors, shape, and function or shall the architect impose his own interpretation? As anticipated, the sociological component of sustainability is central and plays an important role in the feasibility of the intervention. The topic is once again not new, the problematic has been faced often in the history of architecture and has often landed in simplified answers. Friedman (1975) states that "an architectural style can arise from inhabitants' instinctive and automatic decisions, it is a randomness in order (...) design is a game with no explicit rules". "Because the architect of the past served a single client, he was able to become thoroughly acquainted with the client's individual tastes and way of life – he could make the client's decisions for him. The majority of architects designing housing today do not work for millionaires, but for millions of individuals who will work or live in the architects' projects. The architect cannot study the behavior of each user: instead he constructs an ideal user and plans for this ideal. […] He should, instead, devise methods of promoting choice among the users themselves". The same idea is supported from Price as well that writes: "One uses a tight, carefully designed technology to achieve a loose, free-will social patterning. I don't think this sort of variation necessarily requires any compromise on the validity of the first design intention." It is, in other words, a search of randomness in order: the idea is that it can be possible to control the chaos, with the aid of a computer and interface, without the need of defining a formal style and any control on the outcome. Upon this aspect the author wants to stretch a clear distinction between the proposed methodology and the related design outcome of the theories above mentioned. According to the

(*Continued*)

The division in several base modules allows the planner to control the facade composition and assemblage at all the scales, but how is it possible to combine the different facade elements, leaving the possibility for the inhabitants to choose, and at the same time, prevent chaos from governing the entire facade system? The question is strictly related to the idea of defining a set of rules and combinations that are possible and letting the final outcome be open. The designed approach aims at defining the energy renovation practice by seeking the definition of a design method that could lead to multiple design outcomes and not yield one prefixed and overimposed result. The variability of the different elements of the new facade are numerous. The previously mentioned variables are only the primary ones; a broader range can be implemented and can be increased or changed according to the specific case study. In fact, all the possible design solutions can be studied and tested on the primary module According to the suggestions of the planners and the inhabitants, a first set of options is produced and the abacus can work as a catalog of possible solutions among which the inhabitant can choose. Theoretically, the approach is based on the assumption that it is possible to develop multiple variant designs and multiple criteria analyses of a building refurbishment in order to enable from one to an infinite number of alternative versions; in this manner, the architecture is an unfinished work of art and the structure is the support, which leaves blank spaces for the user to participate in the decision-design process. Since a formal design is necessary to guarantee a structured and organized process that corresponds coherently with current energy and safety regulations/requirements, fixed components (structural and functional invariants) must be applied in the (re)design processes of the buildings. On the other hand, a degree of adaptability/flexibility and the adoption of processes that directly engage the inhabitants could offer a real solution both to the anonymity and standardization of these housing complexes. Defining the main design principles and parameters according to their variability leads to the possibility of understanding and controlling a "genotype" that incorporates multiple design solutions in itself. The single components (the phenotypes) can be interwoven, changed, or transformed, but could still guarantee the

here presented process the architect is and should always be the person that stands behind and controls the entire system. The scheme provided is only a reference illustrating the method that stands behind the creation of the abacus. It is clear that, once the base modules have been found and defined, the formal, geometric, material, and chromatic variation possibilities will be determined by the architect. In fact, all the aspects that overcome the merely typological analysis have to be evaluated and based upon geographical and climatic consideration, coherently with the planners' sensibility, the context, and a large number of variables that are not part of the core of this research.

coherence of the final composition as an open and in fieri composition. By iteratively changing the parameters used to generate models, the planner can create multiple possibilities for consideration.[43]

Current experiences on social or participative design have shown great potential and interesting aspects on the theoretical side, but often have displayed a high degree of chaos in the final formal outcome. The proposed approach here is that the rules and the style must be set and defined in order to avoid a deconstructionism ruled only by randomness, within which there is very little beauty. In this frame, we can state that innovation is capable of finding the set of rules that can control the process and its outcome, guaranteeing a formal coherence of the system and of the architectural result as well. The task of the architect is therefore to draw the pieces of the mosaic and the rules for the possible combination, until such time when the final output, which will be unforeseeable until the completion of the choices from the inhabitants, will be determined.

3.1.3.1.2 Energy and Cost Benefits of Volumetric Addition in Energy Retrofitting Actions: Low-versus-High Transformation Retrofitting Options toward ZEUS

Further economic analysis has been developed to test the feasibility of the previously envisaged scenarios. Results show that in each building type, the option of incremental units and add-ons represents an effective strategy to decrease the long payback time of the energy retrofitting.[44] As shown in Tables 3.19–3.21, the potential gains related to the construction of new residential units greatly decrease the payback time of all the initial costs of investment, including the

[43] The possible solutions and the formal suggestions for the facade transformation and extensions should come from the architect that sets the pattern and the series of proposal collected in the abacus, together with the rules that stand behind the computer aided program that is then used as an interactive interface to handle the dialogue with many final users. This ensures the coherency of the final outcome, proposing only fitting solutions and reiterating the trial-and-error loop, narrowing down the possible choices, still defined by the architect, that therefore plays the role of moderator and definitions controller. It is once again the architect that sets the rules of the game, iterates the formal guidelines, and guarantees the correspondence of the project with the general needs, requirements, and pre-existing context. Within this open form and supports scheme, the inhabitants can chose the most fitting option among the possibilities defined by the planner. Interaction and clashing of choices from one inhabitant to the other are also controlled and handled by the program: the options proposed to one inhabitant are influenced by and different than the wishes and decisions made by another inhabitant that, for example, lives next door or above; the neighboring options in the facade will not collide, and the risk of turning the job into a chaotic mosaic of uncontrolled design can be avoided.

[44] For the economic analysis of these hypotheses, we have assumed a price € 1,400 per m^2 per net floor area of new construction (add-ons) and a correspondent sale price of 2,200 €.

Table 3.19 Cost-benefit assessment of the proposed "deep retrofitting," including the creation of new units in the tower building type T11

T11 (40 units)			
Retrofitting options	**Costs/gains related to the option (€)**	**Savings (€/year)**	**Payback time (year)**
A – Complete retrofitting	−371,595	18,120	20.5
B – Metal structural frame	−173,910		
C – PV and plants	−196,000	16,500	11.9
D – Construction of new residential units	−264,000		
Total costs/investments	−1,005,485		
G – Gain from new units	600,000		
Total	−405,485	34,620	11.7

Table 3.20 Cost-benefit assessment of the proposed deep retrofitting including the creation of new units in the double block building type B6

B6 (90 units)			
Retrofitting options	**Costs/gains related to the option (€)**	**Savings (€/year)**	**Payback time (year)**
A – Complete retrofitting	−558,559	39,015	14.3
B – Metal structural frame	−323,897		
C – PV and plants	−440,000	30,800	14.3
D – Construction of new residential units	−1,331,000		
Total costs/investments	−2,653,456		
G – Gain from new units	2,420,000		
Total	−233,456	69,815	3.3

Table 3.21 Cost-benefit assessment of the "deep retrofitting," including the creation of new units in the block building type T7

T7 (28 units)			
Retrofitting options	**Costs/gains related to the option (€)**	**Savings (€/year)**	**Payback time (year)**
A – Complete retrofitting	−280,717	18,704	15.0
B – Metal structural frame	−174,319		
C –PV and plants	−236,800	30,800	7.7
D – Construction of new residential units	−1,582,000		
Total costs/investments	−2,273,836		
G – Gain from new units	1,924,000		
Total	−349,836	49,504	7.1

costs for RES (row C in the tables) that are required to set to zero the energy balance of the buildings. Furthermore, if we consider the hypothetical investments of developers in add-ons, the gains obtained by sales of the new apartments would come close to counterbalancing both the standard energy retrofit cost and the cost of RES (PV and solar panels) to set to zero the energy demand of the whole building. Noticeably, these kinds of transformations go well beyond the concept of deep renovation and imply non-energy-related factors. Next we will move from deep renovation to a radical, major transformation of the existing built environment.

3.1.3.1.3 From Deep to Major transformation in the Retrofitting Options toward ZEUS

These hypothetical interventions designed for the urban compound of Peristeri do not negatively affect the availability of open green areas. As was forecast and indicated in Chapter 2, to properly address the objective of low-carbon, zero energy in existing urban environment, we also need to consider the buildings and the related open areas; this is especially true in the Mediterranean warm regions of the EU, where the snowballing effects of all the buildings and open areas is very important, especially in the summer season. Furthermore, a more holistic vision of the urban energy demand, which considers outdoor spaces and buildings as a whole, can better drive urban planning decisions and bottom-up, grass-roots initiatives toward the adoption of alternative residential configurations/redevelopment of existing urban areas, thus motivating main stakeholders like public bodies, policy makers, urban dwellers, and administrative bodies in the adoption of participative processes or green behavior. This is particularly challenging in urban contexts of "modernism," like the district of Peristeri,[45] where the

[45] Most of the buildings of European suburbs have been designed according to modernist principles and concepts and conceived to be universal. Solutions have been applied with few considerations on cultural and social characteristics all over Europe, generating, in different sites, very similar problems In brief, the functionally oriented vision of architecture has produced dull blocks in a dull environment. Nowadays, these buildings are in urgent need of environmental and energy retrofit. In a complexly structured context, where the number of decision-makers and cultural scenarios overlap; and where the temporal dimensions and social background of the citizens are dissimilar; and where local and global, physical, and virtual dimensions coexist and where, finally, it is no longer possible to ignore the direct and indirect relations with the context, it is necessary to identify design procedures that can quickly adapt to environmental variations and new requirements. Succeeding in this endeavor requires more than getting the engineering right (Webler et al., 2010) and focus should be placed on the social aspects at community level. In fact, developing more sustainable environment depend upon consumers' willingness to engage in greener and more collective behaviors (Peattie, 2010).

majority of the blocks are currently characterized by the presence of pillars and a narrow and dark basement level. Cars are everywhere and block the possible fruition of the street/garden/park level from the pedestrian perspective. A proper renewal action has to be developed to guarantee a higher degree of freedom so that the inhabitants will be able to choose the best solution according to their needs.

(Re)design processes of existing urban buildings are called upon to respond coherently to social and end-users' requirements, to current energy and safety regulations/requirements, and more permanent components (structural and functional invariants) as well. In this process, a certain degree of adaptability/flexibility and the adoption of processes that directly engage the inhabitants could offer a real solution both to the anonymity and standardization of these housing complexes. This approach also should be applied to the ground-floor level, incorporating different levels of privacy in the collective areas, emanating from the direct and active participation of the inhabitants.[46]

A new spatial organization for the outdoor spaces in the Peristeri urban compound has been outlined. To reach the savings potential indicated in Chapter 2, a feasibility study was developed to maintain and increase the green and permeable surfaces as much as possible. Access to the open spaces was reorganized to let people enter the area from the renewed retail and commercial areas into "semi-private" green courtyards, to give a warm and welcoming feeling that would enrich the quality of the communal spaces. Thus, a five-step progressive design scenario was developed for the transformation of the existing open area in Peristeri, taking into account the incremental volumes as designed in the major transformation envisaged so far. The final configuration combines the need for a more inclusive environment for urban dwellers and the cooling potential of increased green and permeable surfaces (see Table 3.22 and Fig. 3.19). The results show how the potential increase of green surfaces in the area spreads to 80% of the existing permeable areas. Thus, notwithstanding a significant increase of existing building volumes, there is still a wide potential for recovering green space and natural open areas in this urban context. In Fig. 3.20 the final master plan, including green surfaces and areas shaded with greenery and PV pergolas, is shown.

[46] As Gehl points out, the majority of social residential areas have been built according to principles and ideologies that give very low priority to outdoor activities, to the connection between distance, intensity, to the closeness in various contact settings has an interesting parallel in decoding and experiencing cities and city spaces (Gehl, 2010).

Table 3.22 Calculation of progressive increase of green and permeable surfaces in Peristeri urban compound

Intervention	Addition of green surfaces (m²)	Green surfaces (m²)	Increase compared to the as-built case (%)
1 – As built – (Existing green surfaces)	—	12,100	0
2 – 2 Multistory parking building and reduction of parking areas at ground level	800	12,900	7
3 – Green roof on the existing commercial porch	1,500	14,400	12
4 – Green roof on the top floors of existing buildings	3,680	18,080	30.5
5 – Green vertical surfaces on buildings	3,700	21,780	30.5
Total amount of potential green surfaces	9,680	21,780	80

3.1.3.1.4 Existing Limits for Add-ons in Dense Built Areas: The Case Study Evripidou

As for the previous case studies, further hypotheses of transformation have been envisaged to understand whether it is possible and cost-effective to realize new construction elements connected with the existing urban setting. Given the location (the historical center) and the urban density, the procedure to perform this analysis in the central Athens area needs to be articulated according the following successive steps:

- Assessment of constraints (historical, structural, morphological, etc.).
- Realization and evaluation of the possible design scenarios.
- Energy analysis and the economic impact of designed solutions.

To determine whether it is feasible to implement the transformation and expansion in the RUE, it is necessary to establish which of the 11 buildings may be subjected to such a transformation, individually and in their mutual relation.

In Table 3.23, two types of possible intervention (addition to the existing buildings and new construction) have been set in relation to the main constraints. The new building hypothesis (demolition of the old building and construction of a new one) can be considered in the following cases:

- The existing buildings do not present historical or architectural features to be maintained/preserved.

Figure 3.19 ***Maps of the five-step progressive design scenario were developed for the transformation of the existing open area in Peristeri.***

- The boundary conditions, consisting of adjacent buildings with blank walls, do not generate property or rights conflicts among dwellers.

In the specific context of the Evripidou central RUE, for the plot area of building 7, which consists of only two floors with no historical value, the demolition and subsequent construction of a new building has been hypothesized. Fig. 3.21 illustrates the analysis of resulting constraints and the possible densification in the Evripidou urban courtyard. Furthermore,

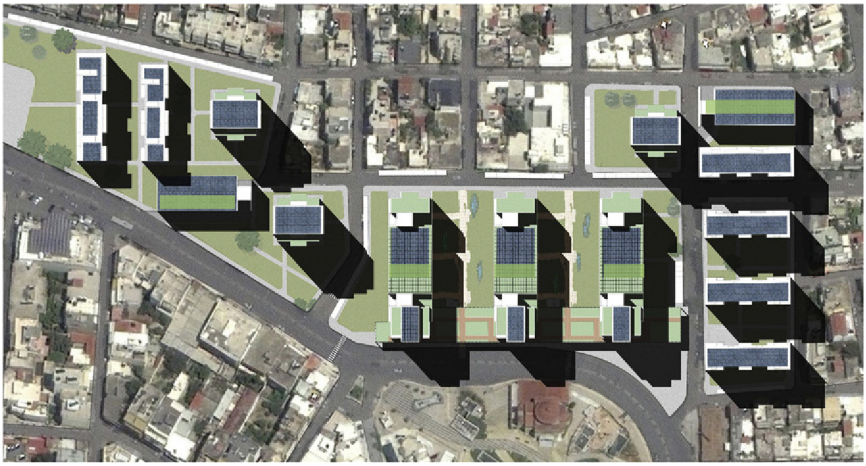


Figure 3.20 ***Plan view, final scenario in the urban compound in Peristeri.***

Table 3.23 Main existing limits/constraints in the analyzed context

Limits/constraints

Historical and architectural constraints	The buildings with historical and architectural features can only be preserved and in no case can change of volumes be admitted
Constraints border	Inconvenient situations related to the reciprocal views of the various buildings (limited or avoided in the presence of blind walls)
Morphological constraints	Most of the buildings present the smaller floors located at the roof level. This makes spaces too small to be suitable for add-ons
Structural constraints	Do not exceed the load bearing of the existing buildings
Existing legislative constraints	• Avoid "pilotis" • Maximum height of 22 m • Not exceeding six floors • Floor area covering ratio within 60% of the surface area • Maximum size achievable for each building is four times its surface area in plan

Table 3.24 illustrates the possible incremental additions in terms of maximum possible surfaces. Calculations to evaluate how potential gains from new additions can counterbalance the retrofitting operation costs have been performed and the results, including and calculated simple payback time, are shown in Table 3.25. Additions and energy retrofit to increase the market

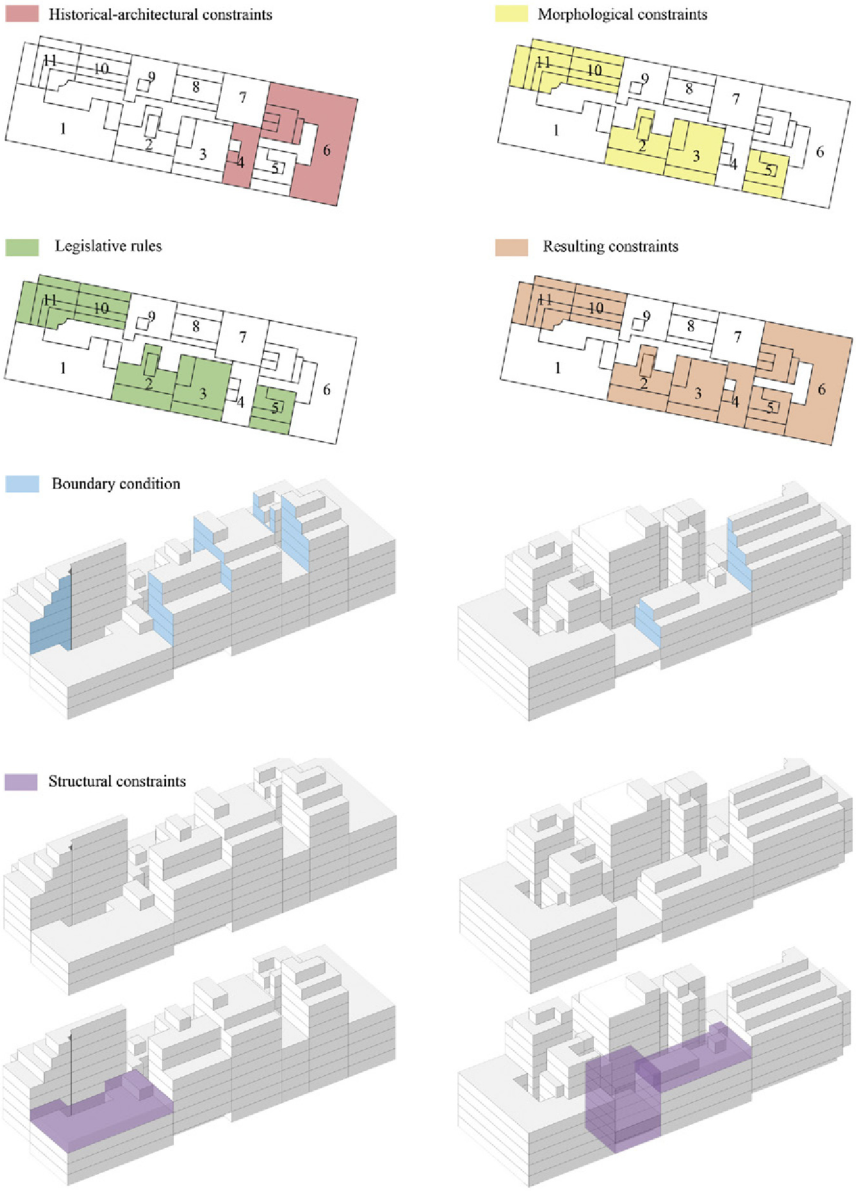


Figure 3.21 ***The resulting constraints and the possible densification in the Evripidou urban courtyard.***

Table 3.24 Admitted incremental volumes as a function of the emerged limits/constraints in the Evripidou urban courtyard

Buildings where possible addition/new construction is feasible	Surface in plan (m^2)	60% surface (m^2)	Max admitted surface (m^2)
1	410	246	1640
7	160	96	640
8	130	78	520
9	140	84	560
8+9	270	162	1080

value and the standards up to nZEBs in this urban courtyard can provide an economical advantage, bringing to 15 years the simple payback time of retrofitting costs, which was initially estimated to equal 20 years (see Table 3.25). Negative values in building 7 (*) means that there is an immediate gain received by the sale of a new building in place of the existing one-story building (7) (Table 3.25). Different views of this final scenario, where RES are again readjusted to new energy demands, are reported in Fig. 3.22.

3.1.3.1.5 Energy and Cost Benefits of Add-ons in Densely Built Areas: Evripidou Case Study

In this last phase, we proceed with the creation of a new model to obtain new results through energy simulations with the program DesignBuilder.[47] In the following tables the new dimensioning of these facilities, the total costs, the savings, and the payback times of the buildings are illustrated; a final assessment is made on the entire urban courtyard.

Studies and simulations performed for the Evripidou central Athens area have demonstrated that zero energy buildings are also achievable in the dense central area of the AMA. However, from the economic point of view, the initial up-front costs are still very high, even if they do sensibly decrease after using deep renovation to bring the standards up to nZEB with volumetric addition.

For a concrete implementation, the energy efficiency of existing buildings at the urban scale should also be considered for the relations (potential

[47] For the modeling of new volumes the assumptions chosen for the previous phases have been used. Regarding the cost analysis of the hypotheses, a price of € 1400 per m^2 has been assumed for the construction of new expansions and a sale price of 2200 €/m^2 has been estimated and applied for calculations. For Building 7, the cost of a building replacement also included the cost of a controlled demolition (estimated equal to € 295.8/m^2), to avoid damage to the adjacent buildings.

Table 3.25 Hypothesized costs for retrofitting operations including new additions and calculated simple payback time

Buildings	Insulation costs (€)	Window replacement (€)	Insulated green roof (€)	Plants and PV costs (€)	Construction costs (€)	Sell (€)	Total costs (€)	Total savings (€)	Payback time
1	87,218	61,531,00	40,370	90,641	344,400	541,200	82,960	9,039	9
2	101,074	87,631,00	14,342	102,161	0	0	305,208	12,094	20
3	82,100	111,230,00	21,247	157,209	0	0	371,786	21,914	13
4	39,960	15,533,00	10,624	40,986	0	0	107,103	6,275	14
5	69,966	106,997,00	12,217	87,370	0	0	276,550	13,188	17
6	152,372	168,229,00	48,337	216,655	0	0	585,593	29,310	16
7*	16,166	17,033,00	15,404	62,916	772,024	1,331,000	−447,457	4,027	0
8	41,972	23,132,00	12,748	55,816	98,000	154,000	77,668	6,999	11
9	33,579	24,332,00	13,280	55,284			126,475	6,914	10
10	54,886	106,163,00	13,811	93,305	0	0	268,165	10,329	21
11	81,159	84,264,00	17,529	118,262	0	0	301,214	12,497	18
Total	760,452	806,075	219,909	1,080,605	1,214,424	2,026,200	2,055,265	132,586	15

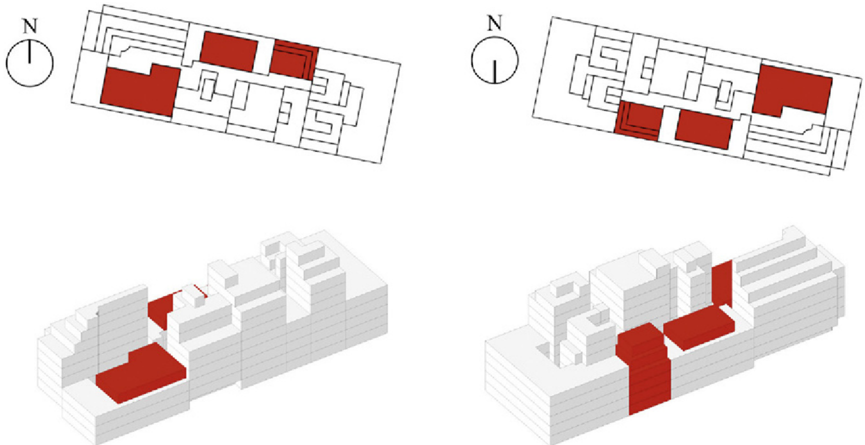


Figure 3.22 ***The considered final configuration for add-ons and densification in Evripidou.***

synergies/constraints/barriers) that may arise in the transition from the single buildings to the urban courtyard. These interrelations open up different scenarios of technical and economic feasibility: social and user-oriented, together with economic factors, become determinant and imperative in this context. For this reason, further possible synergies in the central urban compound can be envisaged.

In other words, we attempt to consider the single buildings as a unique urban service and house settlement; among the many possibilities, considering the building as a single element, it can be hypothesized that all owners can share the total cost of operations. Obviously, this could lead to very lengthy negotiations and nontimely agreements between urban dwellers, considering the disadvantage of those buildings having limited or no additions.

Another possible scenario could be "joint liability," or support, to be established, thanks to or in force of possible recommendation by public administrations and municipalities. For example, again, the owners (or the potential investors) of the buildings where a major transformation is admitted and where major gains can subsequently be achieved, can be charged a quota for the energy retrofitting of the adjacent buildings. This can be done in exchange for possible tariff incentives, incremental volumes, feed-in tariffs, and so on, in order to achieve a fair, balanced and win-win sharing of the burden among different dwellers. In this scenario, shorter and more effective negotiation/agreement times can be obtained, as only the property owners or the investors in the incremented buildings (and not all of them) are the main stakeholders, so they become the negotiators of the retrofitting operations.

In the case in question, for example, in the building undergoing major expansion (building 7), major gains could cover a portion of the expenditure for the roof insulation (the higher cost-effective retrofitting option) and the photovoltaic system.

More generally, considering the payback time of 15 years as in the final scenario, it could be extremely interesting to evaluate the possibility of further incentives in terms of volumetric compensations, to be used in exchange for energy, environmental, and social performance.

3.1.3.2 Discussion

A significant part of the major Athens metropolitan area has been mapped and three significant RUEs have been selected to investigate the energy demand, and to propose hypothetical design scenarios to set to nearly zero the local energy demand, according to incremental assumptions of transformation to achieve nearly ZEUS. The assumed transformations moved from standard retrofit actions to be applied on the envelopes of existing urban fabrics, up to their full mutual combination to reach the level of deep renovation and easily achieve nZEB standards using RES. In particular, the energy analysis on various building blocks in the different RUEs of Athens has demonstrated the energy-saving potential of different standard retrofitting operations (insulation and coatings of opaque elements and envelope surfaces, window replacement, green surfaces). Given the representativeness of Athens' climatic conditions, the availability of data, measurements, and building type descriptions, the urban compound of Peristeri has been selected for further investigation including physical/climatic, architectural, and economic aspects. To identify the economic feasibility of the standard energy retrofit, a cost-benefit analysis was conducted by means of a market survey, determining the evaluation in terms of energy performance improvement and the related cost estimations for each different design option. Simulations have shown that it is technically possible to reach an average EP index of around 25–60 to kWh/m^2 year with the insulation of opaque surfaces and the replacement of existing windows. However, cost analysis and cost-benefit assessments of these interventions have always shown high up-front costs for investments and excessive payback times.

These transformation hypotheses were compared with the hypotheses of a deep renovation, to drastically reduce the energy performance indexes of the buildings up to the target of a passive house, which can easily achieve the nZEB target by employing a reduced use of RES. Furthermore, the different EP indexes (kWh/m^2 y) of the deep renovation options have been compared to the relative options' costs. As expected, the higher the building's transformation, the higher the costs. We found that the economic barrier is the most threatening obstacle toward the adoption of ZEUS in the real estate building practice.

In the search for possible encouragements toward the objective of achieving ZEUS, we found the opportunity given by factors able to reduce energy costs in other nonenergy-related factors influencing the renovation and valorization of buildings, which are corresponding key benefits. We stated that energy retrofitting in RUEs, being connected with technical and architectural modifications of building's components, may involve other qualities that can not be ignored, since they may be a key added value in terms of technical and economic feasibility. Thus, we moved from the concept of *deep renovation* to a *major renovation,* including other energy retrofitting architectural and technical modifications such as the use of new building coatings, sunspaces, buffer zones, and extra rooms (add-ons) integrated with RES. Feasibility studies of these volumetric additions to concentrate them in the most available (and often more dispersive portions) of the existing buildings, like rooftops and blind facades, have been developed. The various design assumptions and the consequent variations in the economic viability were compared. Results showed that in the case of a hypothetical investment by developers or by the same inhabitants in add-ons, the gains obtained by sales of the new apartments would come close to counterbalancing both the standard energy retrofit and the cost of RES (PV) to set to zero the energy demand of the whole building.

It can be concluded that, in the hypothesis of a higher transformation of selected building blocks, the volumetric additions may be conceived as powerful, energy generating, and insulating buffer zones able to set to zero the energy demand of the original building. Furthermore, this effective strategy may help to balance the different EP of the units within the building blocks. As for economic feasibility, the incremental transformation may produce an interesting opportunity to counterbalance the high investment costs of energy transformation. Thus, in the search for additional forms of compensation and incentives for nZEB in existing buildings, volumetric addition, densification, and/or "infill" may represent crucial tools to enhance the technical and economic feasibility of energy retrofitting operations.

The costs of these interventions are not lower than the standard solutions, but their payback (considering roof extensions and construction of new units), together with the direct benefit for potential investors who profit and/or inhabitants who gain space or money the increased asset value that results from the add-ons, have a very positive effect on the technical and economic feasibility of buildings retrofit toward nZEBs.

Other advantages, which are not always quantifiable and are not necessarily related to technical-economic estimations, confirm the strategic role of compensation of volume additions. These are: (1) the possibility of using the add-ons to optimize the thermal operating conditions in summer conditions (due to the reduction of incident solar radiation, for the vertical air flow, etc.). These new structures can also accommodate or act as support for new/renewed ducts for plants and lighting and so forth; (2) the possibility of using the support structures of the volumetric additions for the supplementary purpose of improving the conditions of the static and mechanical performance of existing structures. These "structural invariants," if properly sized and fixed to the frames of existing structures (often made up of reinforced concrete), provide an additional element of construction quality and durability; and last, but not least, (3) the use of these invariants generates a higher degree of adaptability and variability that facilitates the transition from standardized solutions toward custom-made and tailor-designed responses.

The highly flexible and adaptive character of the add-ons gives an extra chance to the nZEB process: different possible add-ons can be studied to meet multiple needs and respond to the heterogeneous demand of users/tenant/dwellers. In this context, it is evident that involving the users represents a necessary step toward the achievement of effective nZEB energy retrofitting.[48]

As stated, we moved from the concept of deep renovation toward a major transformation of the built environment. Major renovations of this kind

[48] This is why a closer collaboration has been developed with the municipality of Peristeri and a questionnaire has been delivered to the inhabitants of the case study urban compound. Results have been used to readjust the feasibility and design scenarios. Outreach initiatives with the inhabitants and the municipality have been undertaken in order to maximize the social participation in the process of retrofitting the whole urban compound in the Peristeri area. The final results of the study were presented on Jan. 16, 2015 to the inhabitants in the municipal hall. Furthermore, contacts with potential investors and with the public district body in charge of regulation and policy recommendation have been established.

have higher costs than "lighter" standard solutions (new plants, insulation, new windows) and deep renovation consisting of the complete retrofit scenarios as presented in Chapter 2, as well. Nonetheless, the reduced payback may have a very positive effect on the technical and economic feasibility of major renovation toward nZEBs. More specifically, major renovations may own the potential to activate the self-financing cycle through add-ons for deep renovation.

Thus, the reflection on economically quantifiable values, whether they are energy-related, economic, or technical, must find the intersection with other aspects, not quantified here. More holistic perspectives are needed to properly assess the competitiveness of deep energy renovation with respect to shallow or more conventional retrofit. In particular, a set of nonenergy-related factors should be considered, consisting of the overall retrofit of the building and addressing other physical, social, and environmental characteristics, as listed in the following points:

1. The possibility of achieving additional and new spaces with volumetric additions without exceeding the load-bearing of the buildings and the possible contribution of external structures to the seismic retrofitting of the building; as a matter of fact, a large majority of existing building stock in the European Union consists of buildings built well before the standardization of regulatory requirements for structural reliability in seismic areas. In many urban areas, especially in the Mediterranean, it is becoming imperative to restructure and retrofit existing buildings to improve their seismic reliability and safety. As a result, when retrofitting the built environment, the adoption of seismic provisions like energy dissipation through external structures and other safety protection devices could be more easily provided by using external structures and high transformation scenarios.
2. The influence of the new external structure as a buffer zone that protects the building from atmospheric agents, thus contributing to the improved maintenance of the existing building envelope and to a longer lifetime of the building as a whole.
3. The possibility of using an external addition for stack ventilation through vertical chimneys and a new pipe network for heating and DHW plant, centralized mechanical ventilation and, generally, for the plant system retrofitting to have less impact on existing residential units and dwellers during retrofitting construction. This may imply a consequent enhanced social inclusiveness for the dwellers (often low-income tenants/owners) who will not be forced to abandon their dwellings

during refurbishment, and will allow flexibility in the internal restructuring of each apartment.

Furthermore, in environmental terms, it is important to highlight the lower environmental impact of using the retrofitting option instead of demolition and reconstruction. The extraction of raw materials for construction, production, processing of materials and their transport, as well as the demolition and removal of the buildings would require high energy and would consequently produce high carbon emissions.

To sum up, major energy and architectural renovation, by incorporating nonenergy-related benefits, might use them to increase the motivation and willingness of main stakeholders (inhabitants, homeowners, public bodies, real estate agencies, ESCOs) in the energy retrofit uptake. In other terms, it can be concluded that retrofit is a multiobjective optimization problem, and the energy and economic benefits are indeed the main objectives but cannot be the sole criteria for the selection of retrofit options; nonenergy-related aspects could help to increase the feasibility of deep renovation toward nZEBs in current building practices.

From a market perspective, the real estate incremented value that potentially could be produced by the volumetric additions, along with the new building envelope and the achievement of nZEBs, are important parameters in estimating the commercial value of the buildings, as will be discussed in more detail in the following paragraphs.

This work is aimed at presenting, investigating, and demonstrating alternative ways of achieving nearly zero energy in urban environments, by exploring the possibility of using energy retrofitting options as form of creating additional value and quality in existing buildings; the scenarios and actions proposed envisaged a series of possible technical actions involving business investors, public bodies, and local communities in the common effort to achieve the decrease of energy consumption up to zero carbon emission in existing urban settings.

The connecting theme of the proposed path is that the crises of energy supply and global warming need to be tackled with an interdisciplinary approach where technical and economical aspects can be intertwined with social and aesthetical qualities of the building fabrics and urban settings.

In particular, the design study and the performed technical-economic evaluation demonstrate that energy efficiency in residential urban complexes can be considered as an extraordinary opportunity to restore environmental, social, and urban quality as a whole.

The technoeconomic feasibility assessment, the proper identification of the types of interventions and their combination in possible scenarios, must be investigated and estimated on a case-by-case basis, with an effective and interdisciplinary design approach. As stated before, environmental sustainability and energy efficiency in urban settings are more than technical problems. In this context, a renewed role of architects and planners is what is needed for a real shift in the building practice. Instead of trying to structure the informal through the architectural production based on authorship, architects should consider the users' perspective and their need as self-organized processes of negotiation. In other words, the architect should not act not as a "Prima Donna," but as a human being willing to donate her/his energy and her/his ideas to society. While during the Modernism period, architects were the absolute form-givers of an over-imposed process of construction, now they must become the interpreter of the process. Thus, instead of trying to structure the informal through the architectural production based on authorship, architects should consider both the technical requirements and the users' perspective, and engage in a participative processes of negotiation.

Even though the approach is based on specific case studies of the city of Athens, the underlying principles will be applicable to other districts and other cities as well. This kind of approach brings about a real shift from the current practice toward a socially sustainable process where inhabitants and designers work together to find effective and real solutions to social and technical questions.

The urban and technological strategies presented here suggest a multifold approach that could stimulate the process of energy renewal according to a multi-oriented combination of energy retrofitting practice up to nearly zero energy with a wider set of elements, components, and tools to solutions belonging to urban environments.

Furthermore, the envisaged solutions are based on the prior assumption that non-energy-related benefits play a key role in the deep renovation up to zero energy of existing buildings.

In particular, our actions have been focused on the following main benefit: the generation of a substantial increase of the real estate value of the buildings through significant energy and architectural transformation (mainly integration of RES systems with new volume additions or new building construction) as an essential process to go beyond the minimum energy performance and aim at achieving nZEBs.

This results in an important reduction of the payback time of the interventions, a strengthening of the key investors' confidence, a higher quality and attractiveness of existing buildings and, finally, concrete market acceleration toward energy-efficient buildings and nZEBs. Thus, the comprehensive renovation process shown is essentially linked to the economic, financial, environmental, and social cobenefits of deep renovations, taking into account the payback time and net present value of investments, by bringing the existing building to a very high-energy performance level.

3.1.4 Potential Impact of Designed Solutions

Is the overall proposal of energy/architectural change with add-ons feasible throughout the existing building stock in diverse areas of cities? Is the concept designed here for the Athens case study feasible in practice? To respond to these questions, we should consider different issues found in the existing building stock and the urban environments.

First, we need to recall the aspects of energy retrofitting related to the current age of our building stock; we have demonstrated the feasibility of the ambitious target in energy performance level (nZEBs), by applying hypothetical energy retrofit to nearly zero in very inefficient buildings like the building stock from the 1950s to1960s onward; in Athens as elsewhere, as already illustrated in Chapter 2, these buildings represent 60–70% of the current building stock.[49]

Second, peripheral areas also represent a large majority of urban areas in European cities; as reported in notable studies (Nilsson et al., 2013), the peripheral urban areas represent the larger majority with respect to central urban areas. Indeed, for the Peristeri case have revealed how dense peripheral contexts do preserve large areas for possible densification. These additions and densifications, if combined with a re-organization of open spaces, may even result in the increase of permeable surfaces. Furthermore, by addressing this type of urban setting, we are concentrating on built environments where change and transformation is feasible (because of free or available areas) and beneficial for energy, architectural, economic, and social reasons.

Finally, by grounding the main actions on the generation of a substantial increase of the real estate value of the buildings through significant energy and architectural transformation, we can largely aim at addressing almost the

[49] These buildings represent the large majority of the EU building stock. As a matter of fact, about 70% of buildings in the EU have been built after World War II (1950s to 1990s) and well before the application of regulatory measures on energy consumption reduction, as reported in prominent studies (EU Report, 2008).

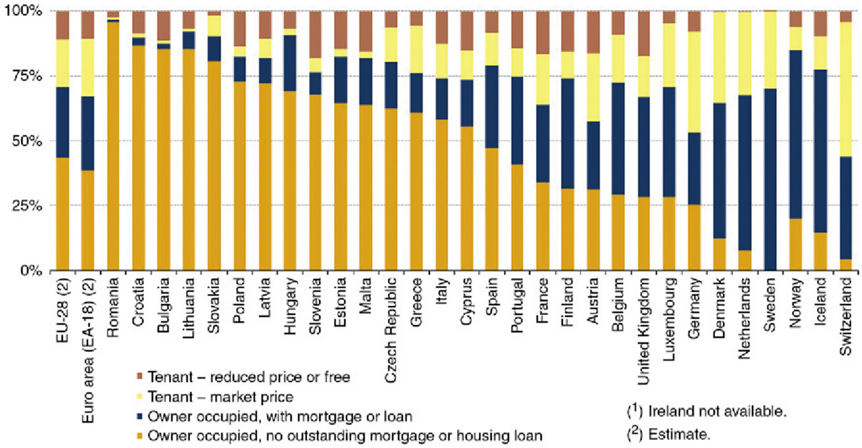


Figure 3.23 ***Ownership is the larger occupancy regime in the EU 28 (more than 75%).*** Tenure split in the member states as a percentage of the total housing stock. Housing statistics in the EU 2012. *(Source: EUROSTAT [online data code: ilc_lvho02]).*

entire residential stock: those owned by owner-occupiers, private landlords, and social housing companies. In other words, we could potentially address the accommodations of almost all EU citizens. Indeed, just over seven out of every ten (70.6%) persons in the EU lived in owner-occupied dwellings, while 18.5% were tenants with a market-price rent, and 10.9% were tenants living in reduced-rent or free accommodations (see Fig. 3.23).

While generic conclusions can not be drawn from case studies, the cases presented for the urban settings in Athens present a remarkable series of repeatable factors at the larger scale of the European urban context. Considering the case study's significance, it should be considered that Modernism in architecture has conceived buildings to be universal; thus, similar buildings in the different contexts of Western civilization and the European Union as well were produced, starting from the 1950s. As a consequence, the relatively recent European building stock presents similar energy and nonenergy problems and many common solutions can be identified, which result in a potentially large impact.

Amongst others, one common solution can be identified in the proposed external structure, representing a powerful tool incorporating other aspects of building performance improvement such as safety, seismic reliability, and market attractiveness.[50] In fact, the volumetric addition presented here is a design answer with high level of technical feasibility, whose novelty relies in the original integration of the main requirements of a building (energy, safety, comfort, attractiveness, etc.) in a single technological solution.[51]

Using a wider perspective, we should also consider that add-ons as additional spaces can then be distributed or combined in the three following ways:

1. As extra living space for the existing units (a bonus for the inhabitants that contribute to the investment)[52]

[50] The new facade layer can be placed in addition to the existing facade when the quality has been tested and proved to be still within high standard levels. In case the existing facade is no longer suitable the living and energy standards, the second option, is to remove (totally or partially) the existing envelope and replace it with the prefabricated facade modules. For load bearing structures, generally, it is favorable to prefer the first option although the wall thickness increases considerably and the light gains are reduced. On the other hand, for columns and beams structure or load bearing panels structure, the possibility of removing the existing facade and replace it with a high energy performing one is the preferable option. The base façade module can essentially accommodate all window sizes and various numbers of ventilation duct runs. The size of the individual components follow a regular pattern established by the planner at the beginning of the project phase. The module size is normally not longer then 10 m and not higher than 3.5 m. Within the module it is possible to open and adapt all sort of windows and doors according to the original facade. In case of existing balcony or loggias it is possible to enclose the area in the new facade and turn it in livable space or follow the original contour of the building and leave it as it is. Although the exploded drawing of the module and the above explained methodology might appear complex at first sight, this merely reflects the attempt to collect and tackle many "problems" simultaneously within a single base module. All components can be factory-assembled. The assembly procedures, together with the joint typologies can be tested in a full-scale working model.

[51] To successfully implement this kind of energy solution in the deep renovation of buildings, further research are under development. They are mainly focused on: (1) the evaluation and assessment of the seismic performance given by the external structures as designed; (2) the lifecycle analysis of the environmental benefit due construction activities in the different design options; and (3) strategies and applications to increase the economical competitiveness of the volumetric additions, using them as a firmer leverage to reach marketable zero-energy buildings within 2020.

[52] This is the case of horizontal extension, especially feasible in the case of existing buildings characterized by a low depth; here is possible and desirable to consider also to extend the façade by adding extra space, increase the size of the existing balconies/loggias and/or add new rooms to the existing unit according to the needs of the inhabitants, as shown for the case study of Peristeri. The ratio of opening and the light gain should be enough to allow the intervention in this direction. The height of the rooms as well as the depth of the building plays a central role in this evaluation. By acting through horizontal extension it is possible to also reconfigure the internal layout and circulation of the building by adding a new elevator for example and proving ballatoires to access the unit or a walkway aside the building. The horizontal extensions can result in punctual addition elements or in a uniform offset of the existing façade. The structure to support the new buffer surface can be entirely independent from the existing one or collaborate. The following schemes illustrate the possible substructures of the new façade and the horizontal extension.

2. As additional units and surface adjoining the blind facades of the buildings, and/or the rooftop addition[53]
3. As an "additional building," a new construction that we may even call the "assistant building", which can be built next to the existing buildings to economically support the renovation investment and help counterbalance the investment costs of retrofitting by reducing payback time; the assistant building may consist of a bonus, a complementary economic instrument for the investors (real estate investors, construction companies in conjunction with ESCO, etc.).[54]

The proposed design scenario can be replicated within different neighborhoods. In particular, the design solutions adopted for potential add-ons, although constrained into a simple prefabricated structure, have lead to a wide set of possible architectural, technical, and structural configurations that develop modular and variable solutions. The different facade abacuses that have been produced for these case studies represent the basis for the development of a new construction system for the facade production. The design becomes a game with no specific rules between technicians and inhabitants.[55] The flexibility and interactive character of the proposed system indicate significant potential impact on the social housing renovation market: through the application of one process, the revision of millions of buildings would be possible, not through standardized intervention but

[53] The possibility of creating additional living space on the rooftop of the existing building is strictly related to the structural safety. In general terms it is possible to elevate the existing building of at least one story in nonseismic contexts. In seismic areas the situation is more complex and the extra building on top has to be structurally independent from the pre-existent or rather be tested for behavior under seismic event. Moreover, the layout and circulation of the building has to allow the extension. As far as it regards the plant systems, the existing cavities and canalizations have to be able to reach the top level. The benefit of combining this type of renovation with the previously mentioned ones has effect on the economic and energetic performance; in fact, the most disadvantage and dispersive units are generally those located on the top level, on the ground floor or on the side. By creating an extra floor, the top units' energy losses are automatically reduced and the roof surface can be used to integrate solar panels. Independently from the geometrical and design purpose of the vertical extension, the structure is strictly related to the original structure of the existing building and the evaluation regarding the reserve in static terms of the existing roof.

[54] It may be used as a possibility of creating a risk fund with the real estate surplus generated by the new building that could cover the risk of arrearage from the inhabitants in paying the bills.

[55] Ethnographic and cultural differences can be considered in the development of customized solutions to revision the envelope toward a more culturally responsive skin, keeping into account not only the performances aspects but also the cultural background of the inhabitants.

with user-driven and tailored solutions, different for each building and each user.[56]

In this context, the availability and accessibility of design software, the growing culture of "making" (or "hacking"), as well as a demand for product personalization and user-oriented design reinforce of the idea of collaboration through hardware and software online communities. The increasing number of open-source platforms for sharing and confronting the ideas, along with growing concerns about the increasing alienation of architecture from its social connotations, bring the question of computer-aided participatory design back to the forefront, and initiate a demand for redefinitions and reformulations.[57]

[56] Illustrated case studies show how the abacus can generate infinite number of facade configuration, even when limited to a few set of possibilities. The rule behind the process has to be set by the planner that is the director of the 'game' within which the inhabitants can personalize their own apartment. Still, in the illustrated projects, there is a character, a driving idea that remains and guides the elevation design, whether the new facade will be based upon a contraposition relationship with the previous one or rather mime the preexistence trying to reproduce its order, or it is playing on the chromatic transition between one architecture span and the other or rather is based on one monochromatic color. The abacus is the instrument to achieve the purpose and the method ensures the possibility by the inhabitants to act and choose, decide, and personalize their own façade ambit, within a certain set of rules. Already several researches have shown the potential of interactive systems to incorporate a high degree of adaptability within the renewal for office or retail spaces, investigating the possibility from the users to actively intervene on the functional distribution and layout of the building. Still very few has been said about how to incorporate the multiplicity of users needs and habits to the complex sector energy refurbishment of existing residential buildings. The machines and the computers can help us in controlling the wishes of inhabitants and integrate them in the decision phase, directly allowing the user to control each one his one part of envelope.

[57] Friedman (1975) inserts the idea of the open form into a programmatic approach of interactions between the users and the architect. His idea is based on a trial and error reiterative process that would lead to a continuous enlightenment of the users as nonexperts actors of the design process but as the best knowledge carrier about what is suitable for them. The dweller becomes the designer through "domesticated" architecture machines that permit to each resident to overlay his architectural need upon the changing framework of the city and fit his own module, within the infrastructure, in the urban context. The suggestion and inspiration for using a machine for this dialog came directly from the research work developed in the 1950s by Yona Friedman who also invented the "Flatwriter," a computer program conceived to enable the process of self-planning. He explained this principle in a lecture that was broadcasted by the French television in 1969. "I call this a choice machine." In practice, we say that there are an incredible number of possibilities for apartments. You can make millions and millions. And in this machine, there is a keyboard which shows the different configurations, the different forms, the different positions for the kitchen, the bathroom, the toilet, and everyone can use different keys on the keyboard,

(*Continued*)

The importance of the continuous transformation and evolution of architecture – through consecutive development phases – is not new and it has been broadly investigated and attributed with important theoretical meaning as a gesture that, in itself, is significant (Eisenman, 1971). The current normative and political revision of the European measures/policies to reduce the increasing consumption of agricultural land and to contain the urban sprawl brought the idea of architecture as means to rewrite the city back to the center of the discussion. It is an alternative solution to the premade recipes of *leaving it as it is* or the *tabula rasa*. The design phase should be no longer conceived as an act of art, a stand-alone gesture of the architect called to interpret the context and society according to his or her own singular sensitivity. The urgent need to act on the existing buildings by rewriting and reinterpreting the original architectural connotation opens fascinating terrains for technological and procedural innovation in the field of architecture. Architects can now take advantage of this opportunity to retrieve architecture's social connotation and explore a new discourse on densification and/or transformative actions.

Coming back to the problem related to the economic barrier toward nearly zero energy retrofitting in existing buildings, these schemes for add-ons and deep renovation could also be implemented on a step-by-step scale, if pre-financing opportunities are limited or not available to cover the up-front costs. Hence, new assistant buildings could be considered as the trigger for a renovation roadmap that would suggest the logical and subsequent (for technical and/or economical reasons) renovation steps that should be undertaken.

To continue modeling in this framework, four hypotheses have been envisaged for the comprehensive renovation of a building of about 3.000 m^2 with 30 residential units of 100 m^2 each (600 net m^2 per floor) and a time lapse of 40 years. The different scenarios consist of:

1. The "as-built" case of a building block consuming 180 kWh/m^2 year.
2. A step-by-step renovation where the plant system renewal is undertaken during the first year with a consequent 30% energy consumption reduction (ECR), and after the first 10 years, the replacement of

and print for themselves the apartment that they prefer. The machine at the same time, checks that this person's choice doesn't block the access to anyone else's apartment. And does not block the light and the ventilation. The utopic envision of Friedman can be an inspiration for continuing the work and translate the questionnaire into a programmatic system that will enable inhabitants to express their desires and receive a direct feedback within possibilities and solutions that will be incorporated and will directly compose the over-whole renovation project.

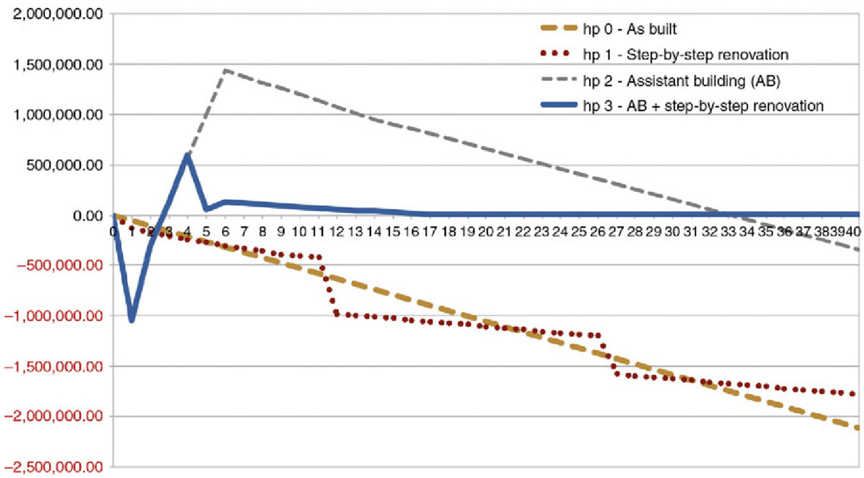


Figure 3.24 ***Calculations performed for the cost benefit analysis in the building model.*** Graphs show how the construction of an "assistant building" can be integrated in the process of a step-by-step renovation.

windows (+15% ECR) with high energy-performing windows is realized; after 20 years, all the surfaces of the building envelope undergo renovation (+25% ECR).

3. The construction of a new building (assistant building) aimed at reducing only 20% of the actual building.
4. Finally, the combination of a step-by-step renovation with the construction of an assistant building of about 1000 m^2 built with passive standards (15 kWh/m^2 year) and producing energy from RES for its own requirements as well as for the requirements of the "adopted building" (Fig. 3.9). In this simulation, the assistant and assisted building are equipped with a PV system to set to nearly zero the energy consumption of both buildings.[58]

Cost-benefit analyses performed for the building models are illustrated in Fig. 3.24. Results show how the construction of an assistant building can be integrated in the process of a step-by-step renovation. Fig. 3.24 derives from the calculated cash flows calculated for the different hypotheses; this figure also shows how the assistant building acts as a trigger in a stepped renovation process. It can be designed to act as the catalyst or attractor for private-sector financing, playing an extremely important role in the context

[58] A total 21,231 kW_p PV plant for the assisted and assisting building has been considered to cover 187.600 kW_e for the total net residential surface of 4000 m^2.

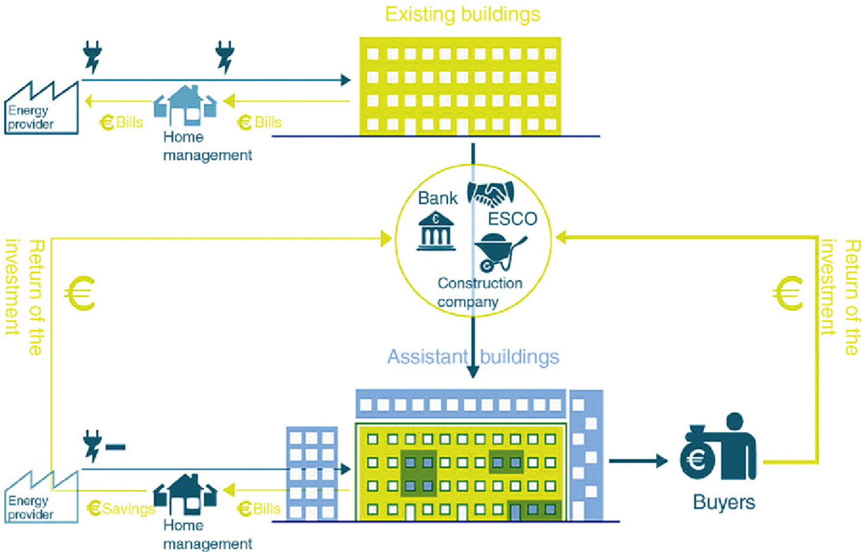


Figure 3.25 ***Scheme of potential actions to be undertaken by an ESCO or a construction company CoCo (or a joint venture between them) in the construction of add-ons and/or assistant buildings to retrofit the "assisted" building.***

of scarce private finance where the search for affordable up-front investments is crucial. Of course, it is important to specify that in the hypothesized scenario, we need to consider a new (lighter) investment after a time lapse of 35–40 years.

The simulated scenario in Fig. 3.24 considers the hypothesis of the inhabitants/property owners as direct investors: it is the basis to calculating the revenues of a potential ESCO[59] or a construction company (or a joint venture between them), as simplified in Figs. 3.25 and 3.26.

Fig. 3.25 illustrates a possible scheme for the creation of assistant buildings (add-ons and new buildings are both represented). In this case, the potential

[59] ESCO is an acronym indicating an energy service company providing a broad range of energy solutions including designs and implementation of energy savings projects, retrofitting, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management. Currently ESCO's business focuses on innovative financing methods including a range of applicable equipment configured in such a way as to reduce the energy cost of a building. The building occupants, or landlord, then benefit from the energy savings and pay a fee to the ESCO in return. At all times, the saving is guaranteed to exceed the fee. The savings in energy costs are often used to payback the capital investment of the project over a 5–20 year period, or reinvested into the building to allow for capital upgrades that may otherwise be unfeasible. Generally, the ESCO is often responsible to pay the difference in the case of a running project that does not provide returns on the initial investment.

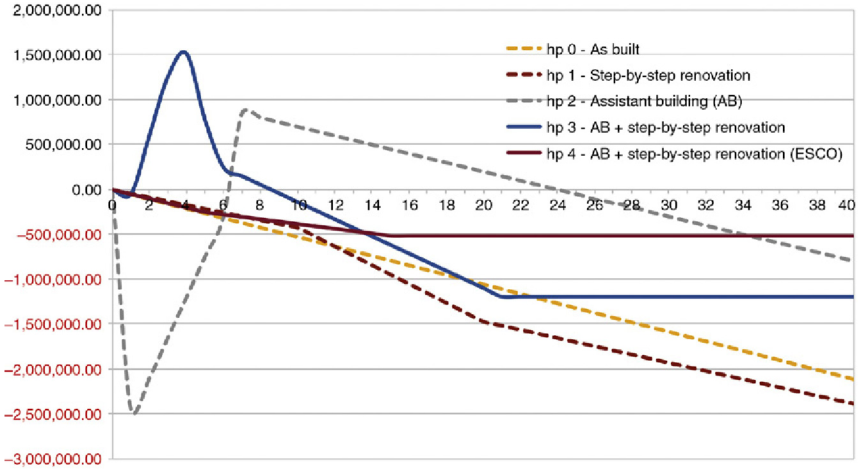


Figure 3.26 ***ESCO/CoCo have return on investments from the combination of both add-on revenues and energy bills from the existing buildings' inhabitants or house manager.***

investors' ESCO, in combination with a construction company, would have a return on investment from the combination of both add-on revenues and energy bills from the existing building inhabitants or the house manager. Combinations of different forms of incentives may result in win-win solutions: on the one hand, the urban dwellers (or property owners, landlords, etc.) may benefit from a reduced fee or a reduced number of years to reimburse the potential investors (ESCO, or ESCO in combination with a construction company [ESCO/CoCo]) while, on the other hand, ESCO/CoCo will receive revenues that can be immediately available. In this case, the financial interests for banks and ESCO have been considered in the diagram on the left.

Results show evidence that the provision of a new building with few or no links with the assisted building does not produce long-term investments (the scenario has considered a reduction of 20% of the energy consumption of the actual building; in other words, it is a case of investing only a part of the revenues from the selling of the new units in the plant retrofit of the assisted building).

On the contrary, in the hypothesis of establishing a binding contract between the construction of an assisted building and the renovation up to nZEB of the assisted or adopted building, a more stable investment climate for market and social actors can be achieved. In fact, on the one hand, the occupants or owners may have a reduced fee or a reduced number of years to reimburse the investor (ESCO or ESCO/CoCo), but on the other hand, the same investor(s) will receive revenues, which can be available within 5 years. This can also result in the co-related benefits of reducing risks and of releasing funds for further investments, thus stimulating other deep renovations in a faster, but well-planned, long-term market strategy (JWG, 2013). In addition to the evidence of the resulting increase of scale and impact of the major renovation processes, it is important to highlight how the scheme minimizes the disturbance for inhabitants. They are generally able to remain in their apartments during the renovation work and, where possible, they will keep paying the bills through the usual system, thus being the provider part of the process.[60]

Completing the financial scheme related to deep renovation, the creation of new buildings would increase the interests from financial actors and banks.[61] In fact, it could help to guarantee the solvency of the investments by consistently reducing the payback times. Of course, this is strictly related to the scale of investment.

Overall, parameterizing with respect to the renovation costs and the estimated value of the assistant building, we could aim at working on the basis of the following simplified formula:

$$\frac{C_r \times y + C_c \times x - P \times x}{R \times y} = PBT$$

where C_r = renovation costs including RES to set to nearly zero the existing buildings; y = surface (m^2) of existing building; C_c = Construction costs of the assistant building (add-ons) per m^2 (€); x = additional surfaces of add-ons (m^2); P = assistant building's price point per m^2 (€) in the reference market of the specific target region; R = cost saving per m^2 (€), PBT= payback time. To this basic formula, it is necessary to add all the financial, commercial, and legislative expenses that will occur in the construction and real estate phases. Using the previous formula, it is possible to calculate the simple payback time for the above-mentioned parameters. Indeed, to make the intervention attractive for owners (who make the ultimate decision to renovate) and for the banks and the financial agencies, we can, for example, decrease the return of the investment up to 10 or even 8 years and still derive the necessary amount of square meters that are necessary to cut the payback time, given a specific real estate market (C_r, C_c, P values). In real market conditions, financial costs and revenues for the ESCO/CoCo have to be considered to produce reliable financial and business plans.

[60] As discussed in the public workshop on innovative financing for energy efficiency and renewables, PWIF, 28 April 2015, Brussels. Executive Agency for SMEs.

[61] Strelnikova, L. European Energy Efficiency Fund, PWIF, Session subject: How to improve the bankability of investments in energy efficiency and renewables?

In fact, the confidence in a win-win perspective can drive stakeholders to work together to find common solutions, thus producing a structured, long-term financing scheme for deep renovation that will be beneficial to market actors (in terms of profit of investments), policy makers, and occupants (in terms of environmental/social benefits). In general, many scenarios can be modeled and combined in the energy renovation of existing buildings and the volumetric additions may assume different configurations, depending on building type, structural conditions, and urban capacity.

The cost-benefit analysis developed in this project demonstrates that the hypothetical cost of additions can be counterbalanced by the increased real estate value of the building on top of reduced energy losses and increased energy savings. Thus, this strategy may generate a self-sufficient business model whose high potential to deliver long-term financing for energy efficiency is undeniable.

3.1.5 Potential Constraints of Add-ons and Urban Densification toward nZEBs

Nonetheless, potential constraints may limit the application of these hypotheses to the wider contexts of the existing built environments. This is due to many shortages.

First (1), we are perfectly aware that major legal obstacles exist in relation to add-ons or assistant buildings. They are notably linked to property rights, tenancy, and condominium law as well as local and urban planning rules. For example, the creation of extra units on the roof of a multi-apartment building needs to overcome legal planning and urban rules at the local level, such as condominium decision-making rules and tenancy contractual arrangements. On top of that, and maybe even more importantly, the question of ownership of the added volume needs to be solved,[62]

Second, (2) there is a lack of confidence about the technical feasibility of add-ons,[63] notwithstanding the fact that additions may assume

[62] In a wider context with respect to the examples reported in this book, we should consider that Add-ons might be also grouped in an additional building, the Assistant Building, which can be built next to the existing to financially support the renovation investment and reduce the payback time.

[63] In the meetings with the inhabitants of Peristeri this aspect has dramatically emerged. But, this is also due to the fact that so far, in the majority of cases, additions have been realized on the top roof of existing buildings; here, the risk of exceeding the load bearing of these buildings, which were not conceived for these additional volumes, is especially thorny, especially in seismic areas. Owners and tenants of highly seismic urban areas like Athens, appeared to be very concerned and anxious about safety requirements.

different configurations, depending on the building type, structural conditions, and urban capacity (a side or facade addition [add-ons], or entire new buildings in the form of assistant buildings). Conversely, as shown in the Peristeri case study, the same additions can be conceived with support structures, which allow additions to be used for the purpose of improving the mechanical, static, and seismic performance of existing structures, providing an additional element of construction quality and durability.[64] Furthermore, (3) current regulatory environments often do not permit these kinds of interventions. However, in some countries both public-private ad hoc agreements and legislative rules have been introduced,[65] thus showing a public sector effort/demand in the search for ways to incentivize the private market uptake of major renovation.[66] Finally, (4) there is a lack of understanding on the balance of the costs and financial benefits of these measures by potential investors and financing institutes; so far, no or little attention has been paid to: the great benefits and effects of the additions in the payback time for a potential ESCO; the possibility of creating a risk fund with the real estate surplus generated by the addition of new buildings; the potential for increasing the bankability by standardizing financial schemes based on volumetric addition and urban densification.

To sum up, there is a general lack of dialog among stakeholders about the possible implementations of this strategy. Further policy actions are thus necessary in order to drive the process of innovation in the construction and real estate sectors by improving the strategy of major renovation through densification and creating a new and attractive market in the deep renovation of existing buildings toward nZEBs.

[64] Structural and safety evaluation will be carried to demonstrate the potential positive impact of the add-ons to the existing structures, since if properly anchored, the additional structure could even provide existing buildings with extra resistance to horizontal stresses, typical of the seismic events.

[65] Public-private ad-hoc agreements have been set for various retrofitting interventions in social housing, like volumetric compensation adopted from Van Shagen in Amsterdam and Kolpa Architecten in Rotterdam. From the legislative point of view, that is, Italy has approved the Law Decree n. 47, 28/03/14 converted in Law n. 80, 23/05/14, the "Piano Casa" which, *inter alia*, sets out measures to give extra volume benefit in deep energy renovation interventions of existent buildings.

[66] At the urban and city district level, an urban policy based on the punctual densification has to provide a correspondent implementation of existing infrastructure like system plants, streets, parking number, and services to compensate the increase in number of population number of inhabitants.

3.1.6 Conclusions and Recommendations

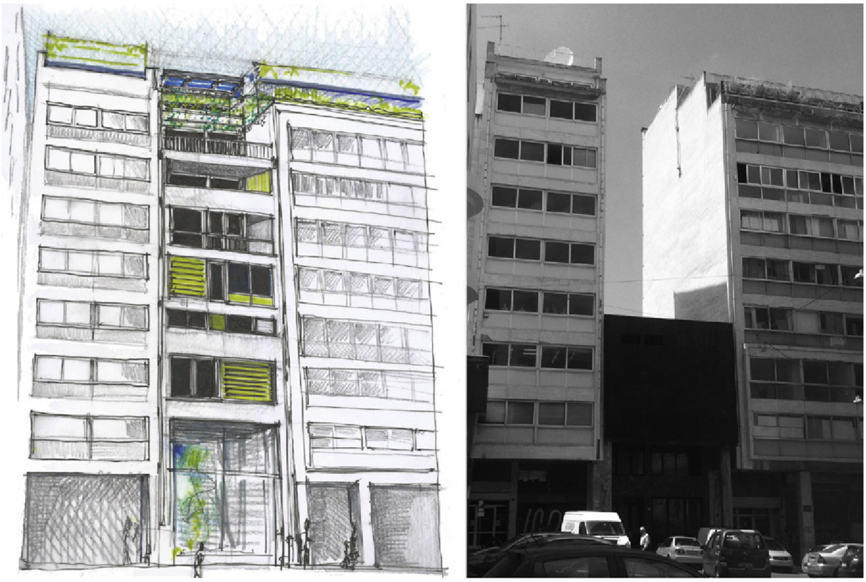
The envisaged actions to achieve nearly zero urban settings focused on the following main benefit: the generation of a substantial increase in the real estate value of the buildings through significant energy and architectural transformation (mainly integration of renewable energy sources with new volume additions or new building construction) to go beyond the minimum energy performance and aim at achieving nZEBs.

The strategy may result in an important reduction of the payback time of the interventions, a strengthening of the key investors' confidence, a higher quality and attractiveness of existing buildings and, finally, concrete market acceleration toward energy efficient buildings and nZEBs.

Thus, the comprehensive renovation process presented here, while bringing the existing buildings and urban settings to nearly zero energy, can be linked to the economic, financial, environmental, and social cobenefits of deep renovations, taking into account the payback time and net present value of investments. The strategy presented combines different domains, especially "the creation of new buildings" for the renovation of old ones, providing the economical circle with trust and bankability and ensuring a return of the investment.

The replicable nature of this punctual densification and the important impact on the mobility and the social benefits that could come from the add-on densification strategy demonstrate that this path could be effective toward the major renovation of our cities up to nearly zero energy; furthermore, it could represent a step forward in defining a new paradigm of sustainability and a new role for architecture design and planning. In particular, as illustrated in the beginning of Chapter 2, the possibility of applying punctual densifications appears to be feasible in the different urban contexts of the metropolitan Athens area, due to the peculiar urban gaps derived form the process of substitution and transformation of buildings involving the historical and central parts of the city.[67]

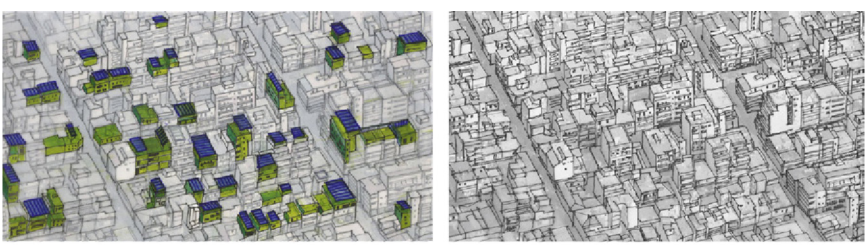
[67] As illustrated, a consistent suburban character is diffusely present in the overall context of the city, embracing the central and peripheral areas as well. Athens cityscape reveals a contradictory, dense and disordered but fascinating structure as a whole. Here, the dramatic city scene seems to define a sort of a conflicting relationship with respect to the historical time: buildings of the 1970s and 1980s overlap the historical urban path, contrasting the old, residual, often abandoned, but still lasting, historical houses of the last century and afar, marking the urban landscape by consecutive shocks and discontinuities. This character is the result of the dramatic grow sped up in the 1980s in the central areas of the cities, destroying and substituting many historical buildings while continuing its spreading at the periphery.



(a) (b)

Figure 3.27 Possible infill option in the center of Athens (a) Existing situation (b).

In Fig. 3.27, the envisaged scenario has left a significant part of the ground floor unbuilt in order to ensure ventilation between the internal urban courtyards and the open public spaces and streets. It is important to note that this contradicts the current rules in the urban regulatory framework for Athens, which suggests avoiding pilotis, considered undesirable for social and health reasons. Nonetheless, a limited use of this architectural solution for densification in dense urban areas could be considered, in the effort to compensate any new construction with the maximum amount of climatic and environmental benefits achievable (Fig. 3.28).



(a) (b)

Figure 3.28 Possible filling and densification at the urban scale in Athens (a) Existing situation Scenario (b).

To expand nZEB practices within the existing built environments, we should work to provide the key market actors with rehabilitation techniques and decision-making tools based on the potential of add-ons, assistant buildings and, in general, densification for promoting major energy renovation. It is also necessary to identify the key enabling conditions to finance deep renovation of buildings through process and organization innovation, capitalizing on the local knowledge. Moreover, at the public level, actions should be promoted to support policies for facilitating the implementation of major renovation strategies through the application of add-ons, assistant buildings, or urban densification. For example, the core elements of binding contracts in a public-private agreement could be represented by such a densification strategy; it should be seen as the delivered bonus in the case of nZEB achievements and environmental compensating actions (as, eg, infrastructural urban adjustments, increasing of permeable surfaces, waste water recycling, etc.). Thus, the nZEB target as the best means of reducing energy consumption should be the threshold target for owners, landlords, and private investors to generate and guarantee a lower-risk and more stable investment climate for public bodies, while promoting a long-term investor confidence market in private sectors and social actions.[68]

To widen the potential actions as designed, it would be necessary to act on norms, since it is through them that the public sphere rules over the private one. Hence, the problem is to neutralize, or, at least, to reduce, the risks in the mutual actions between individuals and organized communities

[68] In this perspective, the designed strategy can help the support of the implementation of European directives to remove regulatory and nonregulatory barriers to energy efficiency, without prejudice to the basic principles of the property and tenancy law of the Member States, in particular as regards: (1) the split of incentives between the owner and the tenant of a building or among owners, with a view to ensure that these parties are not deterred from making energy-efficient investments that they would otherwise have made by the fact that they will not individually obtain the full benefits; (2) costs and benefits sharing between owners/tenants, including national rules and measures regulating decision-making processes in multi-owner properties. At the strategic urban planning level, the strategy here proposed may contribute to implement ambitious, widespread and up-scaled deep energy renovation programs shifting by current public sources of finance toward greater levels of private sector finance provision (EU EED -2012/27/EU- 2013). Contribute to the EU effort toward 'Smart Financing for Smart Buildings' and the related Initiative to be launched by the EC together with the Review of the EPBD in order to make existing buildings more energy-efficient, facilitating the access to existing funding instruments. COM (2015), Communication on a Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, COM (2015) 80 Final, http://ec.europa.eu/priorities/energy-union/docs/energyunion_en.pdf.

toward the adoption of actions to achieve ZEUS. Critical appraisal and comparisons apply to any field of community life, provided it is ruled by norms. One might wonder whether town planning should be considered as a standard for comparison. This also refers to the public behavior, in various countries, in terms of compatibility with the system (environment, market, property, flexibility, etc.). The main public rules, generally applicable throughout the European national territories, define the general principles of the protection of spaces. Every new construction or territorial intervention must conform to those rules that frame the local and special urban regulations.[69]

In the context of possible retrofitting measures to be undertaken toward nearly zero energy environments, the intermediate urban scale (the scale of the real urban settings illustrated), public-private agreements managed at local and municipal levels have to be considered as the first procedural step toward the feasibility of energy-saving and bio-climatic urban design toward nZEBs and ZEUS. Thus, the context of concerted actions and synergies between public and private sectors, including potential sectors of private finance and investors, appears to be the framework that best promotes ZEUS. The presence of a plurality of public-private synergy in the formulation of the central urban laws in many European countries still represents a quite new or innovative formula inside the current tools or instruments provided by urban legislation. The importance of involving citizens (or associations of private bodies that deputize citizens), stakeholders, and private investors is evident in order to define possible medium- or long-term actions that will ensure the feasibility of hypothesized energy-conscious scenarios in the framework of current planning processes and existing legislative issues. The involvement of legislative authorities, private bodies and urban planners in climatic issues is effective in ways that even the best educational projects cannot be.

Concerted management zone plans may be applied to specific sectors or urban areas, and to urban development or restoration at intermediate-scale

[69] The operational urban development uses statutory rules to frame an urban sector-related operation. The possible actions at urban scales are generally case-by case design assuming a series of norms and legislative issues from the national, regional and municipal level. They are subjected to special rules whose decision is mainly public (municipality), with a large set of various and different private involvement all over cities. These operational urban plans represent an opened, flexible and operational framework for a specific urban area. Public communities can act inside them to proceed to the layout and the realization of equipped built or non built areas in the framework of the whole urban plan.

planning decision processes. In many European countries, the urban plan at the intermediate scale leads to the production of very precise plan documents that greatly influence the volumetric features of designed buildings, the designation of spaces, and the main characteristics of the design of public spaces. The layout of this urban tool integrates the third dimension much more than in the other urban tool plans. To deal with urban planning, we have to consider the main urban parameters of the urban built zone[70] on the relevant parameters for urban green zones[71] and consider them in an intercalary dimension, starting from the intermediate urban scale. However, these steps must verify the compatibility with planning processes designed at a larger scale and/or by wider public levels. The additions and densifications as designed in our examples might be not applied or could not be desirable because of other social, political, and economic factors influencing an existing community. We are perfectly aware that the designed scenario cannot solve the problems of market uptake and the social engagement toward ZEUS.

Nonetheless, in the assumption of world population and urban concentration increase as introduced in the first chapter,[72] calibrated, distributed, and locally-based interventions based on densification and add-ons toward

[70] These parameters can be: building density: ratio of the surface building relative to the surface of the urban area considered (impact on porosity, roughness, shading); building continuity: appreciate the buildings arrangement such as isolated buildings, buildings arranges in raw, cluster of buildings (impact on air porosity and roughness); building height: mean height of the buildings (roughness); mineral/vegetal ratio: of the use land (evaporation, filtration, thermal inertia); ground porosity (may be complementary to the precedent); types of buildings and soils (material, heavy, light structure); impact of inertia; colors (of pavement and buildings materials, roofs, walls), impact on reflection; structure and forms of urban spaces (street, courtyards, squares, rectangular grid, predominant exposure); ratio between building height and the relative distance with other buildings or the openness degree to appreciate the openness of public spaces (sky factor); impact on reflective and radiative load; water presence; kind of vegetation; surroundings characteristics (urban, suburbs, rural, park, river, lake).

[71] The relevant parameters for urban green zone can be identified as follows: height of the vegetation, tree density, ratio deciduous/permanent trees; surface, water presence and water required by vegetation; kind and type of vegetation; and the like. As far as it regards the different parameters involved we will mention the following ones: building density, building continuity, building height, mineral/vegetal ratio, type of space, solar orientation, exposure to wind, color, albedo, pavement characteristic, buildings volumetric shape. The typological factors involved in the design interfere with energy, indoor and outdoor comfort, and urban micro-climatic situation in term of porosity, roughness, shading effect.

[72] The percentage of human beings living in cities has increased from 3% in 1800 to 14% in 1900 and is estimated to rise from the current 50–75% in 2050. The figure for Europe is still higher: 83% of the population is expected to live in cities by 2050 (EU Report, 2010).

nearly ZEUS present the a lot of potential for a two-fold benefit. In fact, urban densification schemes may signify a process limiting the negative effects of urban sprawl at the territorial scale while achieving a full-scale energy savings strategy. As shown in the Peristeri case, densification in urban contexts, when combined with a re-organization of open spaces, may even result in the increase of permeable and green surfaces; in this framework, the concept of add-ons or new assistant buildings may even open the way for "adopting" existing buildings in areas where no free space is available, for example, in the historical centers. Thus, we might even envisage a scale-up in this process[73] and hypothesize the exchange of "urban quotes" among different areas of the city, where the centers may be "adopted" by new, renovated, nearly zero energy – or even energy plus – urban peripheries. Thus, starting from the specific limits encountered in the local RUEs, we may utilize the compensative measures given by the possible densification to search for a balance between global costs connected by the initial energy demand and the related retrofitting options to achieve ZEUS (Fig. 3.29).

It is well known that public administrations are called upon optimize energy measures to go well beyond the mere reduction of energy consumption (EU-20-20-20 targets) and achieve the smartest management of energy. In this framework, both historical buildings and urban centers (see point 1, following) and the buildings in peripheral and marginal areas (see point 2, following) should be addressed to optimize the energy management in the whole context of a city. But (1) in historical buildings, energy demand

[73] It is worth mentioning that energy retrofitting interventions like the ones here presented may be assumed as the punctual nodes of a longer term replanning; in fact, small-scale interventions should be seen as key nodes to promote local involvement, rebuild local identity, arouse urban interest and raise human consciousness (energy consumption awareness, cultural and market exchanges, etc.). Further opportunity on research should focus on the feasibility of a system network re-reconnecting the different urban areas, that is testing the potential of the smart areas to generate other smart areas, thus creating a potential network in the city as a whole. This reconnection would be strategic for the construction of urban greenways connecting function also as a catalyst in urban fruition. To do this a large set of possible inconsistencies have to be addressed: new mobility schemes, parking areas creation, enhanced comprehension on the influence on human behavior by spatial layout of buildings and urban places, and so forth. In particular, it is important to understand the possible strategies to foster the creation of local urban communities, involving them in an evidence-based approach to the spatial layouts aiming at producing more safe and vibrant places for social, economic and environmental capital (since poor layouts risk functional failure, loss of investment and social harm). Thus it is necessary to combine social, safety and energy issues, integrating technical and architectural feasibility of zero energy and low carbon areas with the creation of new built environments associated with new forms of urban communities.

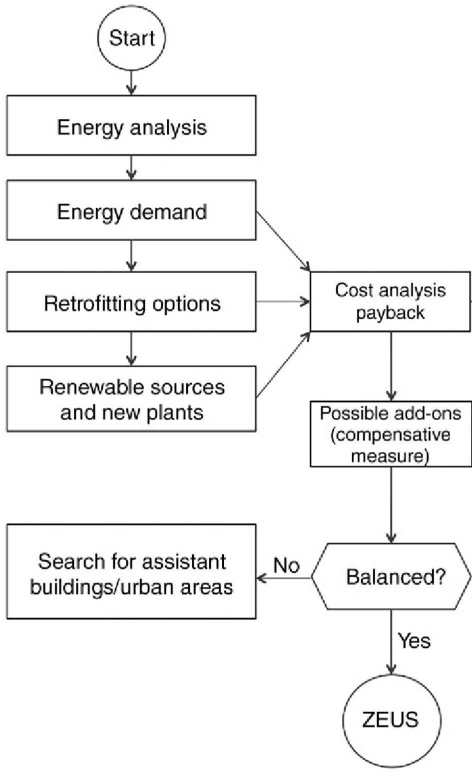


Figure 3.29 ***Proposed procedure for the zero energy urban setting (ZEUS) adoption.***

represents a particular challenge. Here energy-saving solutions via renovation cannot be easily implemented, because historical infrastructures are often connected with and limited by the necessity of preserving authenticity and integrity; thus, they lack a systemic and effective impulse for energy retrofitting.[74] Conversely, (2) major renovation in peripheral areas might

[74] Energy solutions in the field of renovation are not compatible with or adequately adapted for use in historic buildings. In this perspective, a deep renovation of historic buildings appears to be far to be reached by means of mere physical or material processes. Coherently with such constrains, to approach and effectively contribute to solve the problem to reduce the energy consumption and energy costs associated to historical building maintenance and management. Retrofitting actions in these buildings should be based on the human in its relation with the built environment, rather than on usual physical building components (envelope, windows, plants); thus concentrating on the users behavior to reduce temporal and spatial energy consumption both in terms of the period (the time) the users inhabit the building spaces, and in terms of the space dimension (space) they need; the latter is particularly crucial, considering high volumes and surfaces of many historic buildings, often oversized compared to the modern use and habits.

be conceived in a way that can integrate energy requirements and policy measures with the economic and social increase in housing quality by non-energy-related factors, which would contribute to the acceleration of major renovation toward ZEUS. The major challenge of tomorrow's agenda could be the successful integration and combination of issues (1) and (2) into an energy-efficient, holistic strategy for the city of the future, where its outer parts might be conceived to act as the energy suppliers of the historic city core.

Thus, by using the results that have emerged in this work, combined with these final considerations, a first record of proposed steps for policy, legislation, education, and building practices may be outlined. As far as it concerns policy, a carbon zero and zero energy strategy plan, with particular reference to Mediterranean climate, should be oriented at:

- Providing and reinforcing specific target strategies for open areas and public spaces within the urban environment, to promote the use of green and permeable surfaces, thus reducing urban cooling demand at the territorial and urban scale. In this frame, it is most important to promote all forms of passive natural devices according to the potential effects on minimizing the localized pollution problems and to enhance urban microclimate, such as: ensuring pollutant absorption by plants and dispersion by natural ventilation and cooling; improving natural cooling; minimizing solar heat gains both in the open spaces and on the building's facades (allowing protection for southeast and southwest facades by means of shading device systems and natural filters, etc.).
- Incentivizing the use of the most effective and cost-efficient technology mix in relation to local environments and specific sites, considering that passive design features are always cheaper and cost-efficient with respect to active systems. The feasible technology mix should be different according to the type of building, the climate zone, the national energy prices, the availability of know-how and technologies, and cultural and social attitudes.
- Raising capacity at the public level for the adoption of legislative and practicable measures aimed at the deep renovation of existing public buildings up to nearly zero energy buildings in the peripheral or modern areas.
- Setting up special incentives (tax reduction, volumetric building compensation, add-ons, and densification of urban peripheries) to reach fully distributed interventions of zero energy retrofitting of existing buildings with special reference to urban areas, thus achieving win-win

perspectives in relation to urban densification schemes (against urban sprawl) and full-scale energy-saving strategies. This must be combined with a set of specific benchmarks to guarantee the access to the set benefits and incentives. Public bodies should design and request specific measures to be achieved by private owners, landlords, or home managers, with particular reference for the access to the possibility of addition. For example, these can be compulsory measures, binding contracts, required obligations, and the like, set to guarantee the quality and the nearly zero energy target, up to specific technical requirements – example, the respect for cross ventilation between urban zones (see Fig. 3.27), the respect of public network infrastructure, the creation of green surfaces, and limits to increasing impermeable surfaces, and so forth.

- Designing specific public-private agreement tools for the redesign of urban open areas, to assure environmental compensation of densification policies, while providing new layouts of streets and squares to make them more pleasant, accessible, and secure for pedestrians (with specific urban furniture, new pavements, vegetation, and outdoor or covered passages). In general, specific benchmarks and design tools should be provided, and effort should be made to compensate any new construction by achieving the maximum amount of climatic and environmental benefits associable within it and in relation to its boundary conditions.

Thus, as far as it concerns education, care and interest should be focused on:

- Designing education and training aimed at improving the adaptability of buildings, especially within the context of the historical Mediterranean regions, to provide flexibility, adaptability, thermal comfort, and up to nearly zero energy consumption both in the summer and winter seasons.
- Training activities for stakeholders, private owners, and citizens (also within the framework of participative processes) to provide information on the potential of consumers' behavior to reduce cooling demand and save energy. In fact, the minimizing energy use for heating and cooling the buildings could be encouraged by the education of occupants (smart behavior) in addition to the use of free-of cost strategies by intelligent design (using passive architectural strategies).[75]

[75] As for example, training and information on dress behavior and its potential in relation to energy consumption reduction should be encouraged and/or reinforced, since seasonal flexibility in clothing may have huge consequences for energy saving in buildings.

- Training activities and information should also be disseminated to future generations of designers, architects, and engineers to motivate them to embrace the subject of ZEUS. In fact, future designers' attention should shift from fascinating, monumental, and over-imposed actions of new or innovative zero-energy architecture, and instead should stress the importance of dealing with small interventions in the existing environment, showcasing this opportunity as a creative challenge for tomorrow's agenda.

The envisaged actions toward achieving nearly zero urban settings focused on the following main benefit: the generation of a substantial increase of the existing value of the current buildings through significant energy and architectural transformation, in order to go beyond the minimum energy performance and aim at achieving ZEUS. In the search for transitional pathways toward a low-carbon future, in place of large or incremental development plans, we may envision a series of limited, but challenging, nearly zero energy urban settings, which can be conceived as the punctual nodes of a long term re-planning, as they have the potential to generate a new identity for the city as a whole. While on this path, should not refer to the concept of energy performance only in a mechanistic manner.[76] We should rather observe that when the idea of performance is translated into architecture, optimization is embodied by:

- Energy, technical, and constructive efficiency
- Economic and social feasibility
- Multi-functionality
- Aesthetics

These four elements provide added value due to the complex and interconnected system in which the overall worth is grander than the sum of its parts. Following the definition of efficiency as the ratio of the useful energy delivered by a dynamic system to the energy supplied to it, a building could be seen as a system designed to perform in the most efficient way possible. And of course, the most efficient way to perform is the one that

[76] In fact, the notion of performance is normally associated to mechanical elements like engines, and is understood as the manner in which a system reacts to environmental stimuli. A performance analysis can be carried for any object, space, or machinery that has been designed to a specific function. In order to obtain the best performance from a system, it is necessary to provide changes that can make it as functional and effective as possible by minimizing the losses and maximizing results, which is at the base of optimization in mechanics. A system is just a group of interacting units establishing a much more complex and integrated altogether. Given this, a city, a building, an office and even a piece of street furniture can be considered as a system.

can minimize losses and optimize the space required to accomplish the tasks set at the beginning of the design process. An efficient system should also be durable and should require the least maintenance possible; this means that an efficient building also provides economic savings in the long run, when compared to a nonefficient structure.

Incorporating more functions within the same space can be a challenge for designers, but it embodies a variety of positive aspects. In fact, the combination of functions often improves density levels by attracting more people in the same space, preventing neighborhoods from only being used and lived in partially during the day (ie, financial districts versus "dormitory neighborhoods"). The space is filled with new and vibrant energy and is "technically" more efficient and attractive. So much has been written about aesthetics, but we believe that it has always been hard to find a universal definition of it. While other features in a building, such as efficiency and functionality, seem to be more relatable to a general and understandable definition, aesthetics is a very difficult aspect of architecture in all its expressions. So, what makes a building/structure aesthetically appealing? A city, a building, a room, a house, a street is beautiful if it functions properly, if urban dwellers actually use it, if it relates in any way to the built environment in which it resides, and if it creates vitality and identity at the street level or, more in generally, in the city landscape.

Beauty is such a subjective notion, that it is probably not even worth talking about it, but, in the end, we are always attracted to it, by the way order and disorder may combine with each other and generate a vibration. Beauty feeds us, human observers, urban dwellers, and users alike, with peaceful feelings, while at the same time it instills curiosity. Filling the built environments with equality while respecting individuality, in a shared, but animated and exciting vision of the future city, whether in the Mediterranean or elsewhere, is a noble pursuit (Fig. 3.30).

> *Our hope is that (…) we can shift to a culture of sustainability – economic, social and environmental – and that the motto (…) "Better city, better life" can become a reality for the next generation (Baer, EU Report World and European Sustainable Cities, 2010).*

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Figure 3.30 ***Zero energy urban setting (ZEUS) through densification in Peristeri.***

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APPENDIX

Tables reporting the main thermal properties of the ground floor layers, the roofs, and the glazing components, estimated for each study in the as-built scenario.

Aghia Varvara

Table A1 Main thermal properties of the ground floor layers

Ground floor (U = 4.762 W/m² K)						
Layers	**Materials**			**Properties**		
External layer	Gravel	mm	170	Convective heat transfer coefficient	W/m²K	44.87
				Radiative heat transfer coefficient	W/m²K	5.13
				Surface resistance	m²K/W	0.02
Layer 2	Screed	mm	160			
Layer 3	Reinforced concrete	mm	300			
Layer 4	Screed	mm	80			
Internal layer	Ceramic/marble/tiles	mm	20	Convective heat transfer coefficient	W/m²K	0.342
				Radiative heat transfer coefficient	W/m²K	5.54
				Surface resistance	m²K/W	0.17

Table A2 Main thermal properties of the roof layers' components

Flat roof (U = 1.795 W/m² K)						
Layers	**Materials**			**Properties**		
External layer	Concrete tiles (roof)	mm	20	Convective heat transfer coefficient	W/m²K	44.87
				Radiative heat transfer coefficient	W/m²K	5.13
				Surface resistance	m²K/W	0.02
Layer 2	Screed	mm	80			
Layer 3	EPDM (waterproofing)	mm	20			
Layer 4	Concrete slab	mm	250			

(*Continued*)

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Table A2 Main thermal properties of the roof layers' components (*cont.*)

Flat roof (U = 1.795 W/m² K)

Layers	Materials			Properties		
Internal layer	Plaster (lightweight)	mm	15	Convective heat transfer coefficient	W/m^2K	4.46
				Radiative heat transfer coefficient	W/m^2K	5.54
				Surface resistance	m^2K/W	0.1

Table A3 Main thermal properties of the intermediate floor layers

Intermediate floor (U = 1.327 W/m² K)

Layers	Materials			Properties		
External layer	Ceramic/ porcelain tiles	mm	20	Convective heat transfer coefficient	W/m^2K	44.87
				Radiative heat transfer coefficient	W/m^2K	5.13
				Surface resistance	m^2K/W	0.02
Layer 2	Screed	mm	80			
Layer 3	Concrete slab	mm	180			
Internal layer	Plaster (light)	mm	15	Convective heat transfer coefficient	W/m^2K	4.46
				Radiative heat transfer coefficient	W/m^2K	5.54
				Surface resistance	m^2K/W	0.11

Table A4 Main thermal properties of the building's vertical external components

External wall (U = 1.183 W/m² K)

Layers	Materials			Properties		
External layer	Plaster (dense)	mm	20	Convective heat transfer coefficient	W/m^2K	44.87
				Radiative heat transfer coefficient	W/m^2K	5.13
				Surface resistance	m^2K/W	0.02
Layer 2	Blocks	mm	220			
Internal layer	Plaster (lightweight)	mm	15	Convective heat transfer coefficient	W/m^2K	2.15
				Radiative heat transfer coefficient	W/m^2K	5.54
				Surface resistance	m^2K/W	0.13

Stratigraphic description of the building envelopes' components. Main components in the as built scenario in Evripidou.

Table A5 Resistance and U-value for the existing building envelope

Type	Exterior walls		
Description	Brick wall		
	Inner surface resistance	m^2K/W	0.130
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	1.493

Layers:

Table A6 Thermo-physical properties for each component layer in the existing building envelope

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kg K)	Density (kg/m^3)	Resistance (m^2K/W)
Mortar	1.00	0.5		1000	1300	0.02
Hollow brick	28.00		2.174	800	1700	0.46
Mortar	1.00	0.5		1000	1300	0.02
Total	30.00					0.50

Table A7 Resistance and U-value for the existing internal walls

Typet	Internal walls		
Description	Internal partition		
	Inner surface resistance	m^2K/W	0.130
	External surface resistance	m^2K/W	0.130
	U-Value	W/m^2K	1.786

Layers:

Table A8 Thermo-physical properties for each component layer in the existing internal walls

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kg K)	Density (kg/m^3)	Resistance (m^2K/W)
Mortar	1.50	0.5		1000	1300	0.03
Hollow brick	12.00		4.167	800	1700	0.24
Mortar	1.50	0.5		1000	1300	0.03
Total	15.00					0.30

Table A9 Resistance and U-value for the existing ground floor

Type	Ground floor		
Description	Brick walls		
	Inner surface resistance	m^2K/W	0.170
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	1.559

Layers:

Table A10 Thermo-physical properties for each component layer in the existing ground floors

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kg K)	Density (kg/m^3)	Resistance (m^2K/W)
Tiles	2	1.30		840	2300	0.015
Screed	7	1.06		840	1200	0.066
Reinforced concrete	20	2.3		1000	2300	0.087
Oversite concrete	10	0.38		1000	1200	0.263
Total	39					0.432

Table A11 Resistance and U-value for the existing internal floors

Type	Internal floor		
Description	Brick walls		
	Inner surface resistance	m^2K/W	0.130
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	1.402

Layers:

Table A12 Thermo-physical properties for each component layer in the existing internal floors

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kg K)	Density (kg/m^3)	Resistance (m^2K/W)
Tiles	2	1.3		840	2300	0.015
Screed	4	1.06		1000	2500	0.038
Hollow brick	20		2.128	800	1700	0.47
Mortar	1	0.5		1000	1300	0.02
Total	27					0.543

Table A13 Resistance and U-value for the existing roof floors

Type	Roof floors		
Description	Roof floor		
	Inner surface resistance	m^2K/W	0.100
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	1.511

Layers:

Table A14 Thermo-physical properties for each component layer in the existing roof floors

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kgK)	Density (kg/m^3)	Resistance (m^2K/W)
Asphalt	1	0.7		1000	2100	0.014
Reinforced concrete	4	2.3		1000	2500	0.017
Hollow brick	20		2.128	800	1700	0.47
Mortar	1	0.5		1000	1300	0.010
Total	26					0.522

Stratigraphic description of the building envelopes' components. Designed scenarios in the three case studies:

Table A15 Resistance and U-value for the designed exterior walls

Type	Exterior walls		
Description	Exterior wall with AAC		
	Inner surface resistance	m^2K/W	0.130
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	0.492

Layers:

Table A16 Thermo-physical properties for each component layer in the designed exterior walls

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kgK)	Density (kg/m^3)	Resistance (m^2K/W)
Mortar	1.00	0.500		1000	1300	0.02
Hollow brick	28.00		2.174	800	1700	0.46
Mortar	1.00	0.500		1000	1300	0.02

(*Continued*)

Table A16 Thermo-physical properties for each component layer in the designed exterior walls (*cont.*)

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m²K)	Specific heat (J/kgK)	Density (kg/m³)	Resistance (m²K/W)
Gypsum mortar for plastering	1.00	0.180		1000	600	0.056
Autoclaved areated concrete	10.00	0.190		1300	115	1.250
Gypsum mortar for plastering	1.00	0.180		1000	600	0.056
Total	42.00					1.861

Table A17 Resistance and U-value for the designed exterior walls (insulation with polyurethane)

Type	Exterior walls		
Description	Exterior wall with polyurethane		
	Inner surface resistance	m²K/W	0.130
	External surface resistance	m²K/W	0.040
	U-Value	W/m²K	0.219

Layers:

Table A18 Thermo-physical properties for each component layer in the designed exterior walls (insulation with polyurethane)

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m²K)	Specific heat (J/kg K)	Density (kg/m³)	Resistance (m²K/W)
Mortar	1.00	0.500		1000	1300	0.02
Hollow brick	28.00		2.174	800	1700	0.46
Mortar	1.00	0.500		1000	1300	0.02
Polyurethane	10.00	0.026		1590	35	3.846
Gypsum mortar for plastering	1.00	0.180		1000	600	0.05
Total	41.00					4.402

Table A19 Resistance and U-value for the designed roof floors (insulation with AAC)

Type	Roof floors		
Description	Roof floor with AAC		
	Inner surface resistance	m^2K/W	0.100
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	0.494

Layers:

Table A20 Thermo-physical properties for each component layer in the designed roof floors (insulation with AAC)

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kgK)	Density (kg/m^3)	Resistance (m^2K/W)
Sand and gravel	4.00	2.000		650	2100	0.020
Nonwoven fabric	0.10	0.190		1200	1400	0.005
Autoclaved aerated concrete	10.00	0.080		1300	115	1.250
Sheet of bitumen	0.20	0.23		1000	1100	0.01
Gypsum mortar for plastering	1.00	0.180		1000	600	0.05
Screed	4.00	1.060		896	2800	0.038
Reinforced concrete	4.00	2.3		1000	2500	0.017
Hollow brick	20.00		2.128	800	1700	0.47
Mortar	1.00	0.5		1000	1300	0.02
Total	44.30					1.885

Table A21 Resistance and U-value for the designed roof floors (insulation with polyurethane)

Type	Roof floors		
Description	Roof floor with polyurethane		
	Inner surface resistance	m^2K/W	0.100
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	0.216

Layers:

Table A22 Thermo-physical properties for each component layer in the designed roof floors (insulation with polyurethane)

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kgK)	Density (kg/m^3)	Resistance (m^2K/W)
Sand and gravel	4.00	2.000		650	2100	0.020
Nonwoven fabric	0.10	0.190		1200	1400	0.05
Polyurethane	10.00	0.026		1590	35	3.85
Sheet of bitumen	0.20	0.23		1000	1100	0.01
Gypsum mortar for plastering	1.00	0.180		1000	600	0.05
Screed	4.00	1.060		896	2800	0.05
Reinforced concrete	4.00	2.3		1000	2500	0.017
Hollow brick	20.00		2.128	800	1700	0.47
Mortar	1.00	0.5		1000	1300	0.02
Total	44.00					4.481

Table A23 Resistance and U-value for the designed green roof (insulated with AAC)

Type	Roof floors		
Description	Green roof floor with AAC		
	Inner surface resistance	m^2K/W	0.100
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	0.456

Layers:

Table A24 Thermo-physical properties for each component layer in the designed green roof (insulation with AAC)

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kgK)	Density (kg/m^3)	Resistance (m^2K/W)
Topsoil	4.00	1.50		1550	2000	0.027
Gravel	8.00	1.20		650	2100	0.06
Oversite concrete	4	1.06		840	1200	0.038
Nonwoven fabric	0.10	0.190		1200	1400	0.005
Gypsum mortar for plastering	1.00	0.180		1000	600	0.05
Autoclaved areated concrete	10.00	0.080		1300	115	1.250
Sheet of bitumen	0.20	0.23		1000	1100	0.01
Gypsum mortar for plastering	1.00	0.180		1000	600	0.05
Screed	4.00	1.060		896	2800	0.039
Reinforced concrete	4.00	2.3		1000	2500	0.017
Hollow brick	20.00		2.128	800	1700	0.24
Mortar	1.00	0.5		1000	1300	0.02
Total	56.00					2.051

Table A25 Resistance and U-value for the designed green roof (insulated with polyurethane)

Type	Roof floors		
Description	Green roof floor with polyurethane		
	Inner surface resistance	m^2K/W	0.100
	External surface resistance	m^2K/W	0.040
	U-Value	W/m^2K	0.209

Layers:

Table A26 Thermo-physical properties for each component layer in the designed green roof (insulation with polyurethane)

Material	Thickness (cm)	Conducibility (W/mK)	Conduttance (W/m^2K)	Specific heat (J/kgK)	Density (kg/m^3)	Resistance (m^2K/W)
Topsoil	4.00	1.50		1550	2000	0.027
Gravel	8.00	1.20		650	2100	0.067
Oversite concrete	4	1.206		840	1200	0.038
Nonwoven fabric	0.10	0.190		1200	1400	0.005
Gypsum mortar for plastering	1.00	0.180		1000	600	0.056
Polyurethane	10.00	0.026		1590	35	3.85
Sheet of bitumen	0.20	0.23		1000	1100	0.009
Gypsum mortar for plastering	1.00	0.180		1000	600	0.05
Screed	4.00	1.060		896	2800	0.038
Reinforced concrete	4.00	2.3		1000	2500	0.017
Hollow brick	20.00		2.128	800	1700	0.47
Mortar	1.00	0.5		1000	1300	0.02
Total	57.30					4.647

GLOSSARY

AMA Athens metropolitan area
BAT Best available technologies
EPB Energy performance of buildings
EPBD Energy performance of buildings directive
EU European Union
EPc Energy performance index for cooling
EPh Energy performance index for heating
EE Energy efficient, energy efficiency
EC Energy consumption
ES Energy saving
GHG Green house gas
HI Heat island
HVAC Heating, ventilation air conditioning
nZEBs Nearly zero energy buildings
RES Renewable energy sources
RUEs Real urban environments
UHI Urban heat island
ZEUS Zero energy urban settings

Towards Nearly Zero Energy
http://dx.doi.org/10.1016/B978-0-08-100735-8.00005-2

SUBJECT INDEX

A

E

R

V

W

Z