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SUSTAINABLE SOCIAL HOUSING IN TEMPERATE AREAS

Italy and Brazil: the use of vegetation as a retrofit strategy

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2011-2013

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ABSTRACT_ ENGLISH

The thesis aims at identifying sustainable strategies for the retrofit of Social Housing in temperate areas, with focus on the use of vegetation for the renovation of the external spaces and for the improvement of the building envelope performance.

The research starts from the assumption that South Italy and the subtropical region of Brazil, which have similar climatic characteristics, present large urban areas marked out by residential buildings with low energy efficiency and indoor comfort levels. In this sense, the thesis investigates the issues of environmental, social and economic sustainability related to public housing and to the recovery of the existing building stock, in an attempt to offer an overview encompassing, crosswise, developed countries -and the European context, in particular- and the developing countries -specifically, Brazil-.

Starting from the analysis of several case studies related to new or retrofitted buildings, the research addresses:

- the analyses of the influence of vegetation, properly designed, on urban microclimate to enhance outdoor and indoor thermal comfort;
- the assessment of Building-Integrated Vegetation (BIV) systems used to improve the buildings energy performance.

Hence, starting from the analysis carried out on a real case of social housing in the city of Palermo, through the use of specific simulation tools (ENVI-met and EnergyPlus), the thesis identifies a methodology for the design and the assessment of the effectiveness of plants and BIV systems (vertical gardens and green roofs) used for urban and building retrofit interventions.

ABSTRACT_ ITALIAN

La tesi si pone come obiettivo l'individuazione di strategie sostenibili per il retrofit del Social Housing in aree a clima temperato, con particolare riferimento all'utilizzo della vegetazione per la riqualificazione degli spazi esterni e per l'incremento delle prestazioni dell'involucro edilizio.

La ricerca parte dall'assunto che le regioni del sud Italia e le aree subtropicali del Brasile, accomunati da caratteristiche climatiche affini, si trovano attualmente impegnati nell'identificazione di politiche e soluzioni per la riqualificazione di interi quartieri destinati all'housing sociale, responsabili di elevati consumi energetici e di inadeguate condizioni di comfort abitativo. In questo senso, la tesi indaga le problematiche di sostenibilità ambientale, sociale ed economica legate, oggi, all'edilizia residenziale pubblica e al recupero del patrimonio edilizio esistente, nel tentativo di offrire una panoramica che abbraccia, in maniera trasversale, i paesi sviluppati -e il contesto europeo in particolare- e quelli in via di sviluppo -nello specifico, il Brasile-.

Attraverso l'analisi di esempi emblematici di edifici di nuova progettazione e di interventi di riqualificazione energetica, la ricerca si indirizza, in particolare, verso:

- lo studio dell'influenza della vegetazione sul microclima urbano, al fine di aumentare il comfort termico outdoor ed indoor;
- l'individuazione di sistemi efficienti di *Building-Integrated Vegetation (BIV)* per l'incremento prestazionale degli involucri edilizi.

A partire dall'analisi condotta su un caso reale di social housing della città di Palermo, attraverso l'utilizzo di specifici strumenti di simulazione (ENVI-met ed EnergyPlus), la tesi individua una metodologia per la progettazione e la verifica dell'efficacia di interventi di retrofit urbano ed edilizio che prevedono l'utilizzo di diverse specie vegetali (alberi, arbusti, erba) e di sistemi di *BIV* (pareti e tetti verdi), ai fini della mitigazione delle temperature e l'aumento del comfort outdoor e indoor durante i mesi estivi.

INTRODUCTION

The last decade has been characterized by a growing concern on a number of environmental, social and economical issues that made the sustainable development the main challenge of our society and one of our times most deeply embedded governments commitment.

The increase of temperatures registered in the last twenty years and the unavoidable consequences due to the exacerbation of the greenhouse effect, have pushed the scientific community to demonstrate that such changes cannot only be attributed to the natural evolution of the planet[1]. The progressive intensification of extensive farming and agriculture and the related action of deforestation to convert woods in cultivated fields and grazing lands and the rampant increase of greenhouse gases emission caused by transports, industries and building construction, have demonstrated that men became the main responsible of the Earth's global warming. Together with the issues related to the use of fossil fuels, the growth of damaging effects on men health, policies for the provision of non-renewable sources and the continuous threats of energy crisis, became the background of an era where founding alternatives of environmental development is not only desirable but also necessary.

To aggravate this scenario, the global economic crisis has spread throughout a wide range of countries and regions of the Western world causing unprecedented financial and social upheavals. Many of the surveys and studies show that poverty has grown visibly and point out an alarming increase in the number of persons requesting food assistance, clothing and a place to sleep (Perlo Cohen, 2011).

On the other hand, developing countries such as Brazil, China and India are experiencing a huge economical growth while establishing governments commitments for the definition of policies aimed at a balanced social and environmental growth in an attempt to adhere the global development standards.

Following up the environmental, social and financial changes that occurred in the last decades, our cities became the mirror of the massive transformations that societies were undergone. As stated by Donzelot (2006), «...In half century, the city moved from the register of the solution to that of problems...», summarizing two essential nodes that characterized the evolution of urban areas, both in the so called developed and developing countries. Cities «...seem today exposed to contradictions...» (Fedeli, 2010): although they were (and are in the case of developing countries) built up as expression of stability and stabilization, they often disclose an increasing social polarization and fragmentation and a great inattention for some basic rights such as housing, mobility, work and health.

Urban areas, because of the diffuse cementification and use of asphalt surfaces which flatly prevail on green areas, of motor vehicles emissions, industrial plants and heating and cooling systems of buildings, have on average higher temperatures (between 0.5 and 3 °C) than the rural areas nearby, generating the phenomenon known as "heat island effect". Beside the thermal discomfort issue, cities and towns, for all these reasons, experience increasing signs of environmental stress, notably in the form of poor air quality and excessive noise. With respect to air quality, ground-level ozone and fine particulate matter are the main pollutants in terms of their health effects. High concentrations of ozone in the troposphere, typical for the summer months, lead to an increase in the frequency of respiratory symptoms, and the World Health Organisation (WHO) attributes several thousand hospital admissions and premature deaths each year to this pollution (De Ridder, 2004).

At the same time, a large amount of social and anthropological studies is nowadays focused into causal explanations and new ways of understanding the synergies of decline and growth of our cities and the contemporary urban and social dynamics that originated from the financial global crises of Europe and USA and the economic boom of the developing countries. In this scenario, hence, urban planning and architecture design are striving to reinvent the role of the cities, meant as physical and social spaces, in a perspective of long-term sustainability.

The issue of Social Housing, in particular, turns out to be completely embedded in all these aspects. The theme of housing, in fact, in the field of the local welfare became a significative example of the necessity to address emerging global goals of sustainability, in all its meanings.

The European Union, as the world's second largest producer of social housing, following China, in the field of integrated measures for sustainable urban development, has declared in several occasion and through different action tools its commitment in made social housing a policy to support economic and urban growth and to mitigate housing bubbles in the private sector and the devastating effects these have on social and macro-economic balances. Moreover, as stated by the European Economic and Social Committee (2012) "Social housing has to deal with the new climate situation and the need to improve the energy efficiency of its existing stock and new supply".

Current national and international rules on the energy regulation of the built environment and the mitigation of the urban microclimate are strongly reiterating the necessity of effective interventions for the rehabilitation of the existing buildings, which require pondered consideration in terms of environmental, social and economic sustainability. In this sense, the enhancement of Social Housing performance is not related exclusively to the need to improve energy efficiency and foster renewable energy but also to tackle exclusion of marginalised communities from access to housing and to affordable and high-quality social services. The aspects of energy and environmental sustainability, in fact, are strategic for social housing, at a global scale, because it implies a significative reduction of costs of buildings management and hence the possibility, for low-income households, to live in affordable conditions. For new construction buildings this can be relatively easy to achieve but the main challenge, in terms of design, efficiency and resources, is today represented by the retrofit of the large existing building stocks, which is expected to occupy the larger area of the construction sector in the next years representing a chance of awakening from the crisis[2.]

What originates from all these considerations is that the concept of Social Housing today cannot be simply reduced to the construction aspect since the complexity of functions that it addresses to fulfill makes it «... a programme [...] which is becoming increasingly similar to an urban project...» (Rabaiotti, 2010). Researches and experiences of building transformation have demonstrated the need for a "plural" action, able to combine multiple and different requests coming from sites and stakeholders. This implies also an increasing necessity to intervene through harmonic inter-scale actions which can move from the urban planning to the architectural design. Actually, the term "urban retrofit", which refers to the renovation of micro-urban/district scale, has been recently introduced among the scientific community to be distinguished from the "building retrofit" which indicates the upgrading of the buildings performance.

In the context of current worldwide practices, two different approaches can be individuated: "deep retrofit", which entails substantial transformation of the building (envelope performance improvement, systems upgrading, volumetric addictions, etc), and "light retrofit" which consists in more detailed and implemented actions used strategically according to different priority and lower energy standards (Losasso, 2012). And if in some cases these two way of actions reflect different strategies approaches which are however held by planned, assisted and clear environmental policies (see the case of Germany and UK), sometimes they simply highlights difficulties of economic and financial nature.

On that topic, another aspect that should not be disregarded is the importance of energy investment policies that have started to spread out worldwide for the implementation of Social Housing in order to assure the economic feasibility of interventions and promote local employment and regional economic development. The issue of "urban living" is in fact moving from "heavy" and centralized welfare policies to "light" local practices with public provision often coexisting with a growing private sector, mainly consisting of specialised nonprofit or limited-profit bodies.

Starting from these considerations, this thesis investigates on possible strategies for the recovery of the existing Social Housing complexes, able to incorporate and combine the main aspects of sustainability, with focus on the environmental issues and the improvement of thermal comfort. In this sense, the use of vegetation is examined as a possible solution for the urban and the design retrofit in order to improve the environmental conditions of communities situated in temperate areas, where surveys on sustainable systems to cool cities are acquiring significant weight, while providing other indirect benefits.

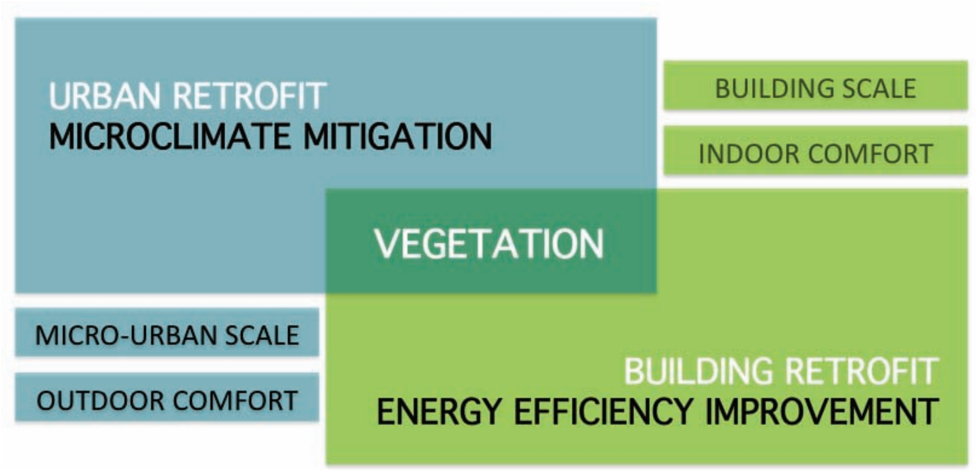

Fig. 1 - Scheme showing the use of vegetation as a strategy of retrofit (Drawing of the Author)

The research has been carried out through a dual investigation conducted for Italy (in particular South regions) and the South-East region of Brazil. The choice of moving through this parallelism arises from two main considerations. The two regions present similar geo-climatic characteristics which partially constituted the reason of their backward position of the two countries in the international panorama of sustainability applied to the construction sector. The undoubted difficulties registered in the last decade in transposing and adapting knowledge related to building energy efficiency, from cold-weather countries -such as USA or North Europe- are still reflected in a uncompleted and sometimes chaotic normative frameworks and in the slowness of application of innovative technique for existing buildings energy retrofit.

Secondly, both countries are experiencing different but substantial social and economic transformation which are having significant repercussions on the reconsideration of the theme of housing and the necessity to promote human capital, urban innovation and strategic development planning, although maintaining a realistic vision on the economic feasibility of possible interventions.

In the light of this, the research aims at evaluating which role “light” urban and design retrofit interventions, that consider green space and building-integrated vegetation (green roofs and vertical gardens) have in alleviating the adverse effects of urbanisation and enhance households life quality, focusing on the environment but also accounting for socio-economic aspects. A methodology for the design and the assessment of the adoption of plants in urban planning and architectural design is provided in conclusion.

The dissertation is divided in three parts. In the first part the issues related to energy efficiency and comfort in buildings are handled regarding global targets, local policies and normative frameworks as well as technical aspect for their achievements. Particular emphasis is given to the benefits provided by the integration of vegetation in the built environment. The second part deals with the theme of Social Housing and the main challenges encountered today, with focus on the case of Italy and Brazil. Local programmes and policies are analysed as well as significative examples of retrofit interventions in Europe. In the third part, eventually, the social housing complex of Medaglie d'Oro, situated in the city of Palermo, is chosen as case study for the assessment of the effectiveness of vegetation used for the renovation of the outside spaces and, in form of living walls or green roofs, for the improvement of the buildings envelope performance. A methodology for the assessment of the current state of the site and for design proposals is provided: by means of numerical simulations performed with ENVI-met and EnergyPlus different scenarios of renovation through the integration of several vegetal species are analysed in order to verify the enhancement the outdoor and the indoor users' comfort.

The research has been conducted at the Department of Architecture of the University of Palermo although the candidate spent part of the doctoral programme as guest Ph.D. student in other institutions abroad. Specifically, in 2011 part of the research was developed with the support of Labaut - the Laboratory of Environment and Energy of the Faculty of Architecture at the University of San Paulo, in Brazil[3] and in 2012 with the collaboration of the Strategic Research Centre on Zero Energy Buildings of Aalborg University, in Denmark[4].

Notes

1) Since its formation our planet went through continuous phases of climate changes more or less rapid and cyclic. The periodical fluctuations of temperatures and rainfalls are natural consequences of this variability. Most of parameters that influence the climate (solar activity, atmospheric characteristics, internal or external planet factors) are in a slow yet continuous variation and, consequently, our climate is never static. Nevertheless, measurements effectuated in the last years, show the hottest temperatures ever registered since global measurements of Earth surfaces are available (1850) and the Intergovernmental Panel on Climate Change (IPCC), declared that the probability that the increase of temperature derives only from natural phenomena is extremely low (less than 5%).

2) It was estimated that in Europe new constructions add only around 1% to the total building stock on yearly basis and that in Italy, e. g., for the next 30 years about 70% of all actions in the field of the building industry will be refurbishment of the existing stock.

3) From May to December 2011, under the supervision of Prof. Denise Duarte.

4) From September to December 2012, under the supervision of Prof. Per Heiselberg.

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PART I

CHAPTER 1
Global challenges for sustainable development

Despite the difficulties due for the most to capitalist market and economic trends, international negotiations have dealt for more than thirty years with the attempt to overcome the stadium of rhetorical declarations to achieve concrete commitments at a global scale, calling for political and participated actions and promoting holistic assessment and resolution approaches to tackle the issue of sustainable development.

Although the topic of sustainability has its origin from the "new awarenesses" acquired following the energy crisis of the '70s and from becoming conscious of the danger deriving from the reliance on fossil fuels, this term was soon given more characteristics that enriched its meaning.

In 1987 the United Nations World Commission on Environment and Development (WCED), in a document known as the Brundtland Report, defined the sustainable development as: « …a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs […] Sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life […] Meeting essential needs requires not only a new era of economic growth for nations in which the majority are poor, but an assurance that those poor get their fair share of the resources required to sustain that growth. Such equity would be aided by political systems that secure effective citizen participation in decision making and by greater democracy in international decision making...».

Therefore, besides the environmental issue, the document places an emphasis on the protection of every individual, in a perspective of universal legitimacy to aspire to better life conditions, as well as on the ethical responsibility of the whole society to put into effect a democracy model that could contribute to the international decision making process.

In 1994 the International Council for Local Environmental Initiatives (ICLEI), stated that «... durable and sustainable development is the one that provides environmental, social and economic services to all the inhabitants of a community, without threaten social, natural and built systems efficiency from which the supply of such services depends...», providing a further meaning to the term where the three dimensions, economical, social and environmental are strictly interconnected so that every programme of intervention has to take into account such interrelations.

For these reasons, today the idea of sustainable development gravitates around three fundamental components: the economic sustainability, meant as the capacity to generate employment and revenues for people sustenance; the environmental sustainability, meant as the capacity to maintain quality and reproducibility of natural resources; and the social sustainability, meant as the capacity to safeguard the human welfare (safety, health, instruction) equitably distributed for classes, genders and stability, democracy, participation and justice conditions.

The cultural path related to the sustainable development undertaken at global level by the political authorities - which started with the United Nations Conference on the Human Environment in 1972 - had, among the first initiatives of action, the Agenda21 action plan. Resulted from the UN Conference on the Environment and Development, held in Rio de Janeiro in 1992, the document consists in an action agenda for the UN, other multilateral organizations, and individual governments around the world to be executed at local, national, and global levels to face the contemporary climate-change and socio-economic emergencies. In the same year, in New York, the United Nations Framework Convention on Climate Change was open for signature at UNCED, as first legal tool which provides a framework for negotiating specific international treaties (called "protocols") that may set binding limits on greenhouse gases.

Following the main principles agreed in the original 1992 UN Framework Convention, it was in 1997 with the Kyoto Protocol that parties officially agreed to the broad outlines of emissions targets to prevent dangerous anthropogenic interference of the climate system. As of May 2013, 191 countries and one regional economic organization (the EC) have ratified the agreement, while the U.S. signed the Protocol, but did not ratify it. Developing countries do not have binding targets under the Kyoto Protocol, but are still committed under the treaty to reduce their emissions. Actions taken by developed and developing countries to reduce emissions include support for renewable energy, improving energy efficiency, and reducing deforestation[1].

The Protocol defines three "flexibility mechanisms" that can be used by the parties in meeting their emission limitation commitments. Among these mechanisms the treaty forecasts the possibility to acquire carbon credits according to the following modalities: the International Emissions Trading (IET), that allows the parties to "trade" their emissions; the Clean Development Mechanism (CDM), that provides for emissions reduction projects which generate Certified Emission Reduction units which may be traded in emissions trading schemes; and the Joint Implementation (JI), that allows the countries to invest in an emission reduction project in any other protocol country as an alternative to reducing emissions domestically, possibly lowering the costs of complying with their Kyoto targets.

1.1. EU's 20-20-20 targets and social challenges

The Europe 2020 strategy, designed as the successor to the Lisbon strategy[2], is the EU's common agenda for the next decade and calls the attention on the need for a new growth pact that can lead to a smart, sustainable and inclusive development. Adopted by the European Council on 17 June 2010, it seeks to reach a set of objectives through the improvement of a competitive and sustainable social market economy by the year 2020, also in an attempt to overcome the current structural weaknesses of Europe's economy. The key areas of the strategy encompass five headline targets for the EU as a whole, including employment, innovation, education, social inclusion and climate/energy, translated into national targets for each EU Member State that reflect the specific situation of each economy.

The Commission is putting forward seven flagship initiatives to catalyse progress under each priority theme; among them the flagship "Resource efficient Europe" aims to help decouple economic growth from the use of resources, to support the shift towards a low carbon economy, to increase the use of renewable energy sources, to modernise our transport sector and to promote energy efficiency. In particular the EU is aiming at:

- the reduction of greenhouse gas emissions by at least 20% compared to 1990 levels or by 30%, if the conditions are right[3];
- the increase of the share of renewable energy sources in our final energy consumption to 20%;
- a 20% increase in energy efficiency;

In the attempt for the reduction of energy consumption from non-renewable sources and for the decrease of greenhouse gas emission in the atmosphere, the building sector plays a strategic role. As the European Commission stated in several occasions buildings are responsible for 40% of energy consumption and 36% of EU CO_2 emissions. In a communication of 2009, EU commissioner Andris Piebalgs said: «...Energy performance of buildings is a key to achieving our EU Climate & Energy objectives for 2020, namely the reduction of greenhouse gas emissions and the achievement of a 20% of energy savings […] Improving the energy performance of buildings is a cost effective way of fighting against climate change and improving energy security, while also boosting the building sector and the EU economy as a whole...». In the Energy Efficiency Plan 2011 (ECb, 2011), the European Commission states again that the greatest energy saving potential lies in buildings and that, by strengthening the provisions of the Directive on energy performance, a reduction of EU's greenhouse gas emissions equivalent to 70% of the current EU Kyoto target can be achieved together with savings of around 300 € per annum per household in their energy bills, while boosting the construction and building renovation industry in Europe. Among others initiatives, the Renovate Europe Campaign, launched in 2011 by The European Alliance of Companies for Energy Efficiency in Buildings (EuroACE) is currently calling for an ambitious roadmap to be drawn up on how to triple the annual renovation rate of the EU building stock from the current rate of 1% to 3% by 2020 and to ensure that the aggregate result of those renovations could lead to an 80% reduction of the energy demand of the building stock by 2050 as compared to 2005. On the other hand, the issue of social sustainability related to the renovation of the built environment mustn't be overlooked. In this sense, EU regional policy is addressing to further economic, social and territorial cohesion, by reducing the gap in development between regions and among Member States of the EU. For this reason, one particular focus of economic and social cohesion policy has been urban development. As of 2007, the EU has reinforced the urban dimension of regional policy and fully integrated this into cohesion policy, with particular attention on promoting social cohesion and environmental sustainability. Several EU programs and initiative have been launched with the objective of achieving a sustainable development of urban areas through a range of policies which cover many areas of activity.

In October 2011 the European Commission published proposals for cohesion policy between 2014 and 2020 (ECb, 2011). Among other issues, these proposals put an increased emphasis on investing in urban environments and in urban transport. For example, they proposed that at least 5 % of resources from the European Regional Development Fund should be focused on sustainable urban development, that innovative actions for sustainable urban development should be supported and that an urban development platform should be established to develop networks between cities and to introduce exchanges on urban policy. One element of this policy is the European Commission's intention to seek direct and long-term interactions with local administrations, aiming to identify future urban and social challenges and the path to undertake to tackle them successfully.

Among the initiatives supported by EU for the sustainable development of urban areas -taking also into account the energy issue-, particular attention is given to specific actions focused on promoting internal cohesion within urban areas by the improvement of deprived neighbourhoods, notably through rehabilitating the physical environment, redeveloping brownfield sites, boosting the energy-efficient renovation of social housing, and preserving and developing their historical and cultural heritage.

Working on the renovation of urban areas turns out to be strictly related to challenges such as suburbanisation, congestion and the risks of poverty, social exclusion and unemployment. Complex issues such as these require integrated answers in terms of urban planning, infrastructure, transport services, housing, training and energy. For this reason, through structural and cohesion funds, the European Union have been supporting a large extent integration of urban development issues into several regional and national programmes.

In this panorama, the issue of social housing is considered of great importance at the community level. The European Economic and Social Committee (EESC), in a own-initiative opinion of 2012, declared that social housing, because of its numerous different aspects and its major presence in the European Union, can play a key role in implementing the Europe 2020 strategy. In fact, on the one hand it can contribute to combating climate change, while at the same time fighting against energy poverty, and on the other hand it can allow to achieve the goal of making the EU "a smart, sustainable and inclusive economy by helping to ensure high levels of employment, productivity, social inclusion and cohesion". For this reason, in the same document, the EESC encourages EU to promote community-level measures in the field of social housing to underpin the Europe 2020 strategy, considering, e.g., the need to improve the energy efficiency of the existing stock.

1.1.1. Overview of the construction sector and buildings energy consumption in Europe

The construction sector is one of the major engines of Europe's growth. It represents nearly 9.1% of EU Gross Domestic Product, with more than 3 million enterprises, most of which are SMEs, and provides jobs to nearly 14 million workers (FIEC, 2013)[4].

Within the industry, the buildings sector -residential and non-residential- represents the largest economic area and has been pointed out as the highest energy consumer in the EU-27 and as one of the main contributors to GHG emissions, accounting for about 40% of the EU's total final energy consumption, 63% of which was in the residential sector. The current European housing stock comprises approximately 160 million residential and non-residential buildings (EC, 2010). Non-residential buildings account for 25% of the total stock in Europe and comprise a more complex and heterogeneous sector compared to the residential sector. The retail and wholesale buildings comprise the largest portion of the non-residential stock while office buildings are the second biggest category with a floor space corresponding to one quarter of the total non-residential floor space (Fig. 1).

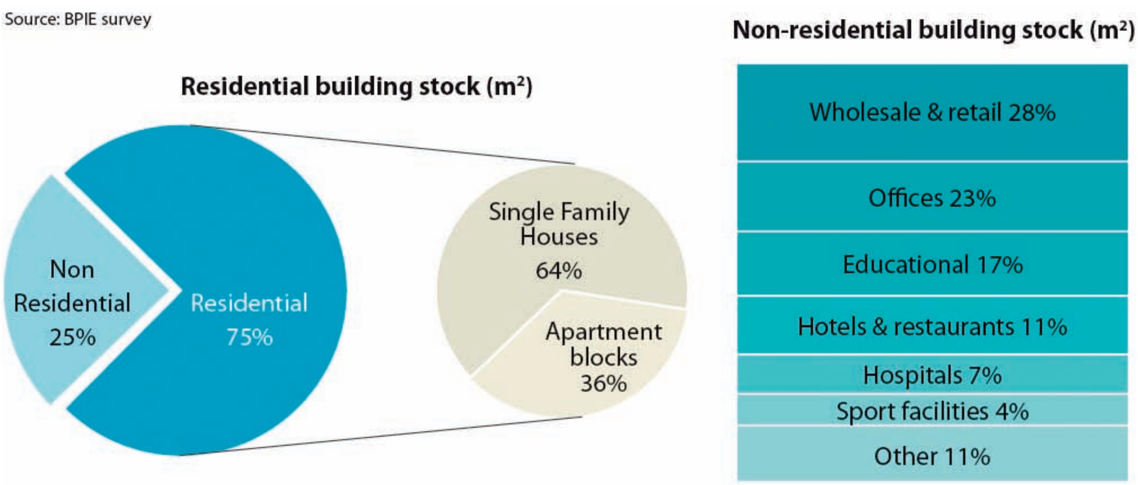

Fig. 1 - Percentage of European buildings according to the use classification (BPIE, 2011)

In a wider consideration of the European contemporary energy position, it must be considered, moreover, that a substantial share of the stock in Europe is older than 50 years with many buildings in use today that are hundreds of years old (Fig. 2). A large boom in construction occurred in 1961-1990 so that 40% of our residential buildings where we live nowadays have been constructed when buildings energy regulations were very limited.

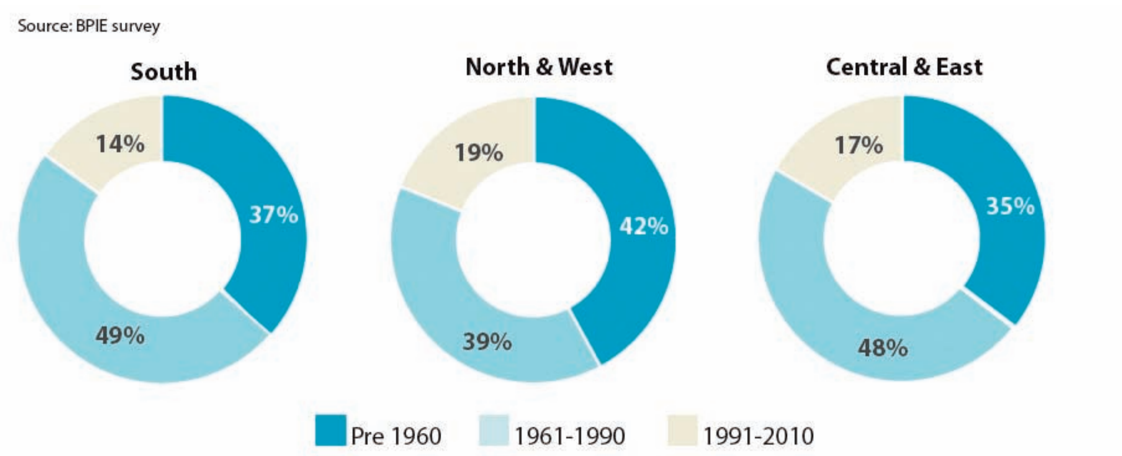

Fig. 2 - Age categorisation of housing stock in Europe (BPEI, 2011)

According to the Building Performance European Institute (BPEI) reports of 2011(BPEI, 2011), annual growth rates in the residential sector are around 1% while most countries encountered a decrease in the rate of new build in the recent years, reflecting on one hand the impact of the current financial crisis on the construction sector and, on the other hand, the increasing need for deep renovations of large parts of our cities, including interventions for the energy retrofit of the buildings.

The energy performance of buildings depends on a number of factors such as the performance of the installed heating system and building envelope, climatic conditions, behaviour characteristics (e.g. typical indoor temperatures) and social conditions (e.g. fuel poverty). Data on typical heating consumption levels of the existing stock by age show that the largest energy saving potential is associated with the older building stock where in some cases buildings from the 1960s are worse than buildings from earlier decades (BPIE, 2011). The lack of sufficient insulation of the building envelope in older buildings was also reflected through the historic U-value data which comes with no surprise as insulation standards in those construction years were limited.

Low housing standards and the high concentration of dwellings in multi-storey buildings typical of a quite diffuse building practice of the second middle of the last century, led today to a great need for refurbishment and for an increase in the quality and the quantity of the surface area available to dwellers (Federcasa, 2006).

Scenario studies expect the demand for electricity to rise, due to the increasing use of appliances, demand for cooling and number of households. Besides, consumers are becoming progressively more demanding, particularly concerning the level of comfort. Flexible working is also on the rise, with an increasing proportion of the population working at home.

A study conducted for the European Commission Directorate-General Energy and Transport demonstrates that retrofitting older, inefficient buildings can be the biggest challenge in Europe, offering an opportunity to apply cost-effective measures and transform them into resource-efficient and environmentally friendly buildings, with an increased social and financial value[5].

Different attempts of retrofitting showed that opportunities exist to improve the energy performance of the existing buildings, reducing the thermal energy demand and increasing the renewable energy production, although it is important to take into account that household energy requirements and users' comfort are closely linked to climatic conditions and that, consequently, energy efficient improvements have to be undertaken differently, depending on climates. Nevertheless, it has been demonstrated that, in average, a wide improvement in energy demand is possible, moving from more than 300 kWh/m^2 to 50 kWh/m^2 per year, with a strong impact in terms of decreased energy use and reduced emissions of CO_2 (EC, 2010).

1.1.2. Italian position

In 2008 Italy has adopted a National Energy Efficiency Action Plan 2008-2016, which sets an energy savings target of at least 9.6% between 2008 and 2016, i. e., 126.3 TWh (10.9 Mtoe) in buildings, transport and small industries (excluding sectors under ETS).

As recently reported by the Energy-Efficiency-Watch Initiative, Italy succeeded in establishing a well-balanced buildings sector framework with mandatory minimum energy performance standards addressing the primary energy demand for new houses (Energy Efficiency Watch, 2013).

As quoted by the Trends in global energy efficiency 2011 Report[5], Italy has one of the lowest levels of energy consumption per capita among countries of comparable industrial development (Enerdata/ABB, 2011). The energy efficiency improvement of final consumers was 15% over the period 1990-2010 against 28% for the EU average. The slow progress, especially in the second half of the '90s, was due to industry and transport sectors that had negative performances (ODYSEE, 2012). After 2000 the increase in energy efficiency has been more rapid: 0.9%/year over 2000-2010 against 0.2%/year over 1995-2000. All sectors showed positive results: in the household sector the improvement in energy efficiency was more rapid in first years of 2000 while industry and transport sectors showed better results in the recent years.

In 2009, total consumption decreased by 5.3% due to the economic crisis and lower demand from the power sector and the final consumption dropped by 3% (-9% for the industrial sector). As shown in Fig. 3 the share of energy consumption by sectors changed during the last two decades with households, services and agriculture sector accounting for the greatest part (38%) in 2009. Nevertheless, household is the sector that showed the best results in energy efficiency improvement over the period 1990-2010, due to the measures set for efficient use of energy in the end-users: energy efficient electrical appliances (improvement of 1.2%/year over 2005 - 2010), renewables for winter and summer air-conditioning, installation of solar panels, substitution with high efficiency appliances, and obligations for new buildings.

Electricity consumption per capita is also far below the European average. Electricity represents 19% of final energy consumption, with a steadily increasing market share. Electricity consumption grew strongly until 2006, although that growth rate slowed down in 2007 and 2008 that were followed by a 7% drop in 2009, linked to the economic crisis and to a fall in power consumption in the industrial sector (-10%).

Notably, efficiency in electricity generation has been improved through the energy substitution of oil by natural gas as well as the diffusion of more efficient technologies. CO_2 emissions per unit of GDP (CO_2 intensity) decreased twice as fast as the total energy intensity over the period 1990-2009 due to substitutions of oil and coal by gas (1%/year compared with 0.4%/year).

Furthermore, since 2002, producers and importers of electricity (>100 GWh) have been obliged to supply a certain proportion of the power from renewable sources including wind, solar, geothermal and biomass (Fig. 4).

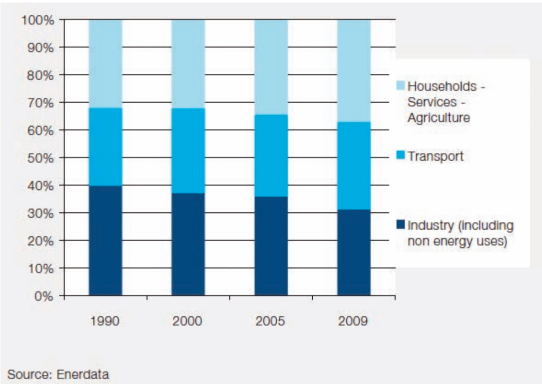

Fig. 3 - Distribution of final energy consumption by sector in Italy (Enerdata/ABB, 2011)

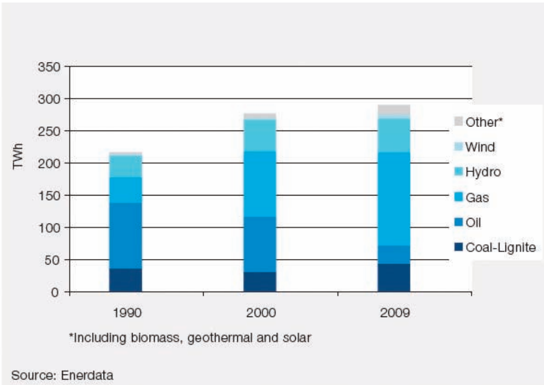

Fig. 4 - Power generation by source in ITALY (Enerdata/ABB, 2011)

The renewable proportion has gradually increased, especially in the last years, passing from 5.3% in 2010 to 7.55% in 2013[7].

This was due also to the fact that the promotion of renewables and combined heat and power (CHP) installations has been supported by financial support schemes, like tax allowances and low interest loans. In 2009,the application of CIP6, a national incentive introduced in 1992, led to the production from RES of 36 TWh (13% of total production), 20% of which was from renewables and 80% from "assimilated" sources (CHP or waste-to-energy).

Furthermore, in December 2005 a decree, called Conto Energia, set up a feed-in tariff for photovoltaic electricity. In February 2007, the government announced a target of 3,000 MW of photovoltaic capacity in 2016, 1,200 MW of which will benefit from the new feed-in tariff for 20 years. As a result of efficiency improvements, the fuel switch in thermal generation and the spread of renewables, the average CO_2 emission factor for power generation has fallen by about 25% since 1990, to less than 450 gCO_2/kWh in 2009.

1.2. Developing countries: the way for a sustainable path

Unlike the the trend prevailing between 1950 and 1975, characterized by a balanced split between urban and rural areas, the scenario of the last decades has seen a world's demographic growth concentrated in urban areas (Fig. 5). In the next 20 years, the "Homo sapiens", will become «...Homo sapiens urbanus in virtually all regions of the planet...» (UN-HABITAT, 2010). At the same time, the pace of urbanization in the world is not accelerating, not even in the developing world.

On a global scale, the urban population is expected to grow at an average annual rate of roughly 1.5% from 2025 to 2030. Indeed, by 2050 urban dwellers will likely account for 86% of the population in the more developed and 67% in the less developed regions. Overall, it is expected that 7 out of 10 people will be living in urban areas by 2050. In the less urbanized regions of the world, namely, Africa and Asia, the proportion of the urban population is expected to increase to 61.8% and 66.2%, respectively, by the middle of the century.

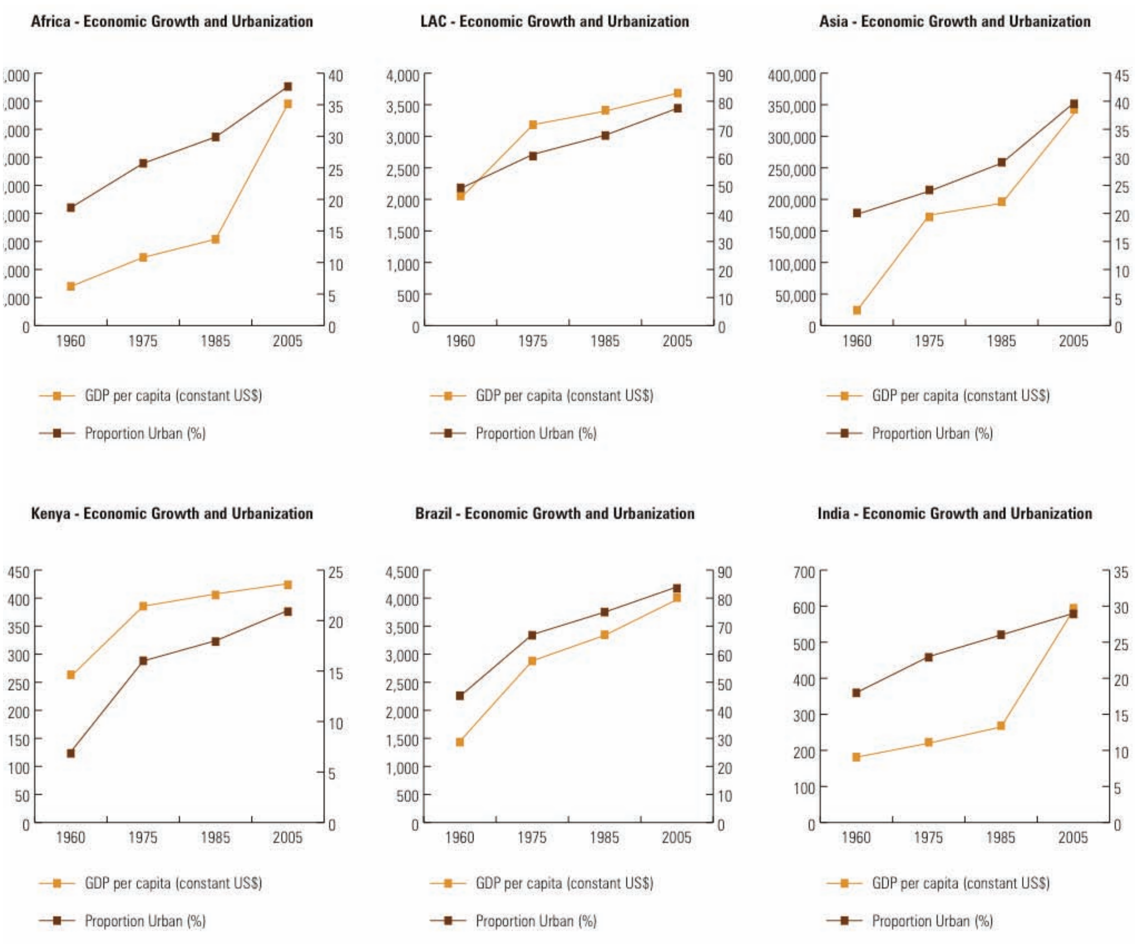

Fig. 5 - Economic growth and urbanization of selected developing countries between 1960-2005 (UN-HABITAT 2010)

As a growing world population aspires to higher material living standards, there is an ever-greater need for goods and services, and the energy required to provide these (e.g. housing, consumer products, transport and travel). The amount of energy consumption per capita has slightly increased until 2008 (+5 % since 1992). In 2009 it decreased for the first time in 30 years (globally -2.2%) as a result of the financial and economic crisis (Enerdata/ABB, 2011), with the decrease being most noticeable for developed countries (Fig. 6). Developing regions show a particularly strong increase in per capita energy consumption in the last five years, although recently this seems to be levelling off.

Globally, CO_2 emissions increased by 36% between 1992 and 2008, from around 22000 million to just over 30000 million tonnes (Fig. 7).

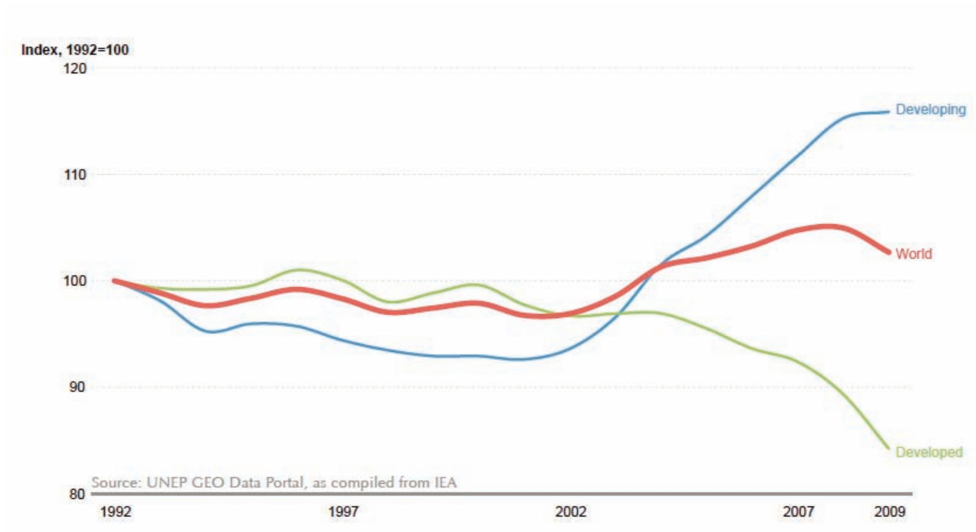

Fig. 6. - Energy consumption per capita between 1992-2009 (UNEP, 2011)

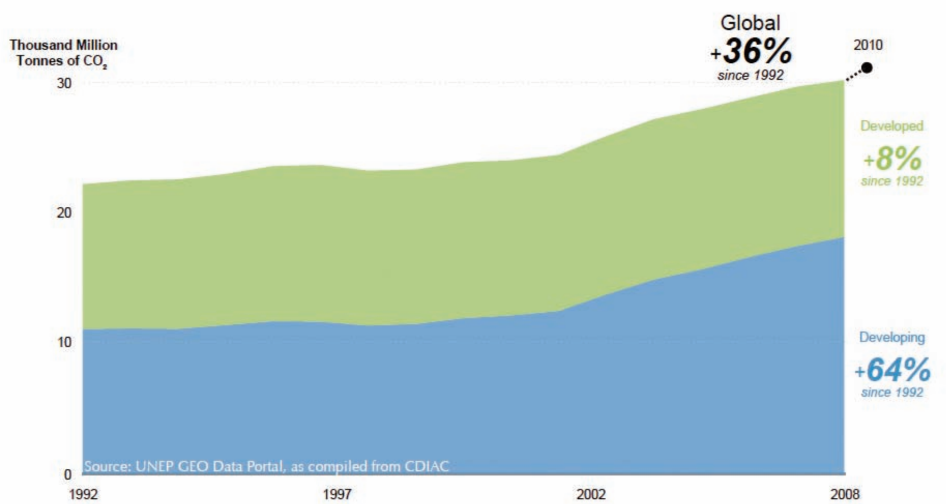

Fig. 7 - Levels of emission of CO_2 from fossil fuels, gas flaring and cement production in developed and developing countries (UNEP, 2011)

With general economic growth, plus developing countries such as Brazil, China and India investing significantly in large development, infrastructural and manufacturing projects, the growth of CO_2 emissions in developing countries over the last few years climbed even more (between 1992 and 2008, a 64% increase of total CO_2 emissions and 29% on a per capita basis) (UNEP, 2011).

Electricity and heat generation account for more than 40% of all CO_2 emissions (IEA, 2010). The strong annual rise of over 3% and a total rise of 66% between 1992 and 2008 - a much larger increase than that of global population (1.3% annually and 26% in total) - is primarily the result of a growth in industrial production, as well as improving living standards in many developing countries.

Nevertheless, on a per capita basis, the largest part of the growth in absolute numbers occurred in the developed countries, increasing from 8.3 MWh in 1992 to nearly 10 MWh in 2008 (a difference of 1.7 MWh per person). The global average of per capita electricity production grew by 33%, from 2.2 MWh in 1992 to 3.0 MWh in 2008; developing countries by 68%, from 1 MWh to 1.7 MWh. In 2010, 1 440 million people globally -that is 20% of the world population- were still suffering from “energy poverty”, not having access to reliable electricity or the power grid, and depended entirely on biomass for cooking and lighting (UNEP, 2011).

Big developing countries like China, India and Brazil have, instead, a way lower gross domestic product and lower energy consumption per head. Nevertheless, according to the growth trends, if these countries will reach an energy consumption rate comparable to an European or North-American citizen, serious problem related to the fossil fuels provision will raise shortly.

Photo 1 and 2 - Growing urban population in Beijing, China (left) and in Dakar, Senegal (right)

1.2.1. Brazilian policy

Brazil is a developing state, but it is the only one in Latin America included in the well-known BRICs group (Brazil, Russia, India, China), as a growing power symbolically shifting economic power from the G7. In obtaining this status and across its various activities, Brazil has become known for both environmental degradation and a relatively successful balancing of development and preservation (Urban Times, 2012).

Comparing to other emerging countries, indeed, Brazil's commitment to environmental sustainability is widely considered commendable. In fact, beside the consciousness that fostering innovation is one of the key challenges to emerge as a force in the worldwide economy, the country is gradually advancing to adhere to the increasingly important global standards for a sustainable development, not only in term of environmental protection, but also from an economic and social point of view. As stated by Doug Gray in 2012, «…the Brazilian route to a more sustainable future is about far more than just reducing fossil fuels or pollution of its waters. It involves rebuilding strategic parts of the city and creating attractive business environments, marrying the increased populations that come hand in hand with greater urban prosperity and the demand for housing, and the subsequent need for sanitation...».

In January 2012, a zero draft of the Rio+20 outcome document was leaked, proposing its own goal areas with slightly more elaboration. In considering some of these prospective sustainable development goal categories, Brazil's performance has been mixed.

Much of Latin America has recently experienced rapid urbanization, and Brazil has achieved a level of urbanization that is greater than that of many countries in Europe.

Photo 3 - The extremely dense urbanization of the city centre of São Paulo

Brazil's population is 80% urban and cities provide 90% of Brazil's wealth, but 25% of its urban citizens are still below the poverty line.

Nevertheless, Since the mid 1980's, Brazil has attempted democratic and comprehensive urban planning[8] and with its economic growth and significant wealth as a nation, Brazil has grown the size of its middle class over the past decade by 33 million. The middle class now composes over 105 million people, out of Brazil's total population of 190 million.

According to the United Nations, it is ranked 84 out of 187 countries on the Human Development Index, which is a measure of well-being that includes health and education, in addition to income. In this sense, Brazil's Bolsa Familia poverty reduction program, launched in 2003, has done much to bring about this progress. It combined education and food subsidy programs into one program that provides cash assistance as long as certain development requirements are met.

Despite the success of this program, more initiatives were lunched to overcome high social inequality such as the Brazil Without Misery, that will expand the program to more children and expand the program to public services and vocational training. On the other hand, the great Brazilian population urban growth entailed a rapid boom of the buildings and construction sector, representing an essential driving force for the development of the country. The most conservative scenario estimates a production of thirty-seven million residential units by 2030 (Fig. 8).

Photo 4 - The Brazilian president Dilma Rousseff launching the program Brazil without Misery

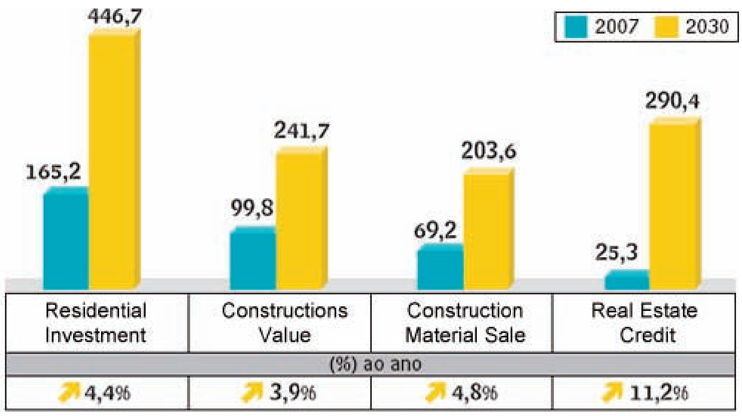

Fig. 8 - Values (in millions) of building and construction market growth within 2030 (Gonçalves at al., 2011. Modified by the author)

This scenario has as a consequence the increasing call of the attention to the energetic issue.

Compared to the rest of the world, Brazil has a relatively clean energy matrix: 47% (including the use of fossil fuels for transportation) are considered renewable sources whereas only 20% of the world's resources are considered renewable. However, with the increase in the Brazilian energy consumption, the energy matrix is becoming "dirtier" and the energy governmental plan, *Plano Nacional de Energia 2030* (PNE-2030), anticipates a fivefold growth in the use of fossil fuels to generate electricity between 2010 and 2030.

About 45% of the consumed electricity is related to buildings in general and 22% to residential buildings. In particular, consumption sources include: refrigerators (19% corresponding to refrigerators and freezers), water heating (24%, mainly for the use of electric showers), air conditioning (20%), lighting (14%), household appliances (15%) (PROCEL/Eletrobras, 2007).

Brazilians' energy system is composed predominantly by hydroelectric power: 77.3% of the generated energy in Brazil comes from water stored in plants. From 1991 to 2001 the electricity consumption increased in average 4.1% per year in Brazil and the production capability only 3.3%, and the gap between offer and request was over 10% in the mentioned decade. Plants, looking for demand supply and higher gains, have used the water storage, not taking into account the security levels established to compensate drought periods in the country. Since rain rates had diminished and the security storage of the main energy source had been used, a crisis in the whole system was unavoidable.

Furthermore, although hydropower has been an important source of electricity in parts of Brazil where it is produced, the country's electricity grid, the far distances that electricity must travel to reach some communities and the environmental risks, have already made it less than ideal, as demonstrated by the hugely controversial development is the Belo Monte dam which, apart from the expected effects on the Amazon Rainforest, may displace as many as 20,000 people, many of them indigenous.

The energetic crisis of 2001 and the will to adhere to environmental and social international standards, pushed officially the Brazilian Government to arrange emergency measures to reduce energy consumption in the country, imposing an energy rationing of 20% to residential consumers.

Photo 5 - Public demonstration in São Paulo against the construction of the Belo Monte dam

Photo 6 - Hydroelectric power plant in Foz do Iguaçu

Notes

1) Under the Protocol, emissions of developing countries are allowed to grow in accordance with their development needs.
2) The Lisbon Strategy, also known as the Lisbon Agenda, is a measure set out by the European Council in Lisbon on March 2000, to propose an action and development plan devised for the economy of the European Union between 2000 and 2010. It aimed to improve EU competitiveness and to strenghten its dynamic knowledge-based economy in a perspective of sustainable economic growth and greater social cohesion, by 2010.
3)The European Council of 10-11 December 2009 concluded that as part of a global and comprehensive agreement for the period beyond 2012, the EU reiterates its conditional offer to move to a 30% reduction by 2020 compared to 1990 levels, provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities.
4) Nevertheless, the European Construction Industry Federation (FIEC), in the 2013 press release, pointed out on the reduction in construction activity observed in all segments and on the drastic cuts in public investments made by the EU governmental consolidation measures.
5) Trends in global energy efficiency 2011 is based on data and information provided by Enerdata and the Economist Intelligence Unit.
6) According to the European Directive on the promotion of the use of energy from renewable sources, the national target is to increase the share of renewables in final energy consumption to 17% by 2020.
7) Interestingly, many are examining Brazil's experience to identify lessons learned for cities in Africa and Asia. The Brazilian government has recognized this role itself, signing the India-Brazil-South Africa Human Settlement Agreement. Recognizing their common challenges, these countries have agreed to share information and cooperate on overcoming them.

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Photo References

Photo 1 - Photo of the Author

Photo 2 - Photo of the Author

Photo 3 - Photo of the Author

Photo 4 - Edgar Lisboa (journalist, http://www.edgarlisboa.com.br)

Photo 5 - Photo of the Author

Photo 6 - By courtesy of William Martinha

CHAPTER 2
Normative frameworks on building energy regulation and environmental protection: Italy and Brazil

2.1. Italian normative framework and implementing provisions

Among the European countries, Italy occupies one of the first places for the highest losses of energy due to the low performance of buildings: even if the global energy consumption in the country is in fall, the building sector, that absorbs the major rate of energy, registered marked increases in the last years, weighting for the 35,2% on the whole national energy consumption (ISTAT, 2010).

The difficulties encountered in the Italian normative frameworks evolution, as well as in the acquisition of a new environmental consciousness of the last decades, had as a consequence the backward position of the country, and in particular of Southern regions, in the application of innovative techniques for existing buildings energy retrofit if compared to international experiences.

Southern regions of the country, in particular, hang still behind in the application of innovative strategies for the design and the retrofit of existing buildings, also because of the difficulty in adapting systems developed for cold countries to temperate climate contexts.

The Mediterranean climate in fact presents specific characteristics, different to Centre and North European countries, that deeply affect the indoor comfort of buildings. This is demonstrated, for example, by the fact that in the Northern part of Europe heating is the main cause of energy consumption in buildings, while in the Mediterranean area most of the problems related to building efficiency deal with overheating during the hot days of the year and the need for air-conditioning.

Regardless these matters of fact, Italy is showing significant advancements in an effort of adequate its position to the worldwide standards.

2.1.1. From the law n.373/76 to the acknowledgement of the European Directives

Even though the first measures relating to energy efficiency in Italy date back to the 70's, with the **law n°373 of 1976** "*Norme per il contenimento energetico per usi termici negli edifici*" (Rules for thermal energy control in buildings), and later with the **law n°10 of 1991** "*Norme per l'attuazione del Piano Energetico Nazionale in materia di uso razionale dell'energia, di risparmio energetico e di sviluppo delle fonti rinnovabili di energia*" (Rules for the actuation of the National Energy Plan regarding the rational use of energy, energy saving and renewable sources development), the country remained for long time short of tools of accomplishment and control for the actual application of these normative provisions.

The European Directive 2002/91/CE on buildings energy performance was successively acknowledged in Italy through the **decree law n° 192/05**, integrated one year later with the **decree law n° 311/06**.

The first decree establishes parameters and conditions to improve the energy efficiency of buildings in order to foster the use of renewable sources and to achieve the national goals imposed by the Kyoto protocol for the reduction of GHGs. The article 3 specifies that the application of the law refers to new construction buildings as well as retrofit interventions. In the latter case, different levels of application of the law are foreseen according to specific conditions of the building.

Following, the **decree law n° 311/06** introduces some modifications of the previous law. In particular new limit values for the thermal transmittance of the building envelopes are provided in relation to the energy requirement needed for heating and cooling, as well as new standards for the assessment of the systems efficiency.

The following **ministerial decree of 26 October 2007**[1] concerns the economic aspect related to energy retrofit interventions on existing buildings, constituting the base for the **Financial Law of 2008 called "Decreto Edifici"** (Building Decree). The object of the ministerial decree is the tax deduction related to expenses due for buildings energy retrofit.

Despite the advancement of the normative framework, the decrees stayed for years almost inapplicable as the instruments for the definition of a national methodology for the evaluation of buildings energy performance were defined only in 2009 with the issuing of the law n°59/09 and with the **ministerial decree 26/06/09** "*Linee guida nazionali per la certificazione energetica degli edifici*" (National guide lines for the energy certification of buildings), that anyway left it up to each Italian region to provide to the individual regulation of sustainability aspects in the construction sectors through adequate certification systems, remaining sometimes unaccomplished and leaving the country in a completely chaotic situation[2].

In 2011, the **law decree n°28 of 3/03/2011** was promulgated with the aim to implement the Directive 2009/28/CE, defining the necessary tools, mechanisms and incentives for the achievement of the 2020 targets in terms of energy production from renewable sources, establishing for Italy the quote of 17%.

Finally, the Energy Performance of Buildings Directive (EPBD) 2010/31/Ue, known also as "EPBD2", which encourages member states to move towards new and retrofitted nearly-zero energy buildings by 2020 (2018 in the case of Public buildings), also through the application of a cost-optimal methodology for setting minimum requirements for both the envelope and the technical systems, was acknowledged by the Italian law in May 2013 with the **decree n.63 of 4/6/2013**, converted with modifications in the **law 90/2013**. It provides new rules for the regulation of new or retrofitted buildings. Among the most significant innovations, there is the obligation of the *Attestato di Prestazione Energetica (*Energy Performance Certificates) for selling and renting of the buildings. Nevertheless, the iter to put into effect the law in not yet complete and further decrees are still required.

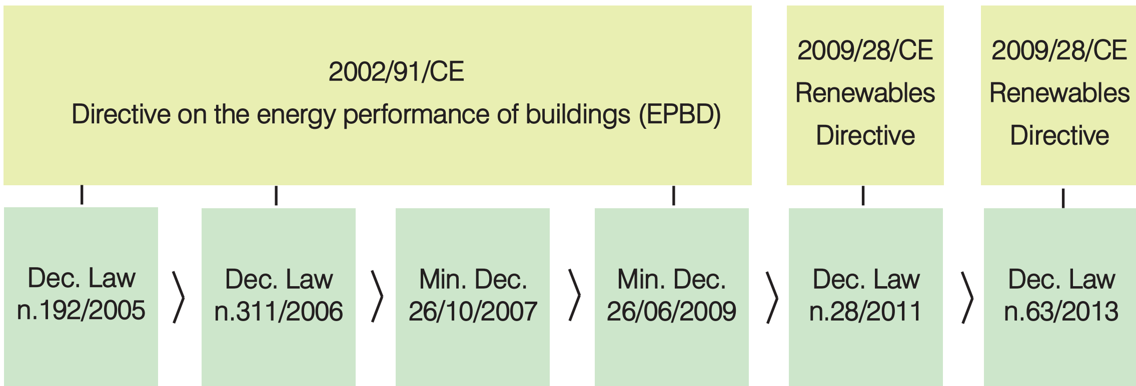

Fig. 1 - Normative framework process for the acknowledge of the EU Directives (Drawing of the Author)

2.1.2. Labelling systems for buildings energy efficiency

The EU Directive 2002/91/CE defines for the first time the *Attestato di Certificazione Energetica* (Energy Performance Certificate) of a building as «...a certificate recognised by the Member State or a legal person designated by it, which includes the energy performance of a building...».

Furthermore, at the article 7 the Directive establishes that «...Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be...».

Despite the attempt made by the Italian governments in the regulation of a energy labelling system at national level, the Italian normative situation is today characterized by a still incomplete legislative framework in which, with the exception of isolated cases of regional advancements, a large number of regions of the country, especially in the South, remain in a state of paralysis. In confirmation of this, the *Comitato Termotecnico Italiano Energia e Ambiente*, in its report of 2012, affirms that, regarding for the Italian labelling system framework «...registered data [...] on the application of energy certification in Italy con-firm a situation of noteworthy non-uniformity...», due to the fact that planning and building control, as well as environmental matters and so the system of regulation of sustainability aspects of construction, are in the competence of the 20 Regions. Of these, five regions (namely Sardinia, Sicily, Trentino-Alto Adige/Südtirol, Valle d'Aosta and Friuli-Venezia Giulia) have a particular degree of legislative and financial autonomy.

Each municipality of the Regions implements its own building regulations, with its own sustainable building codes (*Norme per l'edilizia sostenibile*), based on Regional guidelines. Certain elements are integrated from national laws and decrees, but in principle there is no national system of building regulations.

Building regulations are included in Regional/provincial structure plans, and by each comune in a *Piano Regolatore Generale* (General Regulator Plan). Municipalities issue building licenses and permits for each project. As for sustainability aspects, the Regions and Municipalities variously introduced their standards for sustainable buildings, driven latterly by the implementation of the EPBD (which is also implemented at the Regional/Municipality level). The different adoption of methods for the evaluation of energy efficiency and sustainability, has originated problems for implementation and for the training and certification of inspectors and designers. The energy certificates required for the construction of new buildings, purchase or rent agreements were therefore widely ignored, partly because of the lack of assessors and partly in expectation of changes to be introduced at the national level (EC, 2011).

In addition to this, we need to consider the difficulty encountered for the adaptation of tools - consolidated in cold areas - to the local contexts of those Italian regions where buildings energy efficiency aspects related to cooling and refrigerating systems require greater attention, as demonstrated by several national researches (Margani, 2010, among others).

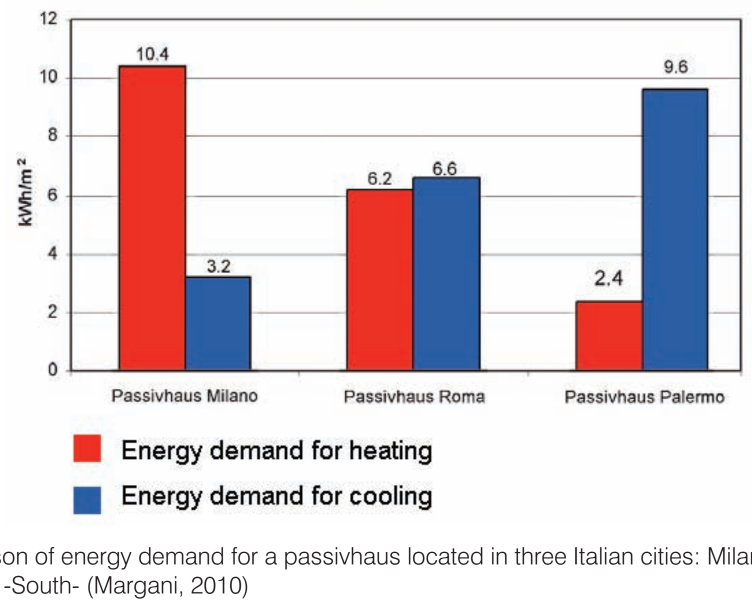

Fig. 2 - Comparison of energy demand for a passivhaus located in three Italian cities: Milan -North-, Rome -Centre-, Palermo -South- (Margani, 2010)

The Green Building Council, represented in Italy since 2008 by GBC Italia, has recently started to promote the LEED (Leadership in Environmental and Energy Design) labelling system, in an attempt to adapt it to the Italian environmental and energetic context.

Launched by the U.S. Green Building Council (USGBC) in 2000, the LEED rating systems address both a wide variety of buildings types, including commercial buildings, homes, neighbourhoods, retail, healthcare and schools, as well as every phase of the building lifecycle including design, construction, operations and maintenance. Projects may earn one of four levels of LEED certification (Certified, Silver, Gold or Platinum) by achieving a given number of point-based credits within the rating system.

Under the last revised version "LEED 2009", there are 100 possible base points achievable, distributed across six credit categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design. Four additional points may be received for Regional Priority Credits, and six additional points for Innovation in Design.

In Italy it counts around 300 members including communes, contractors, design bureaus and materials producers, though it is more used in case of international projects.

In order to define an Italian common methodology for the environmental certification of national buildings, though permitting variations of the parameters according to the different climatic regional conditions of the country, since 2004 the *Istituto per la Trasparenza l'Aggiornamento e la Certificazione degli Appalti* - ITACA (Italian Institute for the Transparency, Updating and Certification of Contracts), launched an energy and environmental building assessment protocol called *Protocollo ITACA*. The ITACA Protocol, developed in collaboration with iiSBE Italia - International Initiatives for a Sustainable Built Environment and the scientific support of ITC-CNR *Istituto per le Tecnologie della Costruzione - Consiglio Nazionale per le Ricerche* (Construction Technologies Institute - Italian National Research Council) and of the Polytechnic University of Marche, is an energy-environmental certification tool including quality of the building and building components, valid for new constructions as well as for buildings renovation. So far it has been integrated within the EPBD implementation system in region Marche, Basilicata, Friuli Venezia Giulia, Lazio, Puglia, Toscana. Other 13 regions use it for building assessment at design stage, e.g., for competitions and call for tenders for residential public building. The ITACA certification allows benefits as incentives for renovation and urbanization burden reduction, volumetric bonuses, controlled loans (for new buildings mainly).

For residential use the protocol establishes 19 criteria, further divided in 34 sub-criteria, belonging to the five headings shown in Table 1.

Beside the ITACA Protocol, the Casa Clima Agency is a public structure settled in the Autonomous Province of Bolzano (one of the two Autonomous Provinces of Sudtirol), that represents an alternative for the sustainability assessment of the built environment, taking as reference a concept of passive house linked to cold climate contexts and receiving a noteworthy assent among the administrations of north regions of Italy.

Quality of the site	
Selection of the site	- Reuse of the territory - Public transports accessibility - Mixed use of the area - Infrastructures proximity
Area Design	- External areas for common uses - Support for the use of bicycles
Resources consumption	
Life cycle non-renewable energy	- Primary energy for heating - Primary energy for water heating
Renewable sources	- Energy for electric uses
Eco-materials	- Reuse of existent structures - Materials recycle - Materials from renewable sources - Local materials for finishes - Dismountable and reusable materials
Potable water	- Potable water for irrigation - Potable water for indoor uses
Building envelope performance	- Net energy for cooling - Thermal transmittance of the envelope - Solar radiation control - Thermal inertia of building
Environmental charges	
Equivalent CO2 emissions	- Emissions foreseen in operative phase
Solid wastes	- Solid wastes produced in operative phase
Wastewater	- Wastewater channelled in sewage system - Soil permeability
Environmental impact on the surrounding	- Heat-island effect
Quality of the indoor environment	
Ventilation	- Ventilation and air quality
Hygrometric comfort	- Summer air temperature
Visual comfort	- Natural lighting
Acoustic comfort	- Acoustic quality of the building
Electromagnetic pollution	- Industrial magnetic camps (50 Hertz)
Quality of the management	
Safety in operative phase	- Systems integrations
Functionality and efficiency	- Quality of cabling systems
Performance maintenance in operative phase	- Maintenance of the building envelope performance - Availability of technical documentation

Table 1 - Categories considered for the certification system Protocollo ITACA

2.2. Rules for the development of green urban areas in Italy

The investigation annually carried out in Italy by the *Istituto nazionale di statistica* - ISTAT (National Institute of Statistic) to collect environmental information related to the chief towns of the Italian provinces have demonstrated that, in 2011, the urban green areas represented the 2,7% of the territory of the towns (over 550 million of m^2) for a average of 30,3 m^2 of green urban area per citizen (ISTAT, 2013).

The analysis highlights big territorial differences. North-East part of Italy has the highest availability of urban green area per capita from which derives a good urban scenarios such as those registered in Trento (429.1 m^2 per capita), Pordenone and Reggio nell'Emilia (respectively 65.5 and 54.6 m^2 per capita). In the South, the good availability of urban green areas of cities make the average values of around 33.1 m^2 per citizens. Nevertheless, in the distribution of green urban areas of South Italy, it is also registered the highest concentration of cities where the availability of green areas are lower than 9 m^2. This is the condition, e. g., that characterizes one third of the chief towns of Sicily. In the city of Palermo, the percentage of green areas in comparison to the town surface is equal to 3.9%.

Moreover the data point out that the green areas protected by the cultural heritage codes, defined as *verde storico* (historical green) and *parchi ville e giardini di non comune bellezza* (parks, villas and gardens of uncommon beauty) count for about one third of the urban green areas; *the verde attrezzato* (equipped green areas) for the 15.9%; the *arredo urbano* (urban decor green areas) for the 9.4%; the *aree sportive all'aperto* (sports areas) for the 3.8%; the *giardini scolastici* (school gardens) for the 3.4%; and the areas of *forestazione urbana* (urban forests) for the 2.4%. The *orti urbani* (urban vegetable gardens) are among the green areas in increasing diffusion, activated in 44 municipalities.

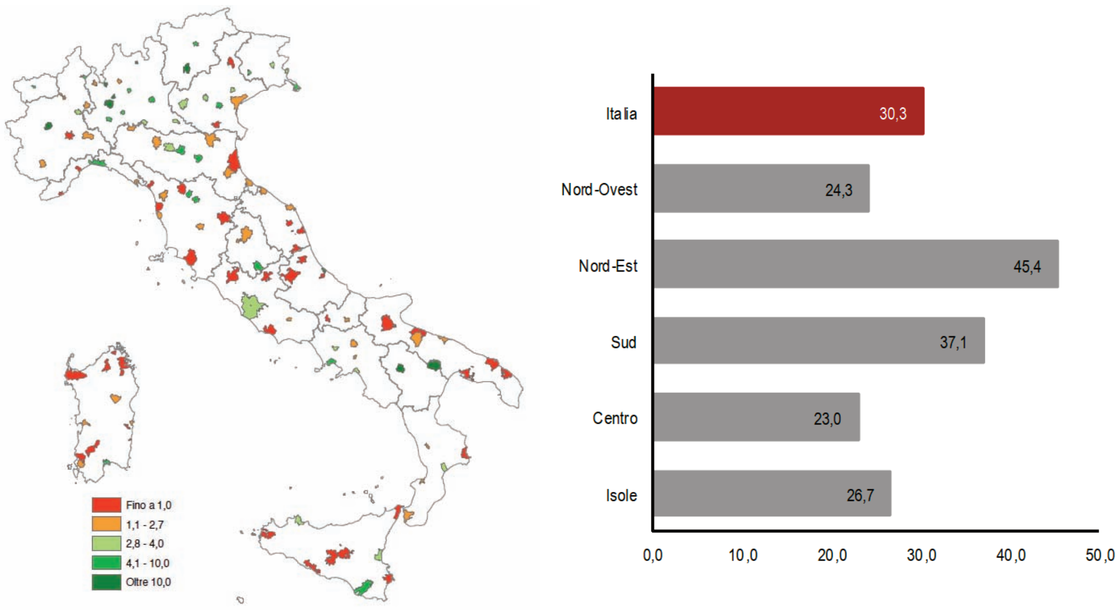

Fig. 3 - Availability of Green urban areas (sqm per inhabitant) in Italian chief towns located in the north/centre/south of the nation and in the islands (ISTAT, 2013)

Tools for planning and management of urban green areas are still barely used by the local administrations: less than one fifth of the town have approved a *Piano del verde* (Green Plan) and only the 45.7% have adopted a *Regolamento del verde*(Green management guidelines) (ISTAT, 2013).

2.2.1. From the law n.113/92 to the law n.10/2013

Despite the deficient design and management programs for urban green areas, Italy's first normative attempt for the improvement and the increase of vegetation in the urban areas dates back to the 90s with the law n.113 of 29/01/1992[3] which forced the municipalities to plant a tree for each newborn citizen. Unfortunately, because of lack of operative tools for its application, the law stayed for the most unapplied and its aims almost unaccomplished.

Nevertheless, with the law n.10 of 14/01/2013[4], Italy has recently introduced new measures for the improvement of green areas in the Italian territory -where local and regional administrations are responsible for the promotion and application of green plans- and guide lines for the definition of best practices for the integration of vegetation in the built environment. This law not only modifies the previous law in order to assure the effective respect of its obligation, but also introduce significative prescriptions aimed at the mitigation of the heat island effect, the reduction of CO_2 levels and the restraint of buildings energy consumption.

In order to achieve these goals, besides the necessity of adopting green plans at urban level, the law focuses the attention on the importance of promoting significant retrofits operation in single residential districts that could include the use of green walls and roofs in buildings and the renovation of the common open spaces through the integration with vegetal elements. The law is enforced for new and existing buildings. Moreover, the norm foreseens the foundation of a specific ministerial *Comitato per lo Sviluppo del Verde Pubblico* (Commitee for the Development of Public Green Areas) with different tasks, including the assessment of the fulfillment of the law.

Nevertheless, despite the normative progress achieved at national level, local administrations, especially in South regions, still demonstrate scarce competences to adequately handle operative tools to carry out appropriate programmes for the design and the management of green plans in the cities.

2.3. Brazilian normative frameworks and implementing provisions

The challenge of defining a prescriptive framework to regulate buildings energy performance in the climatic context of Brazil was discussed, for the first time in 1990 during the *Primeiro Encontro Nacional de Conforto no Ambiente Construído* (First National Meeting on Comfort in the Built Environment) that led to the creation of a project, involving Brazil, Argentina and Uruguay, aimed to define prescriptive guide lines to control the building energy consumption in the three countries. The issue was later approached in the *Primeiro Encontro Nacional de Normalização Ligada ao Uso Racional de Energia e ao Conforto Ambiental em Edificações* (First National Meeting on Normalization related to Buildings Energy use and Environmental Comfort) of 1991.

However, it was only after the heavy energy crisis known as "*Crise do Apagão*" (blackout crisis), that paralyzed the supply and distribution of electric energy in Brazil from July to December of 2001, that the government decided to come into action with decisive normative measures. In the same year, following up this occurrence, and considering the energy consumption due to the real estate market volume increase, the Brazilian government approved the **federal law nº 10295** "*Dispõe sobre a Política Nacional de Conservação e Uso Racional de Energia e dá outras providências*" (Rules about the National Policy for Energy Saving and Rational Use and other measures), that establishes maximum levels of energy consumption for equipments made and sold inside the country and for residential, commercial and industrial buildings.

To support the action of the law, two teams of professional were created: the *CGIEE – Comitê Gestor de Indicadores e Níveis de Eficiência Energética*, (Committee for the development of energy efficiency levels and indicators) and, specifically for the building sector, the *GT-Edificações - Grupo Técnico para Eficientização de Energia nas Edificações no País*, (Technical group for the energy efficiency of buildings).

In 2003 the *ABNT - Associação Brasileira de Normas Técnicas* (Brazilian Association for Technical Rules) issued the **law nº 15520** "*Desempenho térmico de edificações*" (Buildings thermal performance), about thermal performance of buildings, defining, among other things, eight climatic zones of the country and the methods for thermal transmittance and thermal capacity rating.

Further important advancements as been made in 2009 by INMETRO, the National Institute of Meteorology, Normalization and Industrial Quality, through the creation of *RTQ-C - Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edifícios Comerciais, de Serviços e Públicos* (Technical Quality Regulation of the Level of Energy Efficiency of Commercial, Service and Institutional Buildings), followed in 2010 by *RTQ-R -Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edificações Residenciais* (Regulation of the Level of Energy Efficiency for Residential Buildings). These documents specify technical requirements and methods for the energy efficiency labelling of commercial, public and residential buildings, constituting the base for the institution of the certification system Procel INMETRO, that came into effect since 2009. It represents a voluntary certification that can be applied to new or existing buildings, specifically developed in relation to the Brazilian climatic zones.

According to the labelling system, a building can achieve five levels of efficiency (from A to E). The evaluation of the environmental performance is made taking into account the elements summarily exposed in Table 2.

Commercial and Public Service Buildings	Residential Buildings
• BUILDING ENVELOPE • LIGHTING SYSTEM • AIR CONDITIONING SYSTEM • BONUS*	• BUILDING ENVELOPE • WATER HEATING SYSTEM • BONUS*

* Bonus are attributed for other systems implementing the energy efficiency of the building, such as: natural lighting and ventilation

Table 2 - Factors considered for the application of Procel INMETRO labelling scheme

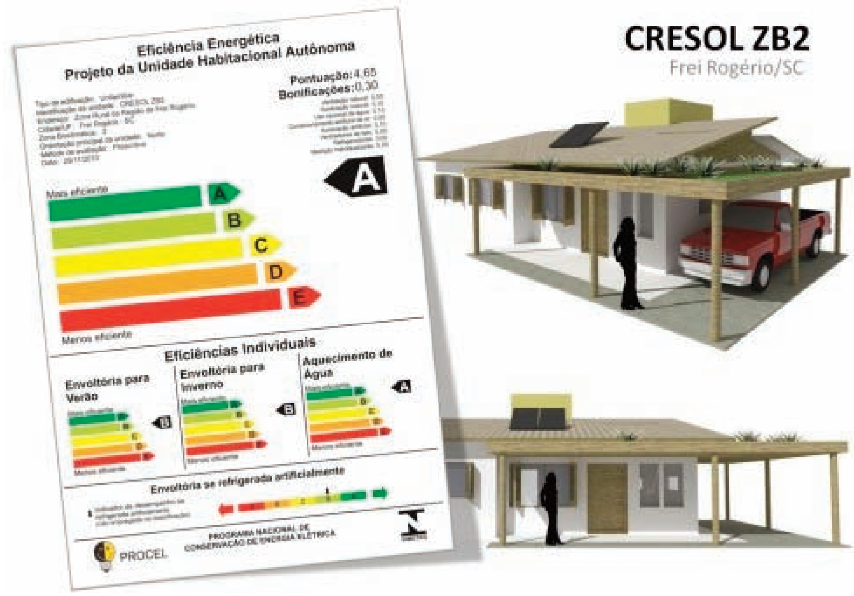

Fig. 4 - Sample of the Procel INMETRO certificate for buildings energy efficiency

For the evaluation of buildings environmental performance, more systems deriving from the adaptation of European or North-American models began to spread out in the country as voluntary certification systems.

Brazil applied for the first time in 2007 the American LEED certification, generating a wide approval and influence among the professionals in the field of building construction.

In the same year the country proposed the creation of the Green Building Council Brazil (GBC Brasil) with the aim of promoting best practices and certification process in the building sector and contributing in the dissemination of knowledge among civil society and experts in the field. GBC Brasil encompasses today more than 500 companies and strongly contributed to the rising of the country to the fourth place of the world ranking of green buildings, with 89 buildings already certificated and more than 700 in certification process (GBC Brasil 2013).

Despite the large assent registered, the system recently aroused some controversies in the application of LEED's principles and parameter in Brazil, because of the big cultural, economic and climatic gap between the American context (for which the LEED certification system was originally set up) and the Brazilian reality. In an effort to face these questions, the GBC Brasil started to improve and adapt the LEED certification system to the Brazilian geo-climatic context and building market, partnering with relevant national and international organizations, in order to develop a certification scheme based on different perspectives of environmental, social and business responsibility (Gomes et al., 2008).

Photo 1 and 2 - Office Building Jatobà in San Paolo, that obtained the certification LEED Gold

Among other international labelling systems adapted to the Brazilian context requirements, it is advisable to cite the AQUA-Alta Qualidade Ambiental system, launched in April 2008, that derives from the French HQE (Haute Qualité Environnementale) approach. Contrary to LEED label, the AQUA Process has undergone a national adaptation before official launching. The certificate system consists of two instruments that permit the evaluation of the sustainability of a building from two different points of view:

- the certification for the construction management system SGE - Sistema de Gestão do Empreendimento;
- the certification for the environmental quality fo the building QAE - Qualidade Ambiental do Edifício

This latter takes into account 4 categories related to the environmental requirements of a new or existing building. These categories are further on divided into subcategories for a total of 14 items (Table 3). The building performance related to the categories is evaluated in accordance to three different quality levels: *Bom* (good), *Superior* (higher), *Excelente* (excellent).

AQUA Categories	
1. ECO-CONSTRUCION • Relation with the surrounding • Integrated choose of products, systems and constructive processes • Building site impact	3. COMFORT • Hygrometric comfort • Acoustic comfort • Visual comfort • Olfactory comfort
2. MANAGEMENT • Energy • Water • Waste management • Conservation and maintenance	4. HEALTH • Quality of environment • Quality of air • Quality if water

Table 3 - Categories considered for the AQUA label process

Photo 3 - Parque Cidade Jardim Corporate Center in San Paulo, that obtained the certification AQUA

Notes

1) *Disposizioni in materia di detrazioni per le spese di riqualificazione energetica del patrimonio edilizio esistente*, *ai sensi dell'articolo 1, comma 349, della legge 27 dicembre 2006, n. 296* (Provisions regulating tax deductions for energy renovation interventions on the existing building stock).

2) In the period of transition - which goes from the emanation of the D.Lgs. 192/2005 to the D.M. 26/06/2009 - some regions issued some laws to regulate the fulfillment of the energy certification measures on their territories. The first region that provided the law was Lombardy, followed by Liguria, Piedmont and Emilia Romagna. It must be remembered that the Autonomous Province of Bolzano approved its laws even before by introducing the system CasaClima. Those regions that anticipated the national guide lines can do it according to the modification of the Titolo V of Constitution which declares that energy issues are under the jurisdiction of State and regions. Moreover the article 17 of the law 192/2005 states that regions and autonomous provinces autonomously acknowledge the EU Directive 2002/91/CE.

3) Law n.113 of 29/01/992, *Obbligo per il comune di residenza di porre a dimora un albero per ogni neonato, a seguito della registrazione anagrafica* (Commitment for the municipalities to plant a tree for each new-born child, following the birth registration.

4) Law n. 10 of 14/01/2013, *Norme per lo sviluppo degli spazi verdi urbani* (Rules for the development of urban green areas)

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Photo References

Photo 1 - Photo of the Author

Photo 2 - Photo of the Author

Photo 3 - http://www.corporatecidadejardim.com.br

CHAPTER 3
Climate, Microclimate and Built Environment

According to the main climate classification, south Italy as well as south and south-west Brazil, considered as representative countries for the purposes of this thesis, belong to temperate climate zones.
Climate, defined by the average of the earth atmosphere physical parameters -temperature, solar radiation, wind speed and direction, pressure, relative humidity and rainfall- in a specific geographic space and for a relatively long period of time, can be classified according to two parameters: the climatic scale and the geographic distribution (Grosso, 2011).
The first refers to the extension -both horizontal and vertical- in which certain meteorological conditions occur exercising significant effects on the atmosphere; the second consists in grouping homogeneous climatic parameters in relation to specific earth areas.
In particular, the climatic scale describes the spatial hierarchy of climatic subsystems existing beneath the general circulation system of the atmosphere (Fig. 1), including:

- Macroclimate, that ranges for 12 km high and is constituted by the elements characterizing the general atmosphere circulation at the continental and oceanic scale;
- Mesoclimate, is constituted by the elements characterizing the subcontinental climate with the predominant presence of specific geophysical components (i.e. desertic Saharan zone, Mediterranean basin, Amazonian area, etc), for an extension of 1000/2000 Km in the horizontal direction and of 3-4 Km in the vertical one;
- Topoclimate, that presents a horizontal extension of some hundreds of kilometres and a vertical extension of around 1 km, referring to the climatic characterization at the local scale (urban climate, lake climate, valley, etc…);
- Microclimate, ranging in the horizontal direction for some hundred meters, and -as regards the vertical direction- it reaches the average high of local vegetation in non-urbanized areas and buildings high in urban areas, constituting the typical climate of built environment.

Regarding the classification for geographic distribution, the methods for the classification can be different and are usually subdivided in:

- Zonal methods, general and qualitative, based on the geographic distribution of climatic parameters such as solar radiation on the floor, temperature or relative humidity. One of these general classification is the one defined by Olgyay, that identifies four main climates related to as many constructive and settlement typologies[1].

- Quantitative methods, that use numerical values (of temperature and rainfall) for the identification of climatic types. Most classifications used today are based on the system introduced in 1900 by the Russian-German climatologist Wladimir Köppen, who divided the Earth's surface into climatic regions that generally coincide with world patterns of vegetation and soils.

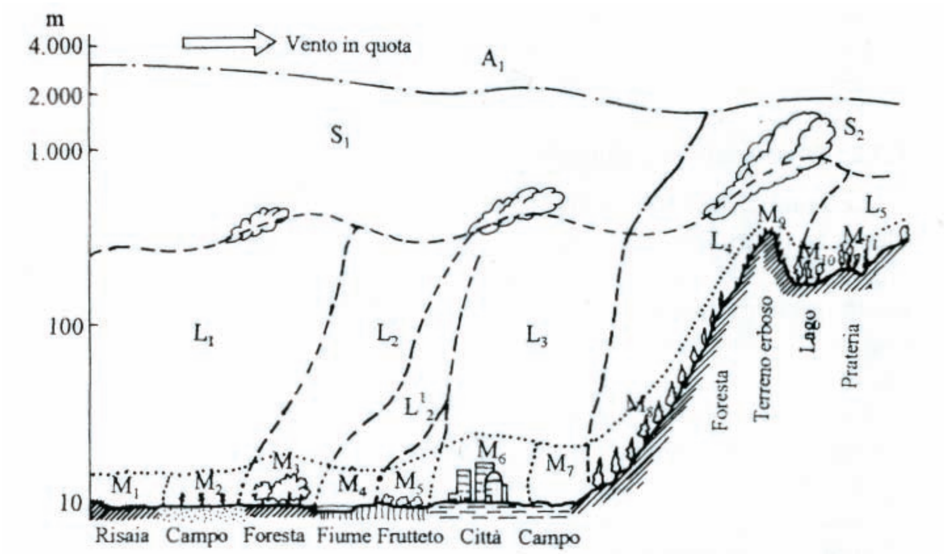

Fig. 1 - Climate classification according to the scale of influence as defined by Yoshino: A= macroclimate; B= mesoclimate; L= topoclimate; M= microclimate (Grosso, 2011)

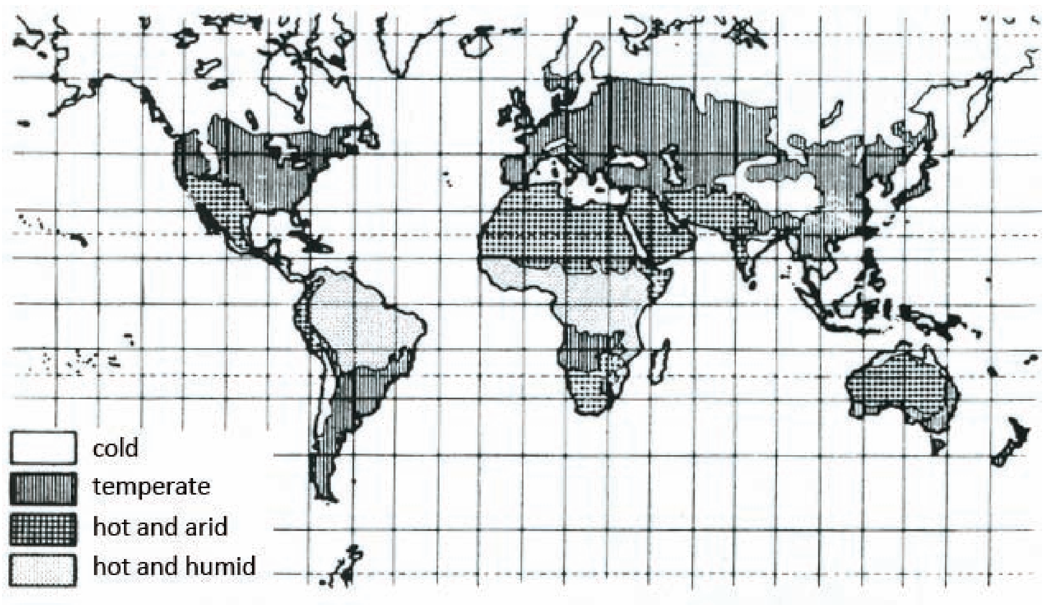

Fig. 2 - Geographical distribution of the main climate typologies according to Olgay (Grosso, 2011)

3.1. Köppen-Geiger e Troll-Paffen climate classifications

The Köppen climate classification is one of the most widely used climate classification systems. It is based on the concept that native vegetation is the best expression of climate. Thus, climate zone boundaries have been selected with vegetation distribution in mind. It combines average annual and monthly temperatures and precipitation, and the seasonality of precipitation. The Köppen-Geiger[2] system recognizes five major climate types based on the annual and monthly averages of temperature and precipitation, each having several types and subtypes. Each particular climate type is represented by a 2 to 4 letter symbol, as show in Table 1.

Main groups (related to temperature °C)		Particular climate type (related to pluviometry regime)	
A	**Tropical/Megathermal Climates** Constant high temperature with average values of 18° C or higher	Af	**Tropical rainforest climate** All twelve months with average precipitation of at least 60 mm
		Aw	**Tropical wet and dry or savanna climate** Driest month (precipitation<60 mm)
B	**Dry Climates** Bh, average annual temp > 18° C Bk, average annual temp < 18° C Bk', temp. in the hottest month < 18° C	Bs	**Steppe climate** Annual precipitation < the threshold but > half the threshold for Group B
		Bw	**Desert climate** Annual precipitation < than half the threshold for Group B
C	**Temperate/Mesothermal Climates** Average temperature above 10 °C in warmest months and a coldest month average between −3° C and 18 °C Ca, temp. warmest month > 22° C Cb, temp. warmest month < 22° C and more than four months with > 10° C	Cf	**Temperate climate without dry seasons**
		Cs	**Dry-summer subtropical or Mediterranean climate** Least rainy month in summer with precipitation < 1/3 than most rainy winter month (< 30 mm)
		Cw	**Dry-winter temperate climate** Least rainy month in winter with precipitation < 1/10 than most rainy summer month
D	**Continental/Microthermal Climates** Average temperature above 10 °C in warmest months and coldest month average below −3° C	Df	**Wet all year**
		Dw	**Dry winter**
E	**Polar Climates** Characterized by average temperature below 10 °C in all twelve months of the year and coldest month average below −3° C	Et	**Tundra climate** Warmest month with average temperature between 0° C and 10° C
		Ef	**Ice Cap climate** All twelve months with average temperature below 0 °C

Table 1 - Main climates according to Köppen-Geiger classification

In geography, temperate or tepid latitudes of the globe lie between the tropics and the Polar Regions. The changes in these regions between summer and winter are generally relatively moderate, rather than extreme hot or cold. Temperate zones cover about 7% of the world's land surface but are by far the most inhabited areas, largely due to the mildness of the climate, the plentiful supply of rain and generally very fertile soils.

The definition of temperate climate can refers to different classification.

According to Köppen-Geiger classification, temperate climates are identified by the letter C and are characterized by constant high temperature (at sea level and low elevations) and average temperatures of 18°C or higher for all twelve months of the year (Figs.4).

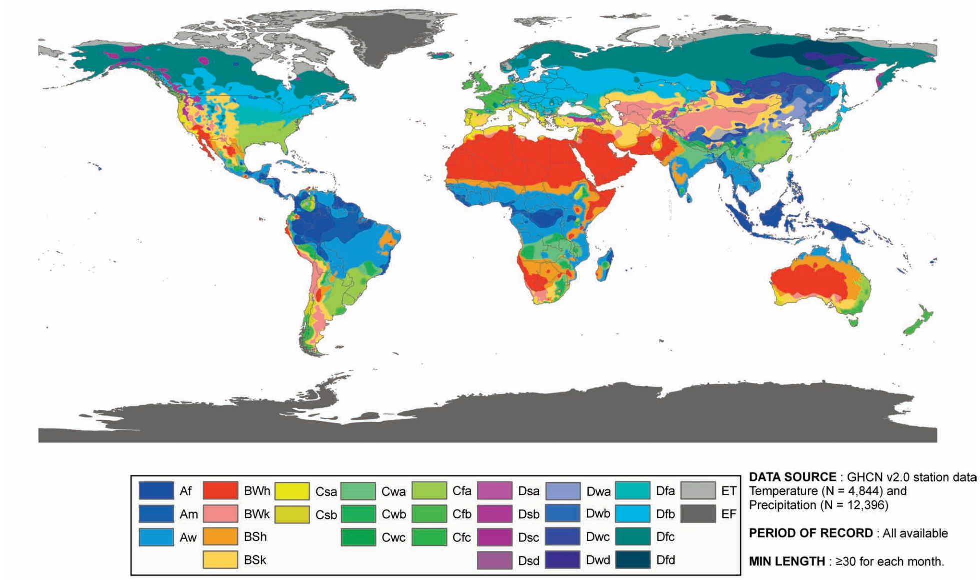

Fig. 3 - World map of Köppen-Geiger climate classification (Peel, M. C. et al., 2007)

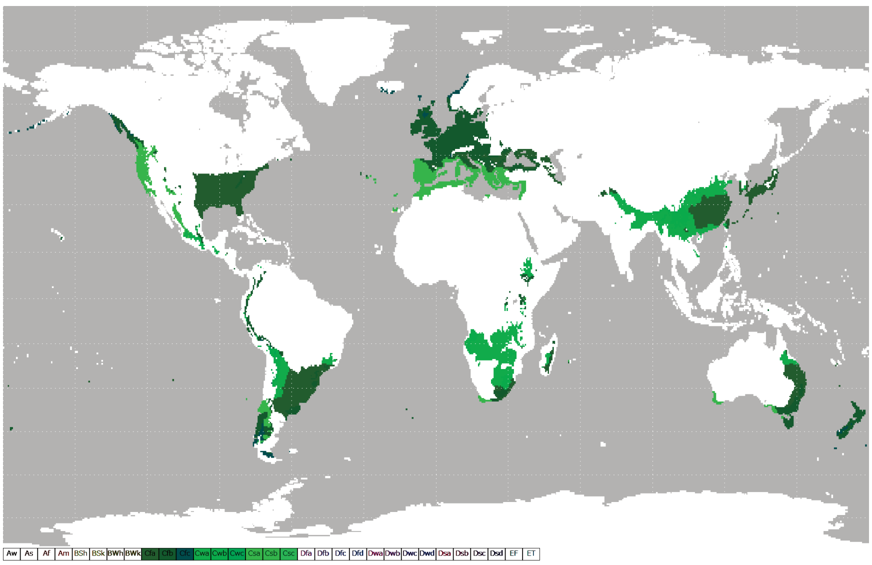

Fig. 4 - Temperate areas according to Koppen-Geiger classification (Wikipedia)

German climatologists Carl Troll and Karlheinz Paffen introduced, instead, a bioclimatic classification scheme based uniquely on considerations of seasonality, which recognizes five primary bioclimatic zones (Fig. 5). These are the polar/subpolar, cold-temperate/boreal, cool-temperate, warm-temperature subtropical and tropical zones, each of which are subdivided into further categories based on various seasonality criteria. Differently from Köppen-Geiger classification, Troll and Paffen defined a large temperate zone called "Warm temperate subtropical zone" characterised by plain and hilly lands having an average temperature of the coldest month between 2 °C and 13 °C in Norther Hemisphere and between 6 °C and 13 °C in Southern Hemisphere, excluding oceanic and continental climates. This wide subtropical zone is further divided into seven smaller areas (Fig. 6).

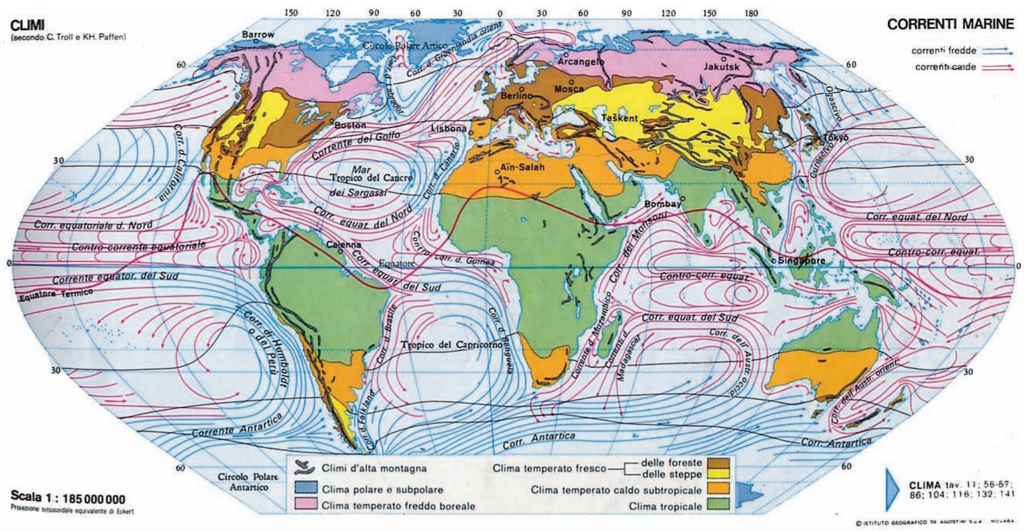

Fig. 5 - World map of Troll-Paffen classification (Istituto Geografico De Agostini)

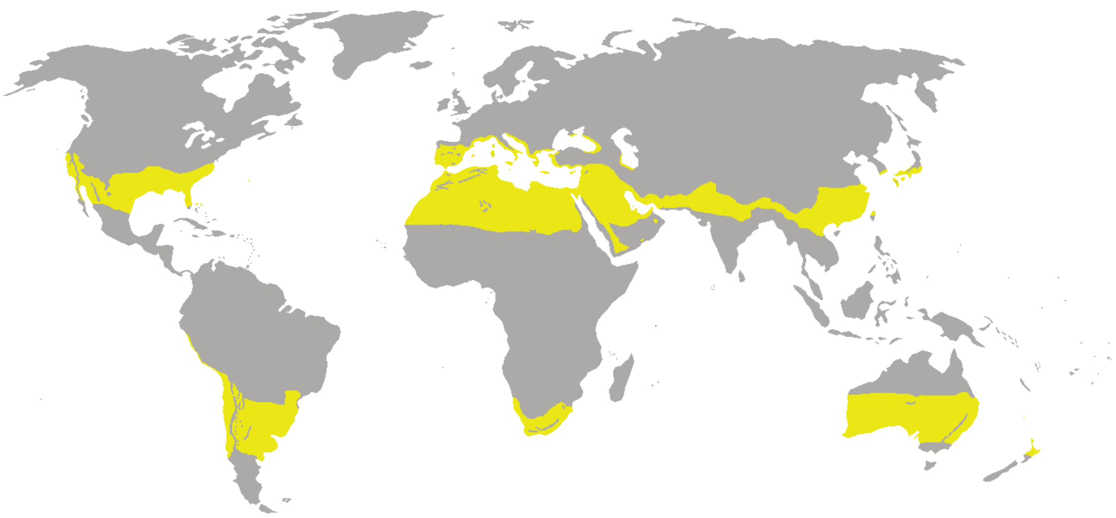

Fig. 6 - Temperate areas according to Troll-Paffen classification (Wikipedia)

Within savannah regimes in the subtropics, a wet season is seen annually during the summer, which is when most of the yearly rainfall falls. Within Mediterranean climate regime, the wet season occurs during the winter. Areas bordering warm oceans are prone to locally heavy rainfall from tropical cyclones, which can contribute a significant percentage of the annual rainfall. These climates do not routinely see hard frosts or snow, which allows a rich and varied vegetation to flourish, including date palms and citrus to flourish.

3.1.1. Climate characteristics of Italy

The weather and climate in Italy varies greatly throughout the peninsula based on both seasonal changes and the geographical characteristics of the country which contribute to create microclimates within regions. Between the north and south there can be a considerable difference in temperature, above all during the winter: in some winter days it can be −2 °C and snowing in Milan, while it is 8 °C in Rome and 20 °C in Palermo. Temperature differences are less extreme in the summer.

The coastal regions, where most of the large towns are located, have a typical Mediterranean climate with mild winters and hot and generally dry summers. The length and intensity of the summer dry season increases towards the south. The coastal areas throughout Italy experience largely similar conditions from north to south with mild winters and hot, dry summers. The western side of the country experiences more rain than the eastern side which is windier, especially in the area subject to the strong Bora wind that gusts across the Adriatic from Central Europe.

In contrast to the settled days of summer, the weather throughout Italy can be very changeable in the autumn, winter and spring. This unpredictable weather can continue until the end of May and can start anytime after the beginning of September. The winter months tend to alternate between clouds and rain and warmer, sunnier weather.

Inland, throughout the peninsula, the weather is often colder and wetter with frequent snow on the mountains during the winter.

In the extreme north, the climate can drop to below freezing in the winter and rise to 30° in the summer. This is a similar climate to that of Alpine Switzerland and Austria, although the Italian side tends to experience more precipitation and also slightly warmer weather in both summer and winter. In this area, summer tends to be the rainiest season and thunderstorms are frequent in spring, summer, and autumn. Lower down, the lake area in Lombardy tends to experience the mildest winter weather and the warmest, sunniest summers. Sunshine levels here are around 3 to 4 hours a day in the winter and around 9 hours a day in the summer. The area of the Po valley and the Padan Plain has its own distinctive climate and can experience rain at any time through the year. Although the winter months can be surprisingly cold, and can experience fog, frost and snow, the summer months can be almost as hot and sunny as southern Italy. Thunderstorms are frequent in the summer and autumn but the rain falls infrequently.

The south of the country, particularly Sardinia and Sicily, can get very hot indeed, with long periods of settled weather and continuous sunshine. During the daytime, sea breezes can lower the temperatures on the coast, but in the evening and overnight it can be extremely hot and humid, especially inland. As can be imagined, the south of Italy has the least rain and the most hours of sunshine of any other area in Italy. In Sardinia and Sicily, there is an average of 4 hours of sunshine a day during the winter and 9 hours a day in the summer.

According to the Italian law D.P.R. n. 412/1993[3], the Italian territory have been divided in six climatic zones depending on the number of "degree days" (called *gradi giorno* - GG) in Italian (Fig. 7). For “degree days” is meant a measure of how much (in degrees), and for how long (in days), outside air temperature was lower than a specific "base temperature" (or "balance point"). They are used for calculations relating to the energy consumption required to heat buildings.

The EN ISO 15927-6 of 2007 indicates the formula for calculating the GG as:

$$GG = \sum_{e=1}^{n} (T_0 - T_e)$$

where
n= num. of days of the conventional heating period
T_0= Temp. of the conventional indoor environment
T_e= Average daily outdoor temperature

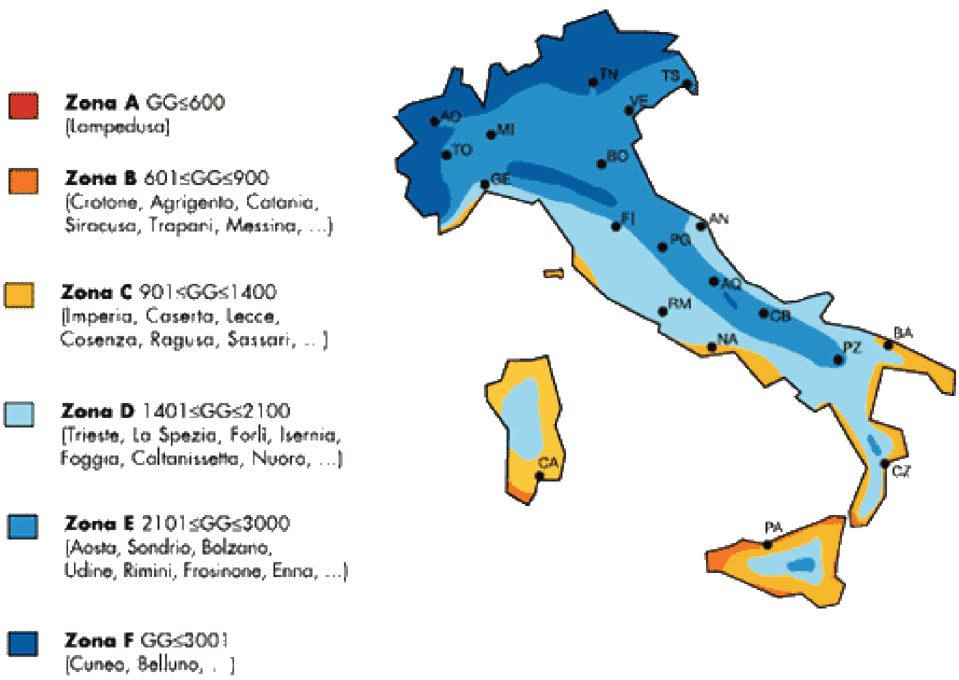

Fig. 7 - Climatic zones in Italy depending on the heating degree days

3.1.2. Climate characteristics of Brazil

Brazil, due to its dimensions, has a very wide climatic diversification, influenced by its geographical configuration, its significant coastal extension, its relief and the dynamics of the masses of air on its territory[4].

The climate of Brazil varies considerably mostly from tropical north (the equator traverses the mouth of the Amazon) to temperate zones below the Tropic of Capricorn (23°27' S latitude). Temperatures below the equator are high, averaging above 25 °C, but not reaching the summer extremes of up to 40 °C in the temperate zones. Brazilian territory is generally subdivided in five distinct climatic zones:

- The Equatorial Zone characterized by rainforests due to the year-round humidity and precipitation. There is no winter season and no period in which it is particularly dry. Rainfall is usually heavy and frequent all through the year, yielding dense, luscious vegetation typical of rainforests. Nighttime temperatures may drop significantly from daytime highs. Given that it is usually overcast in equatorial zones, the daily temperature do not usually exceed the 33°C, and are usually at a comfortable temperature between 25 and 28 degrees.
- The Tropical Zone, as its name implies, found in the tropics. The temperatures of these zones are consistent all year round. In fact, the only distinguishing characteristic of the different seasons is the amount of rainfall that they bring. In areas of rainforests, such as in Brazil, the average rainfall is at least 60 millimetres per annum. Mean temperatures are of over 18°C all year round.
- The Semi-Arid Zone characterized by receiving less rain than that actually needed to make up for evaporation, but not so much less that the area becomes a desert. It is the halfway mark between deserts and humid forests. In semi-arid zones, the vegetation includes hardy shrubs and grasses, rather than trees.
- The Highland Tropical Zone, also called an Oceanic Climate or a Maritime Climate

Photo 1 - A view of the city of Rio de Janeiro, which belongs to the Subtropical Zone

Zone, found along the coast of Brazil. It is characterised by cool summers and warm winters, although the annual temperature does not vary by significant amounts. Rainfall is fairly uniform throughout the year. To qualify as such a zone, the area must experience an annual mean temperature of not lower than 18°C.

- The Subtropical Zone which refers to the areas that are just outside of the formal Tropical Zones. It is hot, but not quite as hot and humid as Tropical areas. Winters are mild to cool, but not cold enough for snow or frost. This areas experience different levels of rainfall, depending on their elevation above sea level.

In the process of development for the definition of a proper legislation about thermal performance of buildings in the country, the Study Commission on Thermal Performance and Energy Efficiency in Buildings by ABNT - Brazilian Association of Technical Standards, prepared standards related to acoustic, daylight and thermal performance of buildings also defining a bioclimatic zoning of the country as an important tool on giving guidelines to an environmental integrated process of design. According to this bioclimatic zoning, eight zones were defined and Brazilian territory was divided in 6500 cells, each one was characterized by its geographic position and monthly average of maximum temperatures, minimum temperatures, and relative humidity. Measured data were used in 330 of those cells, and in the others the climatic data were estimated by average interpolation.

A bioclimatic chart adapted from that one suggested by Givoni (1992) to the Brazilian context was used. The adapted chart is divided in 12 bioclimatic strategies where Brazilian territory cell was registered and classified. By interpolating climatic data it is possible to display lines in the chart, and by their concentration in the graphic it is possible to understand which bioclimatic strategies are indicated for that period or for the whole year. The necessary weather information is, for each month of the year, average maximum and minimum temperature and average maximum and minimum relative humidity.

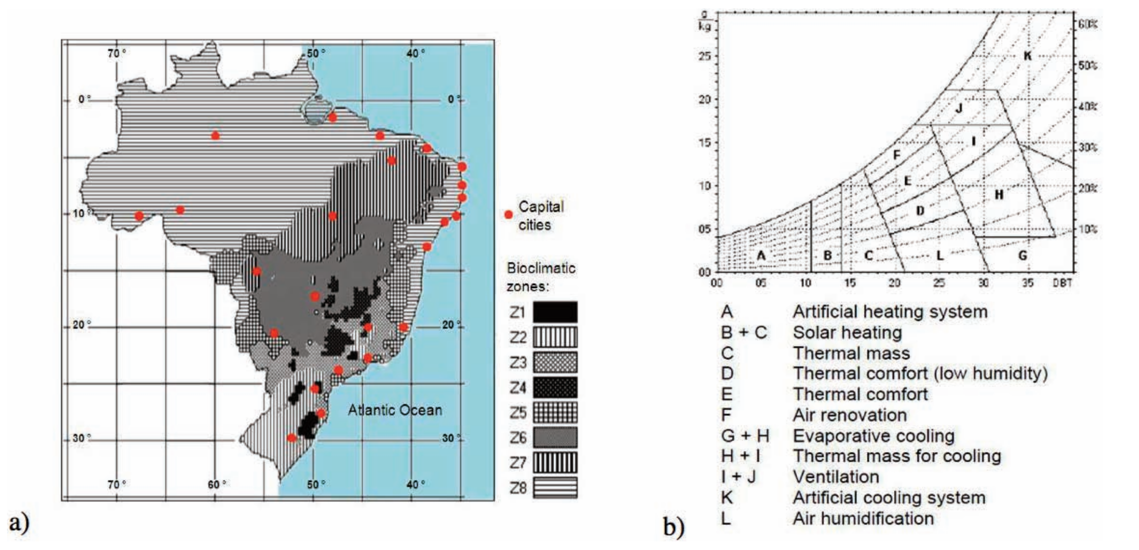

Fig. 8 - (a) Bioclimatic zoning and (b) bioclimatic chart (ABNT, NBR 15220-3, 2005)

3.2. Urban microclimates and heat island effect

Differently from climate, microclimate is directly influenced by human activity and can be somehow controlled in order to produce adequate thermo-hygrometric wellness in both outdoor and indoor conditions. Urban areas, in particular, have a decisive effect on climate, insomuch as they are characterized by specific local climate conditions. Similarly to what happen for other ecosystems, such as forests, urban climate is distinguished in relation to two different air layers: the urban canopy consisting in the air layer comprised between urban building up to their top roofs, and the urban dome, that is the air volume overhanging the city and whose astrophysics conditions are influenced by the whole urban structure (Fig. 9). Inside the urban canopy layer specific microclimatic conditions are generated because of the gradual absorption of solar radiation. The effects of the built environment on earth-atmosphere thermal balance at the lower layers and, hence, on microclimate are related to the following factors (Grosso, 2011):

- the modification of the radiant exchange (low infrared waves) due, essentially, to new values of soil roughness and reflecting surfaces albedo;
- the modification of the latent heat derived from the soil evapotranspiration;
- the modification of the air flows.

These factors, beside the waste heat from automobiles, air conditioning, industry, high levels of pollution, affect all the microclimate components (temperature, humidity, wind speed) inside the lower urban dome layers which are directly responsible for the creation of the so called “Urban Heat Island” (UHI) phenomenon.

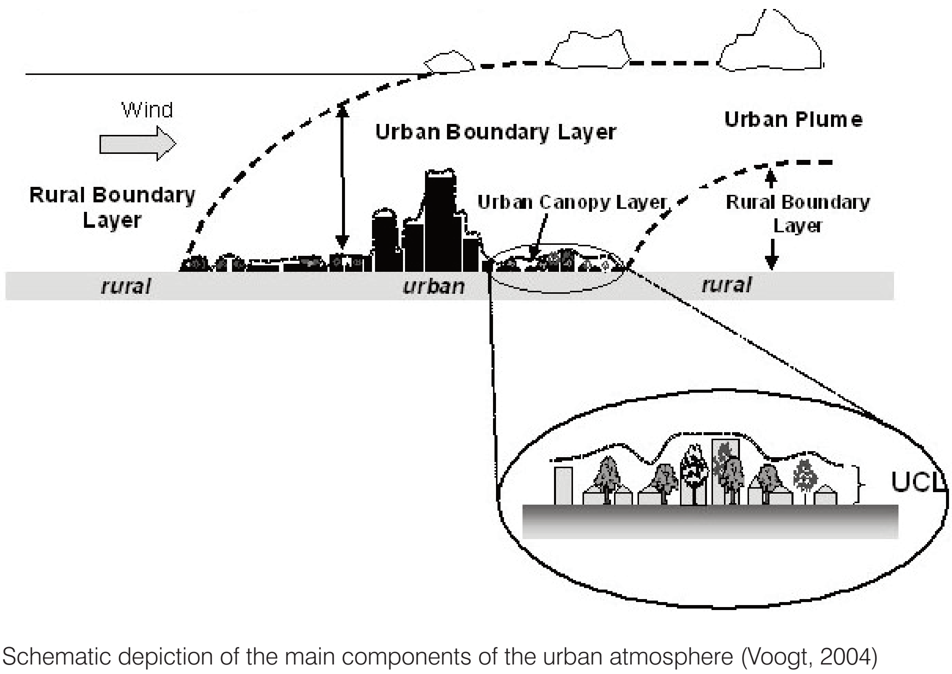

Fig. 9 - Schematic depiction of the main components of the urban atmosphere (Voogt, 2004)

3.2.1. Radiant exchange

The radiative exchange between the surfaces and the atmosphere depends, essentially, on:

- the absorption and reflection coefficients, in relation to their colour and material;
- the level of shading of the surfaces, depending on their shape and orientation and the mutual position of the surfaces;
- the sky view factor, depending on the geometry and the mutual position of the surfaces.

The reflection coefficient, also known as the albedo, is the ratio of reflected radiation from the surface to incident radiation upon it. Its dimensionless nature lets it be expressed as a percentage and is measured on a scale from zero for no reflection of a perfectly black surface to 1 for perfect reflection of a white surface. Asphalt, for example, has low albedo; it absorbs almost ali the solar energy falling on it. This means that, combined with asphalt inability to evaporate water, streets and parking lots paved with this material often reach blistering temperatures on sunny summer afternoons. The replacement of vegetation or soil by concrete or asphalt reduces an urban ability to lower daytime temperatures through evaporation and plant transpiration. Instead, the solar energy normally delegated to the evaporation process is left to raise surface temperatures. Urban areas get hotter than rural settings not only because their ability to cool evaporatively is reduced, but also because they reflect less incoming solar energy.

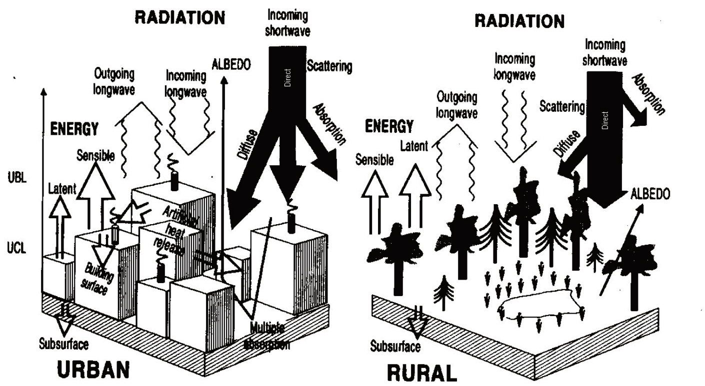

Fig. 10 - Schematic depiction of radiation and energy fluxes over an urban and a rural area (Oke, 1988)

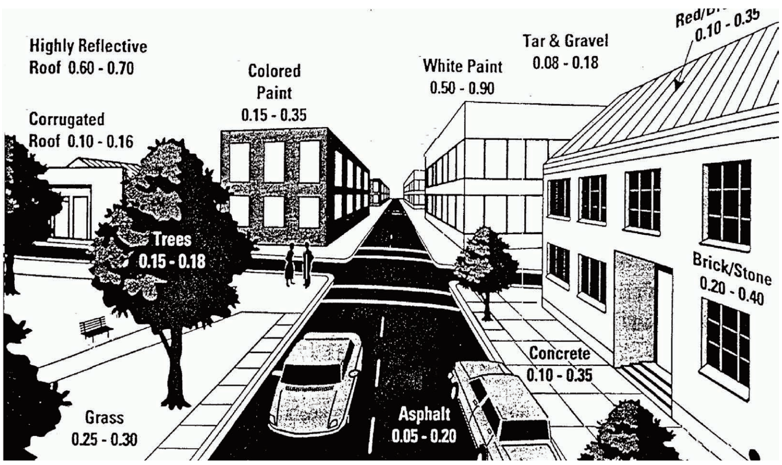

Fig. 11 - Schematic depiction of albedo values for materials commonly used in urban areas (Huang et al., 1990)

Moreover tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the air temperature. This is called "urban canyon effect".

3.2.2. Air temperature and humidity

The heat island phenomenon makes air temperature in the built environment usually higher and relative humidity lower in respect to the rural environment. As shown in Fig. 12, UHI provokes a distinct rise of temperatures at the edge of the city. Starting from the countryside temperatures continue to rise slowly closer to downtown, with pockets of cooler air hovering over parks or other wooded areas. Urban heat island “peaks" are almost always in the downtown areas. The center of the city usually contains the highest density of buildings, and there seems to be a direct correlation between the amount of buildings per unit area and variations in temperatures.

A winter heat island in a cold climate can be a moderate asset because it lowers heating bills, in warm and hot climates, however, the higher temperatures result in increased energy demands for air conditioning. Initial research shows that for every 1°F increase in summer temperatures, peak cooling loads will increase 1.5 to 2 percent (Akbari, 1992). The effects of urban heat islands, however, have to be related to the different climatic zones: Cold, Temperate, Hot-Arid, Hot-Humid. Cities in the first zone typically have cold long winters and mild short summers. The effect of urban heat islands in these locations is generally positive, with some improvement of winter conditions and small increases in energy use during the short summer. Current thinking suggests that lightening surfaces and planting trees, however, will probably have little effect on winter heat islands. Hence, mitigation strategies for summer heat islands would still be a benefit in these areas. Cities in the second zone have moderately cold winters, and mild to hot summers varying in length from three to four months. The effect of urban heat islands in these locations are generally detrimental, since their winter benefits do not compensate for their significant degradation of summertime conditions and increased air-conditioning demand. Cities in the last two zones have short mild winters and long hot summers. There, the urban heat island definitely intensifies temperatures and increases demand for air conditioning.

Correlations between temperature and energy use can be established by comparing utility-wide electricity loads to temperatures at the same time of day. According to Akbari (1992), since urban temperatures during summer afternoons in the United States, i.e., have increased by 2 to 4°F in the last six decades, we can assume that 3 to 8 percent of the current urban electricity demand is used to compensate for the heat island effect alone.

Another aspect that has to be considered is that summer heat islands also increase smog production; the incidence of smog events may increase by 10 percent for each 5°F increase in temperature. In this sense, even if the "intensity" of the heat island in relation to one urban area may seem slight, we need to consider that such an effect multiplied at a global level, besides the environmental issue, heavily affects the global economy in terms of energy expenditures, smog damage and increased water consumption.

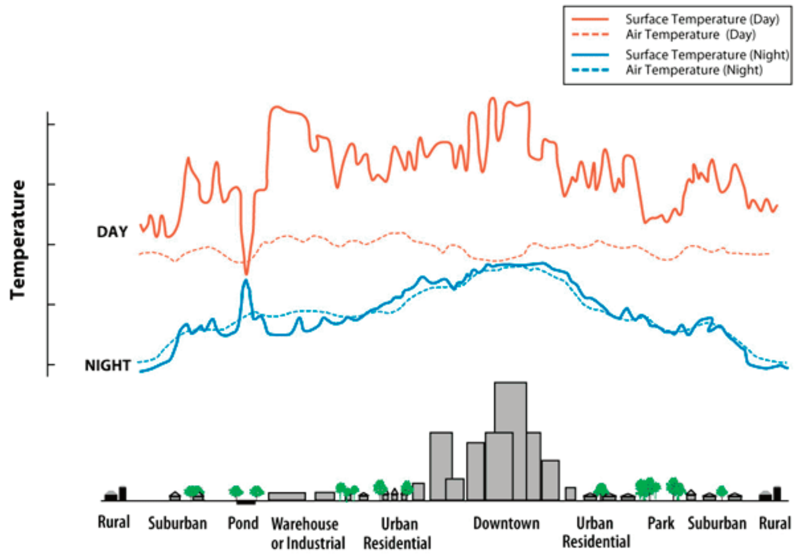

Fig. 12 - Schematic depiction of the UHI effect (EPA, 2008)

3.2.3. Air flows

On a global scale wind comes from air moving from high-pressure areas to low-pressure areas. the wind velocity and direction produced by the global weather systems are subsequently influence by the regional and landscape typology. The free undisturbed wind high above the surface of the earth is called the geostrophical wind. The geostrophical height varies from around 275 m to about 500 m depending on the roughness of the surface of the earth (RUROS 2002). In urban areas, main air flows from prevailing winds are strongly modified (Fig. 13), depending on constructions morphology and urban microclimate effects (Ahmed & Bharat 2012). In fact, buildings and other architectural structures obstruct the natural flow of breezes, making wind speeds noticeably lower in the cities and inhibiting cooling by convection. This prevents winds from carrying heat build-up away from the city and from assisting in the reduction of the heat island.

The direct effect of the wind can be divided into two main categories: the mechanical and thermal effects (Penwarden and Wise, 1975). Mechanical effect can be felt with wind speed above 4-5m/s. Above 10m/s an unpleasant condition occurs for pedestrian and above 15m/s there is a direct risk of accidents. Furthermore exposed building have critical areas, usually consisting in: those near the corners at the base of the building, which are effected by the side-stream effects; the base of a wide face of the exposed building where the downwash effect can take place; openings at the base of the building open to opposite aspects of the base of the tall building subject to the gap effect (Fig. 14).

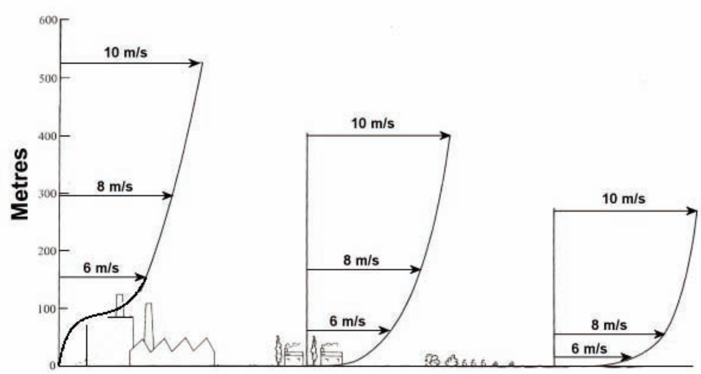

Fig. 13 - Wind speed variation according to height and environment (http://www.wind-power-program.com)

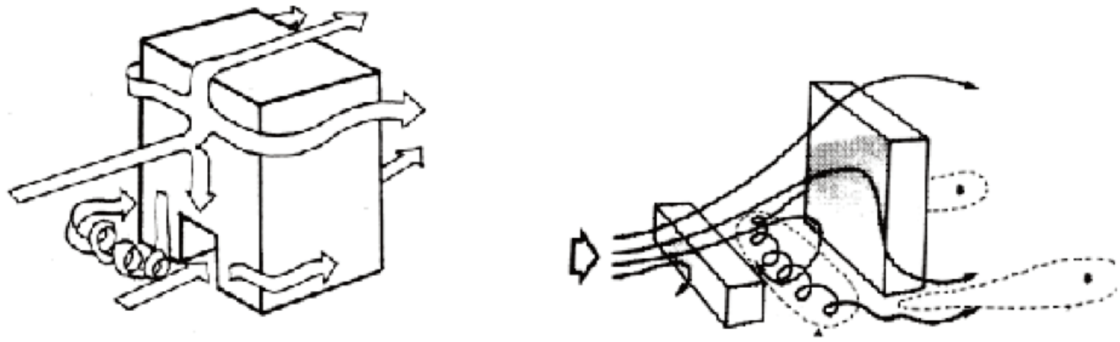

Fig. 14 - Wind movements in and around an exposed building (left) and flaw patterns around tall, slab-like buildings (right) (Penwarden and Wise, 1975)

Notes

1) Cf. Chapter 4, Paragraph 4.1., p. 71.

2) It was first published by Russian German climatologist Wladimir Köppen in 1884, with several later modifications by Köppen himself, notably in 1918 and 1936. Later, German climatologist Rudolf Geiger collaborated with Köppen on changes to the classification system, which is thus sometimes referred to as the Köppen–Geiger climate classification system.

3) *Decreto del Presidente della Repubblica 26 agosto 1993, n.412 - Regolamento recante norme per la proettazione, l'installazione, l'esercizio e la manutenzione degli impianti termici degli edifici ai fini del contenimento dei consumi di energia, in attuazione dell'art. 4, comma 4, della legge 9 gennaio 1991, n. 10* (Rules for the design, the installation, the use and the maintenance of thermal systems in buildings aimed to reduce the energy consumption).

4) This factor assumes great importance, because it acts directly on the temperatures and the pluviometric indexes in the different areas of the country.

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Photo references

Photo 1 - Photo of the Author

CHAPTER 4
Comfort and Environmental Control

4.1. Indoor Comfort and Energy Efficient Buildings

It was between the '60s and the '70s that buildings became significant consumers of energy due to the application of mechanical systems in their environmental control. This "transition" was described in those years by Rayner Banham in his seminal work "The Architecture of the Well-Tempered Environment" of 1969. There he defined three distinct modes of environmental control that may be applied in architecture: the *Conservative*, the *Selective* and the *Regenerative*[1]. The first mode, defined by Banham as "the ingrained norm of European culture", aims to mitigate thermal fluxes by thermal storage, primarily by massive walls. The second mode eliminates unwanted conditions and is always combined with the *Conservative* in elements such as windows, shades and ventilation devices. The third mode uses energy in the form of heating or cooling and introduces artificial light.

In traditional construction, all three modes are employed but most built forms tend towards one or other mode. Banham claims that the Conservative/Selective mode «...sees power consumption as an embarrassing aberration. Their embarrassment was fortified in the Sixties and Seventies by the growing tide of concern about pollution, energy costs and the depletion of finite natural fuel resources...»[2].

The debate on the relationship between buildings and environment in the '60s was also enriched by Victor Olgyay 's contribute, that supported the importance of the integration between architecture and nature, also providing a first attempt to put into relation climate and comfort in given conditions. By emphasising the concept of "design with climate", Olgyay made one of the first significant gestures of resistance to the common assumption in mid-twentieth-century thinking that technology provided the solution to most problems, arguing that mechanical systems should only be considered in the final stage of a design project rather than as the primary instrument of mediation ((Hawkes et al., 2002). This is well expressed by his "Flattening the curve" (Fig.2) that shows the sequence of actions in proceeding from the varying external environment to the more stable condition of comfort.

In 1980, Dean Hawkes adapted Banham's categories in order to make a clear distinction in environmental design strategy that could be observed in contemporary design practice.

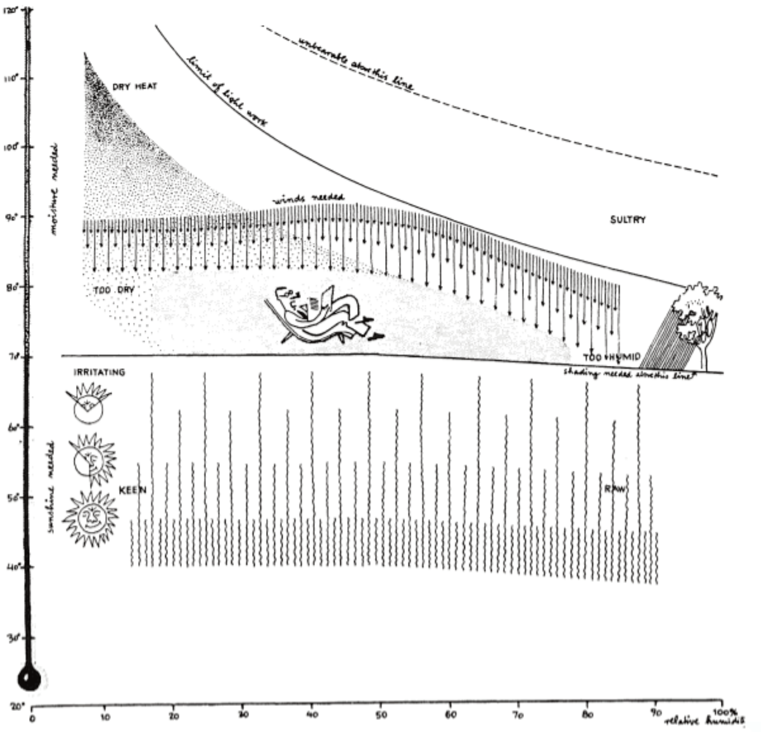

Fig. 1 - Bioclimatic Chart (Olgyay, 1963)

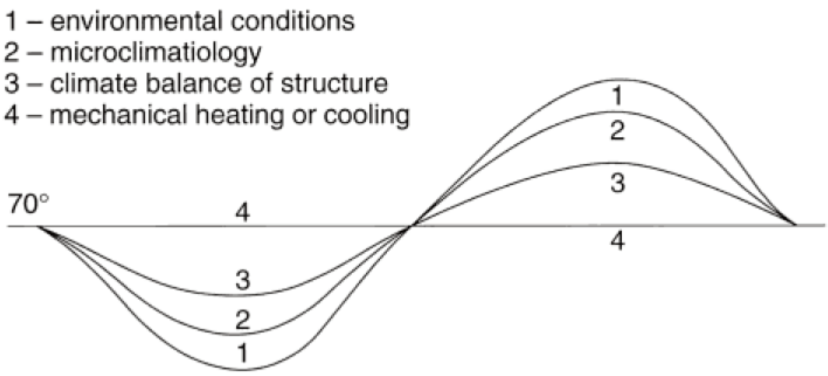

Fig. 2 - Flattening the curve (Olgyay, 1963)

This defined two modes of environmental control, the *Exclusive* and the *Selective*, whose principal characteristics are summarized in Fig 3. These modes correspond precisely to distinction between “global” (*Exclusive*) and “regional” (*Selective*). This latter, in particular, denoted the possibility of making a return to a rich relationship between climate and comfort in which a building is understood as a complex system of interrelated uses, spaces, materials, components and energy sources.

Exclusive Mode	*Selective Mode*
Environment is automatically controlled and is predominantly artificial.	*Environment* is controlled by a combination of automatic and manual means and is a variable mixture of natural and artificial.
Shape is compact, seeking to minimize the interface between exterior and interior environments.	*Shape* is dispersed, seeking to maximize the potential collection and use of ambient energy.
Orientation is disregarded.	*Orientation* must be carefully observed.
Windows are generally restricted in size.	*Window* size varies with orientation, large on south-facing facades, restricted to the north.
Energy is primarily from generated sources and is used throughout the year in relatively constant quantities.	*Energy* combines ambient and generated sources. The use varies seasonally, with peak demand in winter and "free-running" operation in summer.

Fig. 3 - General characteristics of Exclusive and Selective mode buildings (Hawkes, 1980)

As Hawkes et al. (2002) state

«… "selective design" was conceived with reference to the temperate climate of Northern Europe. This, with its relative absence of extremes, but with clear-cut seasonal variations, leads to a "selective" architecture which expresses, in its form and detail, the environmental differences between northerly and southerly aspects, with plan, form and cross-section being relatively elaborate to maximise the interface between internal and external environments, and with glazing concentrated to the south to exploit useful solar gains to supply space heating in the winter months. From these factors, a distinctive architectural language emerges which is, in some respects, a formal analogue of the conditions of climate in which it is located […]. In extending these original principles to the global context, this specific relationship between form and environment must be reconsidered...».

Moving to the tropical and equatorial regions, where seasonal differences in climate are significantly reduced in comparison with the higher latitudes, the form and environment is further transformed.

According to different climates, Olgyay identifies four main settlement typologies:

- Cold Climate: Compact building shape;
- Temperate Climate: Different building shape according to the environmental context;
- Hot-humid Climate: Lengthened building shape along the NW-SE axes, with wide openings on the main facades to enhance natural ventilation;
- Hot-dry Climate: Closed patio building shape, with high thermal mass envelope and few openings.

In the course of history, indeed, traditional architecture produced a large repertory of buildings typologies derived from the adaptation to the available resources - materials, technologies, knowledge and competence - and deeply tied to the environment and the climatic context (Fig. 4).

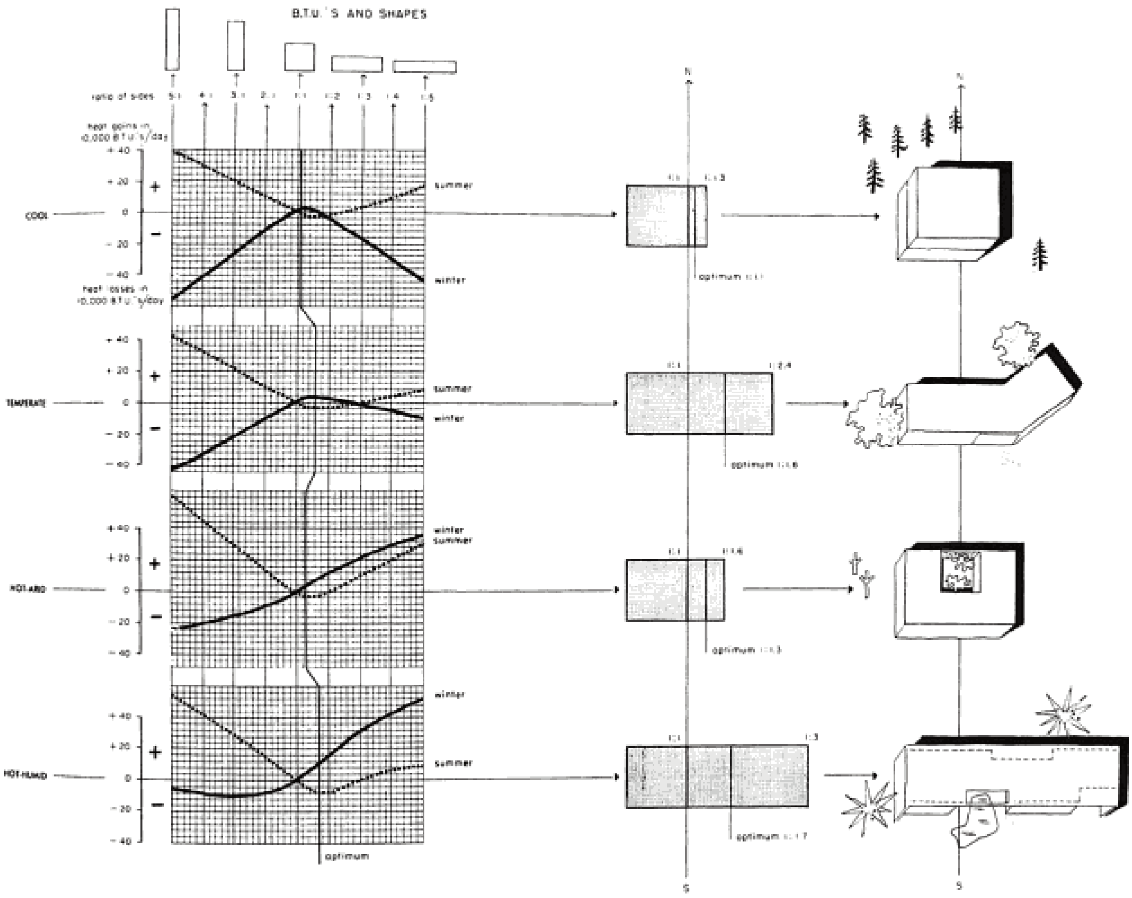

Fig. 4 - Classification of environmentally determined building forms (Hawkes, 2002)

Because of the improvement of building techniques that occurred following up the II World War and the large availability of fossil fuels, since the second half of the XX century, traditional technologies for buildings comfort were generally disregarded and substituted by systems related to the engineering of single buildings components, acting independently one from the other. These design and constructive practises had as a consequence the negation of a holistic approach at the basis of the project origination, where structure, architecture and environment are indissoluble aspects. The result is a huge quantity of energy consumed by buildings where, in most cases, sealed envelopes combined with mechanical and electrical service systems allow the internal environment to be almost entirely artificial.

Notwithstanding, today issues related to climate changing, environmental protection and fossil fuels supply have called new attention to bioclimatic design approaches and to the research of techniques and principles for reducing the environmental footprint for buildings construction and management in order to minimize the energy needs of the building and to create a more comfortable environment in relation to contemporary users' lifestyles.

Sustainable design principles are generally distinguished in:

- Passive strategies, that, in order to achieve adequate indoor comfort levels, use ambient energy sources instead of purchased energy like electricity or natural gas, including evaporative cooling, daylighting, natural ventilation, heat gain and solar radiation control.
- Active strategies, that use purchased energy to keep the building comfortable from renewable energy sources such as photovoltaic, solar panels, wind turbines, biomass and geothermal.

Regarding the two strategies listed above, most academics and professionals (Green, 1979, Akbari, 1992, Grosso 2011, among others) agree upon the fact that a hierarchy should be considered during the design process of a building, according to Fig. 5, giving priority to the urban passive design meant as the fundamental aspect for the enhancement of the outdoor comfort and for the energy regulation of the buildings. On the contrary, active systems for the production of energy from renewable sources should be considered as last step of the entire design process.

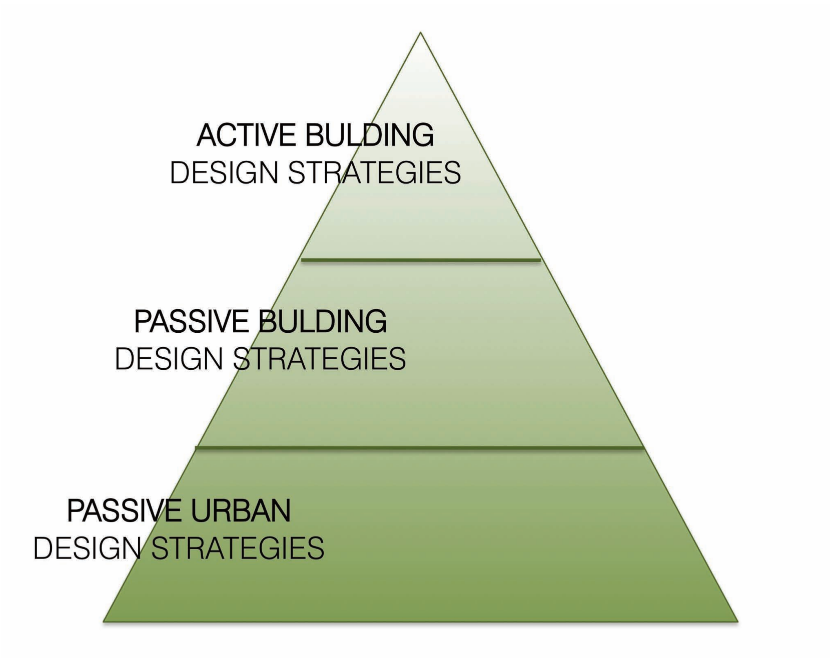

Fig. 5 - Sustainable design strategies pyramid (Drawing of the Author based on lecture held by Poul Bæk Pedersen during the Urban Design Studio Workshop, Aalborg University, Sept. 9th, 2012)

4.2. Systems for passive cooling

4.2.1. Microclimate control

In 1979 K. W. Green claimed «…If the best offense is a good defense, the best passive cooling strategy pays as much attention to the microclimate surrounding a building as to the building itself...»[3].

Several researches have demonstrated that landscaping, built environment and vegetation can have a tremendous impact on thermal comfort inside a building, affecting both summer cooling and winter heating loads. The presence of plants and of water, as well as the albedo control of the built environment surfaces are the main strategies to improve the outdoor thermal comfort during the warmest days.

4.2.1.1. Water and evaporative cooling

Evaporative cooling is one of the most effective techniques that can be used in order to reduce outdoor air temperature especially in climates of low relative humidity. It can occur through the presence of fountains or water pools. Evaporation from the water cools the air immediately around it, which becomes heavier and spills away from the pool and into the surrounding spaces. Evaporative cooling can also consists in the production of an "artificial fog" by means of nebulizers that inject high pressure water in the air through tiny openings. The generated minuscule drops evaporate immediately, taking the heat out of the air and, consequently, cooling it down. This strategy can also be put to work to cool a radiative roof deck or any other radiative surface in contact with interior spaces. If a roof is sprayed with water, evaporation cools the roof surface, encouraging its absorption of heat from the interior and the dispersal of that heat into the atmosphere.

Photo 1 and 2 - Two example of evaporative cooling strategie: systems of fountains in the XII cent. arab building "La Zisa" in Palermo (left) and nebulizers installed in a square in Padua, Italy (right)

4.2.1.2. Vegetation

The evaporative cooling process can also occur through the leaves of trees. Combined with air movement, the evaporation of water into the air that occurs in plant transpiration has an evaporative cooling influence. Moreover, leaves reflect infrared, heat-bearing energy and filter cool, green light to the ground.

The general effect in an area of massed vegetation is to keep temperatures in the shade significantly lower then the ambient.

In the course of history, the integration of vegetation with buildings has always been a common architectural practice: whether simply low-tech way of providing shade or part of more sophisticated building components, plants were often considered as an integral design element because of the environmental benefits they offer. A in-depth analysis of the effect of vegetation on microclimate is provided in Chapter 5.

Photo 3 and 4 - Two example of use of vegetation for microclimate amelioratioin: Energy and Environmental Building of theTsinghua University in Beijing (left) and a house in San Francisco (right)

Photo 5 - Use of vegetation at urban scale: the Ibirapuera Park in São Paulo, Brazil

4.2.2. Heat gain and solar radiation control

The temperature of a building envelope surface exposed to the sun depends on the entity of the solar radiation and on the characteristics of thermal exchange of the surface itself. The control of this temperature, in order to reduce the heat gain inside the building during the warmest days, can hence occur through the choice of proper technical elements of the building closures, taking mainly into account:

- the possibility to provide shade to opaque and transparent surfaces.
- the possibility to create a discontinuity between the layers of the closures;
- the kind of material for the finishing of the surface, in terms of material, colour, raughness.

4.2.2.1. Shading devices

Well-designed shading devices can significantly reduce building peak cooling load and energy consumption, while enhancing daylight utilization in buildings. Shading devices can also avoid glare by reducing contrast ratios of building interior. This can be achieved by designing location-specific wide eaves or overhangs above the Equator-side vertical windows (South side in the Northern hemisphere, North side in the Southern hemisphere).

Shading of external windows can be provided by natural landscaping such as trees and hills, or by building elements such as overhangs, awnings, fins and trellises. Some shading devices -called light shelves- can also act as light reflectors to channel sunlight into the deep building interior. Installing fixed shading devices can be an efficient way to provide thermal and visual comfort to building occupants. The design of fixed shading devices will depend on the daily and yearly variation of solar position. For example, the use of overhangs is most effective on the south-facing window in summer when sun angles are high. In winter, overhangs allow the low winter sun to enter south-facing windows. However, the same horizontal device is ineffective at blocking low morning and afternoon sun from entering east- and west-facing window respectively in winter.

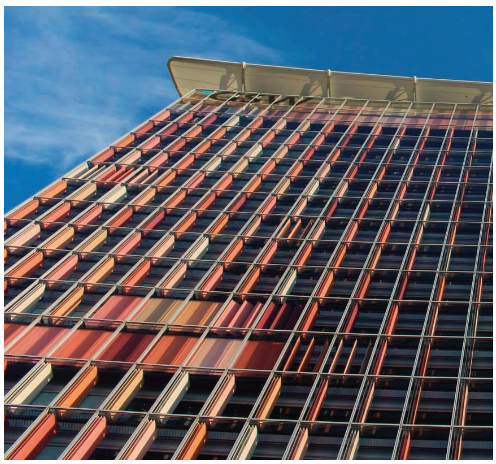

Photo 6 and 7 - Two example of shading devices: Distorted Courtyard House in Beijing (left) and the GSW headquarter in Berlin (right)

4.2.2.2. Ventilated façades and roofs

Ventilated façades consist in the positioning of modular elements made on proper support structure anchored at a distance to the external wall in order to create an air gap between the two elements. The modular elements are left open at the top and bottom of the wall allowing the passage of an air flux for the dissipation of heat accumulated in the external walls.

The external layer of a ventilated façade can be made of different material such as stone, glass, ceramic tiles, fibrocement and metal. Recently photovoltaic ventilated façades and roof systems have also been launched on the market.

Ventilated roofs have an analogous functioning: the layers of the roof are organized so that an upward motion of the air is created: fresh air coming from outside enters through the drip getting warmer until coming out from the roof top. This system is usually applied for pitched roof but also for plane roof, even if with lower efficacy (Grosso, 2011).

4.2.2.3. Cool roofs

Reflective surfaces are artificially-altered surfaces that can deliver high solar reflectance (the ability to reflect the visible, infrared and ultraviolet wavelengths of the sun, reducing heat transfer to the surface) and high thermal emittance (the ability to radiate absorbed, or non-reflected solar energy). The most well-known type of reflective surface is the cool roof that reflects and emits the solar heat back to the sky instead of transferring it to the building below. Solar reflectance and thermal emittance are both measured from 0 to 1 and the higher the value, the cooler the roof. Cool roof can be made of different finishing products including asphalt shingles, coatings, membranes, metal roofings and tiles. The acknowledged benefits provided by cool roofs regard not only the possibility to reduce building heat-gain (saving up to 15% the annual air-conditioning energy use of a single-story building), but also the mitigation of the urban heat island effect (U.S. Department of Energy, 2010).

Photo 8 - Ventilated façade made of glazed, photovoltaic and opaque elements in the GENyO building of Granada

Photo 9 - Experimental cool roof made of eco-friendly white organic water paint in Trapani, Sicily

4.2.2.4. Thermal inertia

Thermal inertia of a closure, in relation to the variation of the outdoor temperature or heat flux, assumes a higher importance in summer than in winter. In fact, during the warmest days, because of the variability of the climatic conditions of both indoor and outdoor environment, the thermal behaviour of a component of the building envelope cannot exclude an evaluation on the dynamic effects. As soon as the ambient temperature rises, any building material absorbs a certain amount of heat. This amount of heat per square meter is known as the thermal capacity: the greater the mass of the material, the higher the value. The control of thermal inertia of the building envelope can be operated through the assessment of two parameters: the thermal phase displacement and the thermal damping that can be defined respectively as the ability in delaying and in reducing the effect of a thermal solicitation/temperature variation. In order to optimize the energy performance of a building envelope during the warm seasons, the components of the façades need to have high thermal phase displacement and a damping of about 12 hours (Grosso, 2011). The use of heavyweight construction materials with high thermal mass (concrete slab on ground and insulated brick cavity walls), indeed, allows reducing the thermal flux energy that reaches the internal surface only in the coolest hours of the day when it can be easily dissipated through the natural ventilation of the indoor environment.

In summer, in particular, thermal mass absorbs heat that enters the building. In hot weather, thermal mass has a lower initial temperature than the surrounding air and acts as a heat sink. By absorbing heat from the atmosphere the internal air temperature is lowered during the day, with the result that comfort is improved without the need for supplementary cooling. During the night, the heat is slowly released to passing cool breezes (natural ventilation), extracted by exhaust fans, or released back into the room itself (Fig. 6). Inside temperatures at nighttime will be slightly higher than if there was low thermal mass, however with the cooling night effects, temperatures are still within the comfort zone (unless a long spell of consistently hot days and nights is experienced).

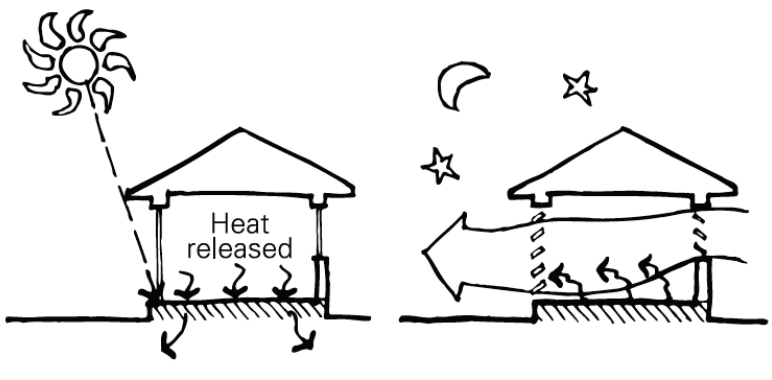

Fig. 6 - Thermal mass effect in the daytime and at night (TerraSolar, 2013)

4.2.2.5. Glazing systems

Glazed surfaces are by their nature highly thermal emissive. In recent years, to improve their thermal efficiency, glazing options available to designers has expanded greatly and glazing performance can be altered by varying tints, coatings, films, number of panes, and other features.

The characteristics of glazing systems are expressed through the following technical terms:

- Visual Transmittance (Tv) indicates the proportion of visible light that passes through a glazing system. Glazing systems with high values of Tv (0.7 to 0.9) provide lots of natural light, but they can also be a source of unwanted glare if not properly controlled. Systems with lower values of Tv (less than 0.4) can be visually distorting and quite gloomy on cloudy days.
- Solar Heat Gain Coefficient (SHGC) and Shading Coefficient (SC) are both measures of a glazing system net solar gain.

SHGC, is the sum of the solar radiation transmitted through the glazing and the portion of absorbed energy that ends up supplying heat inside. Glazing systems with high SHGCs (0.7 to 0.9) provide substantial solar gain, whereas those with low values (0.2 to 0.4) provide little solar gain.

The SC expresses the net solar energy delivered by a given glazing system in relation to how much is transmitted through clear float glass 3 mm thick under the same circumstances.

- The light-to-solar-gain (LSG) ratio is a useful index to compare how much light (and visibility) a glazing system provides in proportion to how much solar gain it produces. Systems with an LSG ratio greater than 1 provide more light than heat.
- U-value (also known as U-factor) expresses how much energy a glazing system transfers by conduction and convection. The lower the U-value, the more resistance a glazing system poses to heat transfer.

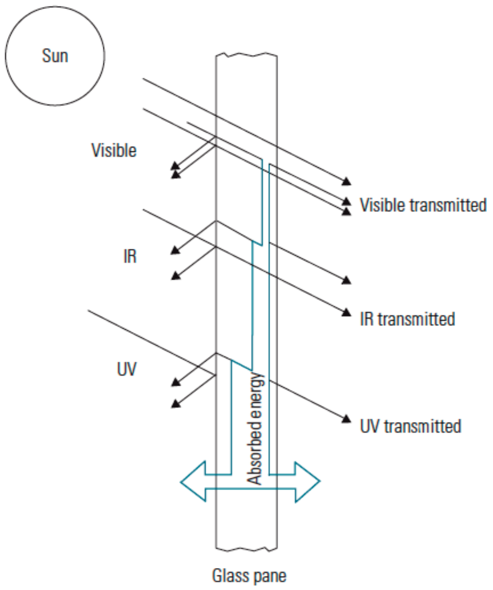

Fig. 7 - Heat and light reflectance and trasmission in a glazing system: when the sun's rays strike the pane of a glass, they are in part reflected, in part absorbed and in part transmitted (Southern California Edison, 2000)

In temperate and hot climate areas, building should be provided with appropriate windows and glazing to minimise unwanted heat gains and maximise ventilation.

Insulated glazing, for example, are double or triple glass windowpanes separated by an air or other gas filled space to reduce heat transfer across a part of the building envelope. The maximum insulating efficiency of these kind of glasses is determined by the thickness of the space containing the gas and the thermal conductivity of the gas itself[4].

Low e-glasses, instead, are glass panes coated with a low-emissivity substance able to reflect radiant infrared energy, encouraging radiant heat to remain on the same side of the glass from which it originated, while letting visible light pass. This often results in more efficient windows because radiant heat originating from indoors in winter is reflected back inside, while infrared heat radiation from the sun during summer is reflected away, keeping it cooler inside. Low-e metal based coating are able to lower the glass emissivity to values comprised between 0.8 and 0.1. The thermal losses in the window cavity are significantly reduced, hence improving the thermal insulation. The characteristics of these glasses are the high level of visible transmittance and thermal gains. These coatings reflect radiant infrared energy, thus tending to keep radiant heat on the same side of the glass from which it originated, while letting visible light pass. This results in more efficient windows, especially for temperate climate areas, because radiant heat originating from indoors in winter is reflected back inside, while infrared heat radiation from the sun during summer is reflected away, keeping it cooler inside. Nevertheless, it is necessary to verify the real efficiency of this kind of glazing, not only in relation to the thermo-physical parameters, but also to the specific building and climate conditions.

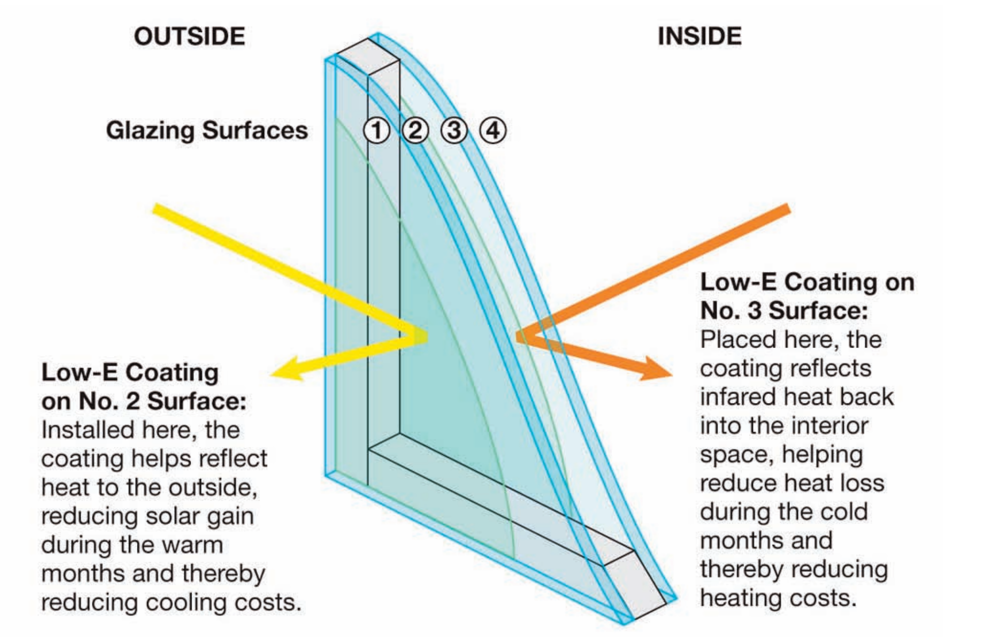

Fig. 8 - Performance of glazing systems with low-e coating (Hren, 2012)

4.2.3. Natural ventilation

Ventilating is the process of changing or replacing air in any space to provide high indoor air quality (i.e. to control temperature, replenish oxygen or remove moisture, odors, smoke, heat, dust, airborne bacteria, and carbon dioxide). Failure to provide adequate ventilation in a building can result in problems with moisture, unpleasant smell, lack of oxygen, and unacceptable content of poisons gases such as CO_2 which cause medical conditions for occupants (Lien and Ahmed, 2011).

Natural ventilation is the ventilation of a building with outside air without the use of fans or other mechanical systems. Most often it is assured through operable windows but it can also be achieved through temperature and pressure differences between spaces.

Usually natural ventilation refers to two types of situation that can occur in buildings: *wind-induced ventilation* and *buoyancy-driven ventilation*. In the first case the wind is the main mechanism ventilation, while in the second case the ventilation occurs as a result of the directional buoyancy force that results from temperature differences between the interior and exterior (stack effect).

4.2.3.1. Wind-induced ventilation

When wind meets an obstruction such as a building, it is deflected and due to its momentum this creates positive and negative pressures over the surface of the building. The pressure distribution map is complicated and non-uniform, even over an individual surface, but is generally positive on the windward side, and negative over the roof and leeward side. Ventilation air will flow between any two points on the envelope at a different pressure if openings are provided in the envelope at those points (Fig. 9). For this reason wind-induced ventilation is most commonly realised as cross-ventilation, where air enters on one side of the building, and leaves on the opposite side, but can also drive single sided ventilation (Fig. 10), and vertical ventilation flows.

The openings can be windows, but there also exist other forms of controllable slots, grilles and louvres, where the ventilation function has been separated from the daylight and view function.

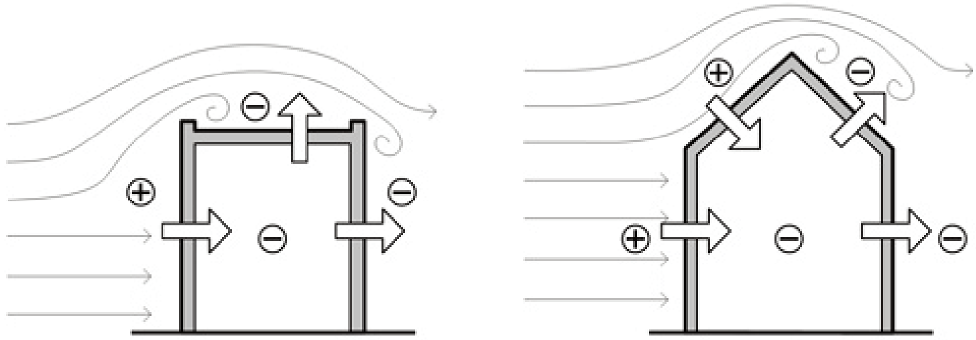

Fig. 9 - Wind Pressure Effects on Representative Buildings (Straube, 2007)

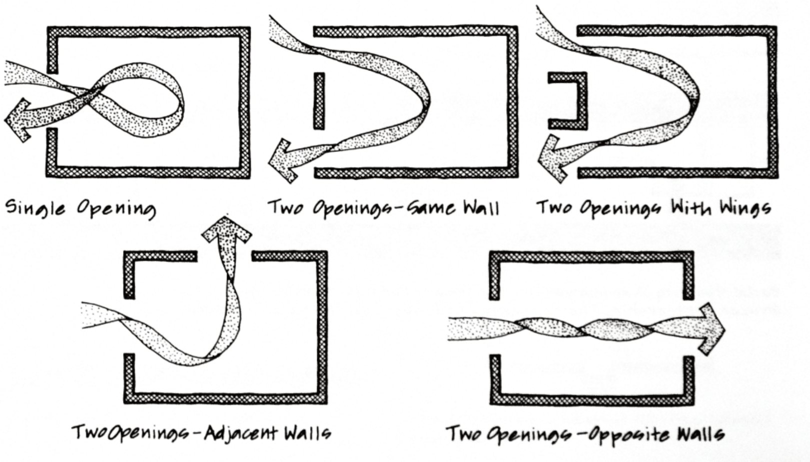

Fig. 10 - Single-sided and cross ventilation (Brown and DeKay, 2013)

4.2.3.2. Buoyancy-driven ventilation

Buoyancy-driven natural ventilation, also known as stack ventilation, can operate when no wind pressure is available. It can also operate in deep plan buildings where the distance from openings in the perimeter, and the presence of partitions, make wind-driven cross ventilation impractical. It takes place when the average temperature in the stack is greater than the outside air. Three distinct situations can be identified:

- where the stack is formed by the occupied part of the building itself;
- where the stack exists in the occupied space but where the space is tall (such as in an atrium) and the heated air is well above the heads of the occupants;
- as a separate element such as wind tower or chimney (Fig. 11).

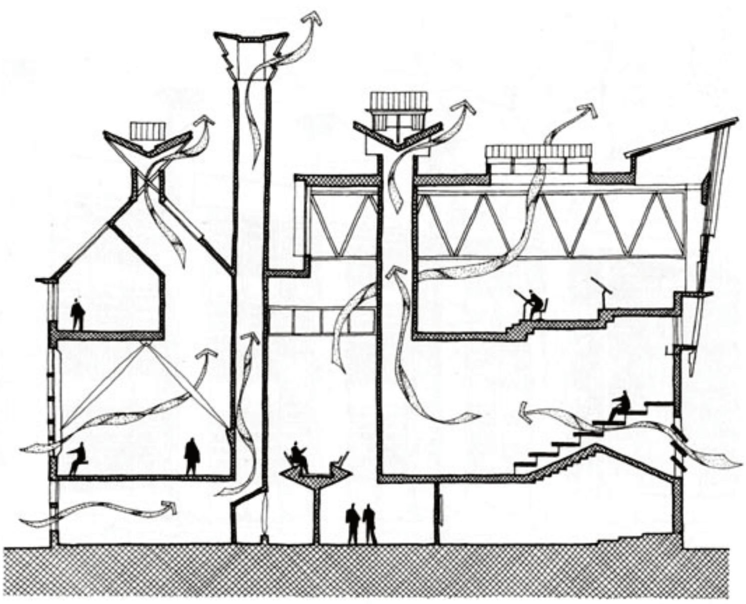

Fig. 11 - Example of Buoyancy-driven ventilation (Brown and DeKay, 2013)

4.3. Methods for comfort assessment

One of the central themes of contemporary urban and building physics has been to establish an objective understanding of the relationships that exist between the environmental conditions and the human responses to these conditions.

R.G. Hopkinson (1964), made a distinction between two kinds of "stimulus-response" relationship, which he called the "linked" and "unlinked" relationships. The first kind refers to the cases in which the more (or the less) we have of a particular element of the physical environment the most we feel comfortable (as generally applies in the case of light, where visual acuity improves as illuminance increase or, on the contrary in the case with noise) and the second kind occurs when the relationship with external stimulus is more complex. For example, if we consider the way in which we respond to the stimulus of heat, we are comfortable at some intermediate point, when neither too cold nor too hot. Also, in the case of visual comfort, the effect of high levels of illuminance can often lead to the experience of glare, when some brightly lit places become uncomfortable.

The observable relationships between a property that may be measured and predicted, related to the desired environment within a building and the conditions that support human activity, underlie the codified environmental standards which are the basis of modern environmental design practice.

The design manuals contain tables of recommendations for temperatures, light levels and noise levels deemed congenial for the performance of an enormous range of activities. However, several researches demonstrated that the nature of comfort is more complex than what is implied by these simple prescriptions. Regarding thermal comfort, it can be shown that the interaction between human body and the environment is more than a matter of specifying air temperature.

Important researches undertaken in different parts of the globe (Humphreys, 1975; de Dear and Brager,1998), for example, show very clearly that the thermal comfort is not a matter of simple physiology, in which optimum conditions may be universally proposed. The findings confirmed, e.g., the "common-sense" perception that people living in hot places are comfortable at higher temperature than those who live in cooler places.

Humphrey's work revealed another important relationship between people, climate, comfort and the nature of the buildings when he discovered that there is far less tolerance of variations of temperature in air-conditioned buildings than in those which he called "free-running", that is a building that mediates between the internal and the external environments solely through the capability of its form and fabric. For this reason, depending on circumstances, different comfort model can be used. Currently, when discussing thermal comfort, there are two main different models recognized by the international standards: the static model (PMV/PPD) and the adaptive model.

4.3.1. The Static Comfort model: PMV/PPD

The static model is based on the physiological approach, according to which the comfort zone can be the same for all occupants, disregarding location and adaptation to the thermal environment (La Roche, 2011). It basically states that the indoor temperature should not change as the seasons do. Rather, there should be one set temperature year-round. This is taking a more passive stand that humans do not have to adapt to different temperatures since it will always be constant. This model is based on the Predicted Mean Vote/Predicted Percentage of Dissatisfied (PMV/PPD) model, that uses the formula developed by P. O. Fanger. The PMV is the average comfort vote, using a seven-point thermal sensation scale from cold (-3) to hot (+3), predicted by a theoretical index for a large group of subjects when exposed to particular environmental conditions. Zero is the ideal value, representing thermal neutrality. This model was originally developed by collecting data from a large number of surveys on people subjected to different conditions within a climate chamber. These data were then used to derive a mathematical model of the relationship between all the environmental and physiological factors involved. The comfort zone is defined by the combinations of the six key factors for thermal comfort for which the PMV is within the recommended limits (-0.5<PMV<+0.5). The PMV model is calculated with the air temperature and mean radiant temperature in question along with the applicable metabolic rate, clothing insulation, air speed, and humidity. If the resulting PMV value generated by the model is within the recommended range, the conditions are within the comfort zone[5].

The PPD is related to the PMV as is defined as an index that establishes a quantitative prediction of the thermally dissatisfied people assuming that who votes -2, -3, +2 or +3 on the thermal sensation scale is dissatisfied. The model is also based on the simplification that PPD is symmetric around a neutral PMV.

The Fanger model has been widely validated in case of artificial cooling/heating but it has not been significantly verified for hot and temperate zones (especially where the maximum temperature are over 35°C) and in case of natural ventilation (Grosso, 2011).

Category	Thermal state of the body as a whole	
	PPD %	Predicted Mean Vote
I	< 6	-0,2 < PMV < + 0,2
II	**< 10**	**-0,5 < PMV < + 0,5**
III	< 15	-0,7 < PMV < + 0,7
IV	> 15	PMV<-0,7; or +0,7<PMV

Table 1 - Example of recommended categories for design of mechanical heated and cooled building according to the PMV model (EN 15251:2007)

4.3.2. The Adaptive Comfort model

Some academics studies other models that, starting from the Fanger studies, can be better adapted to hot climate conditions. With regard to this, the adaptive model has been introduced by ASHRAE 55-2004 and EN 15251:2007 to apply especially to occupant-controlled, natural conditioned spaces, where the outdoor climate can actually affect the indoor conditions and so the comfort zone.

The model is based on the concept that the indoor thermal conditions are regulated directly through opening and closing of windows, based on several studies by de Dear and Brager which show that occupants in naturally ventilated buildings are tolerant of a wider range of temperatures during different times of the year. The adaptive hypothesis predicts that contextual factors and past thermal history modify building occupants' thermal expectations and preferences (de Dear and Brager, 1998).

The comfort temperature is defined according to the running mean of the outdoor temperature using the formula

$$T_{comf} = 0.33\ Trm + 18.8$$

where T_{rm} is the Outdoor Running mean temperature (°C).

The Outdoor Running mean temperature can be calculated with the simplified formula

$$T_{rm} = (1-\alpha)\ T_{ed-1} + \alpha\ T_{rm-1}$$

where T_{ed-1} is the running mean temperature for previous day;
T_{rm-1} is the daily mean external temperature for the previous day and
α is a costant between 0 and 1 (EN 15251:2007 recommends to use 0.8)

The allowable maximum difference between this comfort temperature and the actual indoor operative temperature (Tdiff) is given in terms of the categories (Tdiff±2K for Category I, ±3K for II and ±4K for III). This means that the limiting temperatures vary with the running mean of the outdoor temperature (Fig. 12).

Above these temperature bands the building is assumed to be overheating (as in the MCBs buildings they are above the specified upper value of PMV) and below they are in compliance.

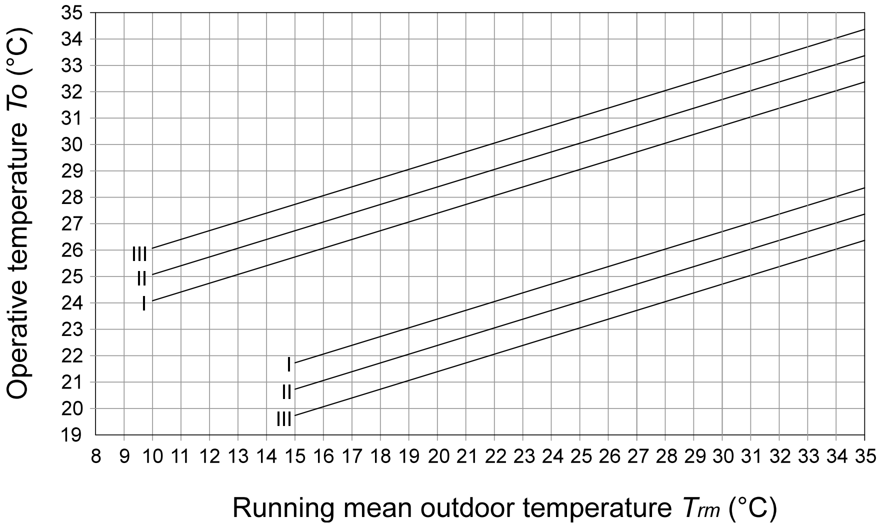

Fig. 12 - Design values for the indoor operative temperature for buildings without mechanical cooling systems as a function of the exponentially-weighted running mean of the outdoor temperature (Drawing of the Author based on EN 15251:2007)

Notes

1) Banham's classification was derived from empirical observation of historical building types and effectively served the ends of his primarily historical analysis.

2) Banham, R., *Architecture of the Well-Tempered Environment*, University of Chicago Press, 1984, p. 277.

3) Green, K. W., 'Passive Cooling: Designing Natural Solutions for Summer Cooling Loads', *Research and Design: The Quarterly of the AIA Research Corporation*, Vol. 11, N. 3, 1979, p.7.

4) Gas convective heat transfer is a function of viscosity and specific heat. Monatomic gases such as argon, krypton and xenon are often used since (at normal temperatures) they do not carry heat in rotational modes, resulting in a lower heat capacity than poly-atomic gases.

5) ASHRAE Standard 55-2010 sets an acceptable range of conditions that must be complied in order to apply this method and draw the comfort zone: occupants' metabolic rates between 1.0 and 1.3 met, clothing between 0.5 and 1.0 clo, air speeds under 0.2 m/s.

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Photo References

Photo 1 - http://www.unospiteapalermo.it

Photo 2 - http://www.archinfo.it

Photo 3 - Photo of the Author

Photo 4 - Photo of the Author

Photo 5 - Photo of the Author

Photo 6 - Photo of the Author

Photo 7 - Photo of the Author

Photo 8 - http://www.onyxsolar.com

Photo 9 - http://www.provincia.trapani.it

CHAPTER 5
The use of vegetation in the built environment

5.1. The integration of plants for the improvement of the urban environment

In the last century, increasing urbanization and industrialization have exacerbated the heat island. As cities have grown, increasing numbers of buildings have crowded out trees and other vegetation, deeply affecting global energy costs and the quality of urban life. In studying global change and long-term monitoring of the environment and man's effect on it, the necessity detailed and reliable spatial distributions of biophysical parameter is rapidly increased (Giordano, 2007). Researches that have been carried out in the last decades demonstrate that effective ways of mitigating heat islands exist, and that, fortunately, these methods are fairly simple and inexpensive to implement. In particular, there is a increasing interest and potential for studying the effect of vegetation on microclimate. In fact, vegetation plays a unique role in global climate change studies, regulating the energy, water and gas exchanges between the earth-atmosphere interface (Akbari, 1992; among others). Plants can improve the urban environment from both macro and micro perspectives. At the macro-level, large green areas benefit their surroundings. At the micro-level vegetation, strategically placed around the buildings as well as green roofs and living walls, can significantly improve the energy efficiency of the built environment. In a comprehensive consideration, vegetation is recognised to provide several benefits in relation to environmental, social and economic sustainability.

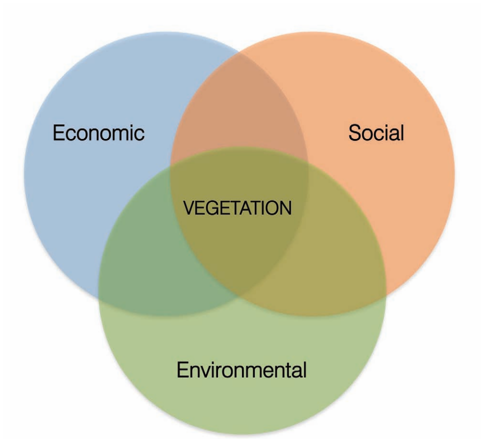


Fig. 1 - Mutual relationship between economic, social and environmental sustainability related to the use of vegetation in urban areas (drawing of the Author)

5.1.1. Environmental benefits

It has been widely demonstrated that the integration of trees, grass, shrubs, and other vegetal species, applied also in form of green roofs and walls, can have multiple effects on the environmental improvement of urban areas. The main repercussions are shown in succession.

5.1.1.1. Mitigation of the urban warming and enhancement outdoor thermal comfort

Generally, the way trees affect urban climates and building energy use is referred to two different effects provided: direct effects and indirect effects. The firsts refer essentially to the shading and lowering wind speed and the seconds to those effects that modify the surrounding urban environmental conditions, like evapotranspiration. In general, direct effects like shade accrue to one building while the benefits of indirect effects accrue to a whole neighbourhood or city.

Leaves and branches reduce the amount of solar radiation that reaches the area below the canopy of a tree or plant. The amount of sunlight transmitted through the canopy varies based on plant species and its related Leaf Area Index (LAI) value. In the summertime, generally 10 to 30 percent of the sun's energy reaches the area below a tree, with the remainder being absorbed by leaves and used for photosynthesis, and some being reflected back into the atmosphere. In winter, the range of sunlight transmitted through a tree is much wider (10-80%) because evergreen and deciduous trees have different wintertime foliage, with

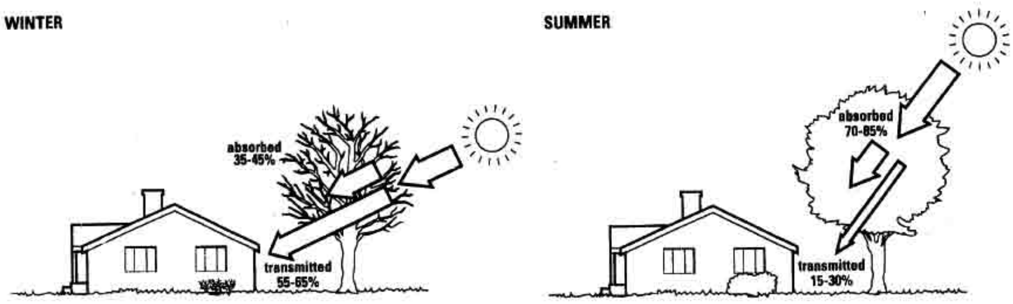


Fig. 2 - Dynamic relationship between shade trees and incoming solar radiation (Brown University, 2013)

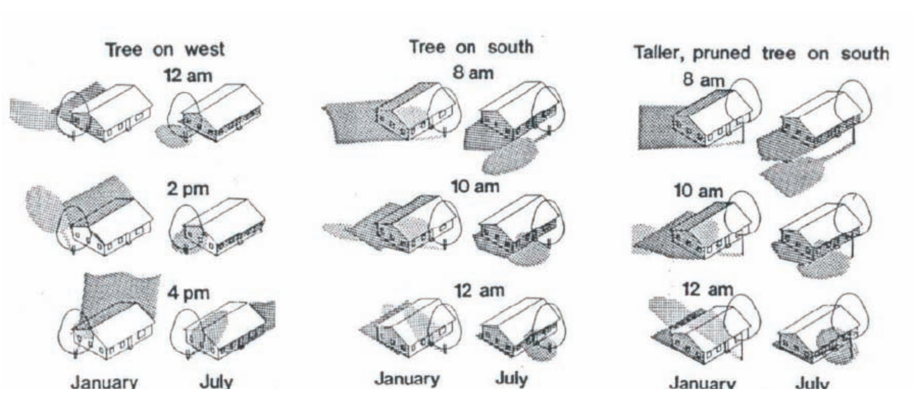


Fig. 3 - Study of shading provided by trees on west and south façade in summer and in winter (Heisler, 1986)

deciduous trees losing their leaves and allowing more sunlight through. The accurate choice of plant, hence, turns out to be of great importance. During the winter, e.g., shading is not desirable in temperate and cold climates, because it will increase heating needs and, on the contrary, blocking the wind could be beneficial in the coolest days. During the summer, the opposite is true: shading helps reduce energy needs, while wind screening can reduce cooling breezes. Trees shade reduces cooling energy use inside a building in three ways. First, shading windows prevents direct solar radiation from entering the structure. Second, shading walls, windows, and roofs keeps them from getting hot, thereby reducing the amount of heat reaching the interior. Third, shade similarly keeps the soil around a building cool, which can then act as a "heat sink" for the house. With regard to this, Akbari (1992) asserts that shade of trees can actually be more effective for cooling a building and its interior than other traditional shading devices such as venetian blinds, plastic coatings, or heavy, reflective coatings on glass.

Trees and other large vegetation can also serve as windbreaks or windshields to reduce the wind speed in the proximity of buildings. Indeed, the area within a single crown or stand of trees can be very calm, even when the wind is strong outside the stand. This is a benefit in the winter considering that such wind reductions can contribute to keep a building warmer. On the other hand, it can represent a detriment in the summer when cooling breezes are welcomed. It is possible, however, to plant trees around buildings to channel winds and create cooling ventilation. Taking into account all this factors, strategic planting can help to maximize the positive effects in both seasons, while minimizing the negative ones.

Studies conducted by Heisler (1989) and Santamouris indicate that, in a residential area, to an increase of 10% of the amount of trees corresponds a wind speed reduction of around 10-20%. Fig. 4 shows the relation between the wind speed and trees with different crowns formulated by Heisler in 1986. As it can be observed, the wind that encounters a group of trees with low dense foliage has a speed reduction up to 40% and the starting speed is taken back at a distance equal to 20 times the height of the tree. On the other hand, for very dense crowns, wind speed reduction can be up to 75% and the effect is protracted for a distance equal to 30 times the height of the tree.

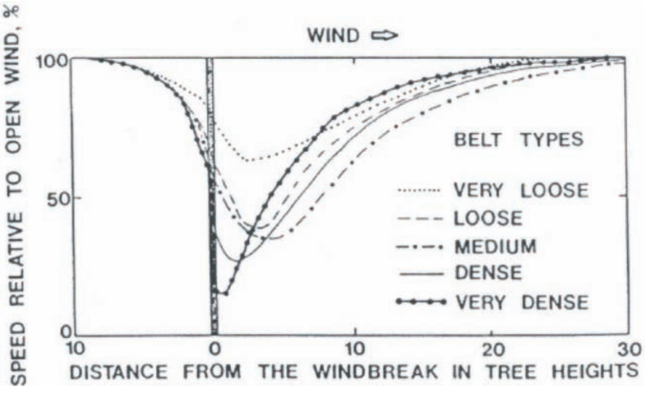


Fig. 4 - Reduction of wind speed (%) in relation to the distance to a group of trees with different crown densities (Heisler, 1986)

Besides the effect due to the shade they provide, plants contribute to the mitigation of the urban microclimate thanks to the evapotranspiration occurring through their leaves. Evapotranspiration (ET) is the sum of evaporation and plant transpiration. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies. Transpiration accounts when trees and vegetation absorb water through their roots and emit it through their leaves. Types of vegetation and land use significantly affect evapotranspiration, and therefore the amount of water leaving a drainage basin. Since water transpired through leaves comes from the roots, plants with deep reaching roots can more constantly transpire water. Herbaceous plants generally transpire less than woody plants because they usually have less extensive foliage. Conifer forests tend to have higher rates of evapotranspiration than deciduous forests, particularly in the dormant and early spring seasons. This is primarily due to the enhanced amount of precipitation intercepted and evaporated by conifer foliage during these periods (Swank and Douglass, 1974).

Potential evapotranspiration (PET) is the amount of water that would be evaporated and transpired if there were sufficient water available, that is the maximum amount of water vapor that can be returned to the atmosphere by evaporation or transpiration. This demand incorporates the energy available for evaporation and the ability of the lower atmosphere to transport evaporated moisture away from the land surface. It is directly dependent upon the temperature of an area so the greater the temperature, the higher the potential evapotranspiration. Since air temperatures are directly determined by insolation from the sun, this will also affect potential evapotranspiration. PET is also higher on windy days because the evaporated moisture can be quickly moved from the ground or plant surface, allowing more evaporation to fill its place.

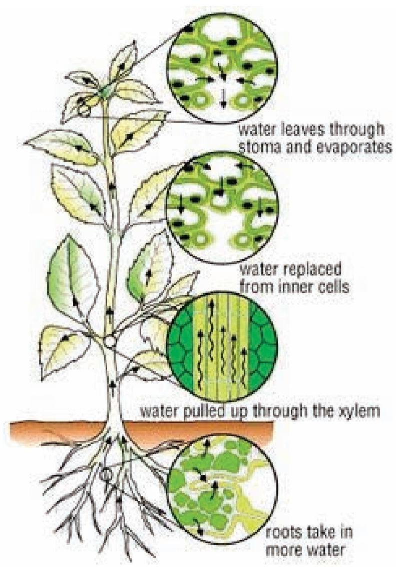


Fig. 5 - Plants take water from the ground through their roots and emit it through their leavesknown. Water can also evaporate from tree surfaces, such as the stalk, or surrounding soil (www.talktalk.co.uk, 2013)

Evapotranspiration, especially in combination with shading and ventilation, can help reduce peak summer air temperatures. Various studies (Huang et al., 1990; Kurn et al. 1994) have registered significant reductions including peak air temperatures in tree groves 5°C cooler than over open terrain, air temperatures over irrigated agricultural fields that are 3°C cooler than air over bare ground, suburban areas with mature trees that are 2 to 3°C cooler than new suburbs without trees and temperatures over grass sports fields that are 1 to 2°C cooler than over bordering areas (Photo 1). This is also true when green roof and/or living walls are integrated with buildings.

Numerous communities and research centers have compared surface temperatures between green and conventional roofs and walls. For example, in Chicago a comparison between summertime surface temperatures on a green roof with a traditional showed that on an August day, in the early afternoon, the green roof surface temperature ranged from 33 to 48°C, while the conventional roof of the adjacent building was 76°C (EPA, 2013). The near-surface air temperature above the green roof was about 4°C cooler than that over the conventional roof (Photo 2).

Photo 1 - Golden Gate park in San Francisco is a green area providing multiple environmental and social benefits to the city

Photo 2 - Temperature differences between a green and conventional roof in Chicago

5.1.1.2. Reduction of GHGs emission and improvement of air quality

The effect produced by plants shading and wind speed control have great repercussions inside the building, not only because cooler air coming from outside can improve the thermal indoor comfort but also because green roofs and living walls greatly contribute to the thermal performance of the building envelopes. The combination of these factor implies a less demands for cooling provided by electrical systems which also means that less CO_2 is emitted in the atmosphere because of building maintenance.

Furthermore it is common knowledge that plants are an effective tool in reducing air pollution and creating healthier urban environments.

Vegetation remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces (Smith,1990). Vegetation also removes pollution by intercepting airborne particles. Some particles can be absorbed into the plants, though most particles that are intercepted are retained on the plant surface. The intercepted particle often is resuspended to the atmosphere, washed off by rain, or dropped to the ground with leaf and twig fall (Novak et al., 2006). In the United States, the overall impact of a city's urban forest on concentrations of fine particulate pollution was estimated (Nowak et al., 2013), to assess how much fine particulate matter is removed by trees in 10 cities, their impact on PM2.5 concentrations and associated values and impacts on human health. The study demonstrated that, although the removal of PM2.5 by urban trees is substantially lower than for larger particulate matter, the health implications and values are much higher. The total amount of PM2.5 removed annually by trees varied from 4.7 metric tons in Syracuse to 64.5 metric tons in Atlanta. Most of these values were dominated by the effects of reducing human mortality; the average value per reduced death was $7.8 million. Reduction in human mortality ranged from one person per 365,000 people in Atlanta to one person per 1.35 million people in San Francisco.

Photo 3 - Vegetation contributes to the reduction of air pollution derived from transports

5.1.1.3. Fostering urban biodiversity

Plants in cities and towns, whether on streets, in parks, near the buildings or applied on the building envelopes provide a wealth of benefits relating to biodiversity. They are unique in their ability to support a great variety of wildlife in some of the harshest locations in our urban areas. Many of these species are relatively common and easily recognizable whilst others, such as bats and bees, are in decline (Trees for Cities, 2013). The European Commission declared that biodiversity loss has accelerated to an unprecedented level, both in Europe and worldwide, estimating that the current global extinction rate is 1000 to 10000 times higher than the natural background extinction rate. Natura 2000, the EUwide network of nature protection was launched since 1992 with the aim to assure the long-term survival of Europe's most valuable and threatened species and habitats. On April 2012 The European Parliament adopts resolution on the EU 2020 Biodiversity Strategy for the promotion and maintenance of healthy ecosystems that can protect the richness of biological diversities and help mitigate climate change impacts.

In an attempt to create or improve habitats for plants and animals in the cities, several programs have been also launched, such as the Trees for Cities' projects which operate in either streets or greenfield sites of urban areas with the aim to enhance the existing habitats of the site. Where projects take place on brownfield sites or where they involve a change of land use, detailed biodiversity audits to establish are undertaken to identify what wildlife they currently support and ensure.

The National Center for Ecological Analysis and Synthesis (NCEAS)[1] has been carrying out several studies to examine the relative impact of environmental and socioeconomic factors on urban biodiversity patterns across the United States in order to identify cities that support greater wildlife diversity and investigate which city policies may be contributing to their success (NCEAS, 2013).

Photo 4 and 5 - The integration of vegetation in the urban areas create healthy habitat for plants and animals

5.1.1.4. Reduction of storm-water runoff

Storm-water runoff is rainfall that flows over the ground surface. It is created when rain falls on roads, driveways, parking lots, rooftops and other paved surfaces that do not allow water to soak into the ground.

Storm-water runoff is the number one cause of stream impairment in urban areas. When rain falls on paved surfaces, a much greater amount of runoff is generated compared to runoff from the same storm falling over a forested area. These large volumes of water are swiftly carried to local streams, lakes, wetlands and rivers and can cause flooding and erosion, and wash away important habitat for critters that live in the stream.

Storm-water runoff also picks up and carries with it many different pollutants that are found on paved surfaces such as sediment, nitrogen, phosphorus, bacteria, oil and grease, trash, pesticides and metals. These pollutants come from a variety of sources, including pet waste, lawn fertilization, cars, construction sites, illegal dumping and spills, and pesticide application.

Researchers have found that as the amount of paved surfaces and impervious covers in the watershed increases, stream health declines accordingly. For this reason urban forests, green roof, living walls but also little areas of vegetation and soils can reduce storm-water runoff and adverse impacts to water resources. Trees and vegetation intercept rainfall, and the exposed soils associated with plants absorb water that will be returned to ground water systems or used by plants.

Rainfall interception works best during small rain events, which account for most precipitation. With large rainfalls that continue beyond a certain threshold, vegetation begins to lose its ability to intercept water although storm-water retention further varies by the extent and nature of a community's urban forest.

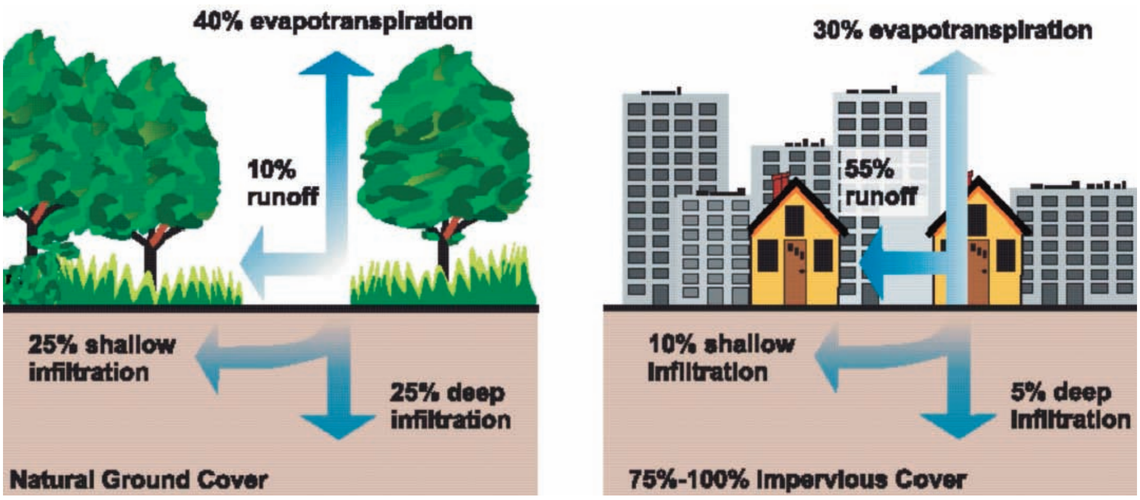


Fig. 6 - Retention of water in paved or asphalt surfaces and in soils (EPA, 2003)

5.1.1.5. Reduction of levels of noise exposure

Noise pollution has become a common problem in big cities and most of the noise is generated by transportation. The use of vegetation to provide screening has been studied by many researches. This is generally restricted to field measurement studies, although some tentative attempts have been made to develop mathematical models to describe the phenomenon (Kotzen and English, 2009). It was demonstrated that a row of trees and shrubs right positioned can reduce urban noise by 3 to 5 decibels, while wide, dense belts of mature trees can reduce noise by twice that amount, which would be comparable to noise reduction from effective highway barriers (EPA, 2009). Different research, e.g., were carried out to determine the effect of roadside vegetation on the reduction of road traffic noise levels under varying traffic conditions (Kalansuriya et al., 2009; among others) resulting that higher frequency noise is heavily attenuated by the vegetation barriers and that width of the vegetation barrier is linearly proportional to the amount of sound absorption.

Besides these characteristics, vegetation represents a good alternative to other noise screenings also from an economic point of view besides having natural appearance and being often pleasant in visually inspection. Vegetal barriers can be constituted by rows of trees or bushed, or consist in green walls.

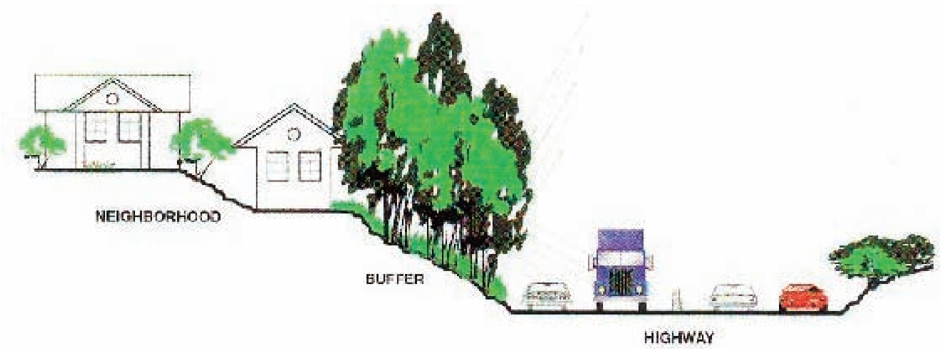


Fig. 7 - Schematic depiction of vegetation used as a buffer to reduce noise pollution (Texas Southern University, 2006)

Photo 6 - Vegetation used on the road side as noise barrier

5.1.2. Economic benefits

The primary costs associated with planting and maintaining trees or other vegetation include purchasing materials, initial planting and ongoing maintenance such as pruning, pest and disease control and irrigation. Other costs include program administration, lawsuits and liability, root damage, and tree stump removal. However, the benefits of urban trees almost always outweigh these costs (EPA, 2009). The main economic benefits related to the use of vegetation in the urban environment include:

- Savings due to the reduction of energy consumption for the management of buildings;
- Increase of the property value;
- Air quality/quality of life improvement;
- Possibility to obtain special incentives.

Interesting researches weight these benefits against the costs of planting, pruning, watering, and other maintenance throughout a tree's life. Although the benefits can vary considerably by community and tree species, they almost always outweigh the expense of planting and maintaining trees. For example, one five-city study found that, on a per tree basis, cities accrued benefits ranging from roughly $1.50 to $3.00 for every dollar invested (EPA, 2009). These cities spent about $15-65 annually per tree, with net benefits ranging from approximately $30-90 per tree. In all five cities, the benefits outweighed the costs, as shown in figure where the categories of annual costs and benefits are associated with trees that vary between these cities (Fig. 8).

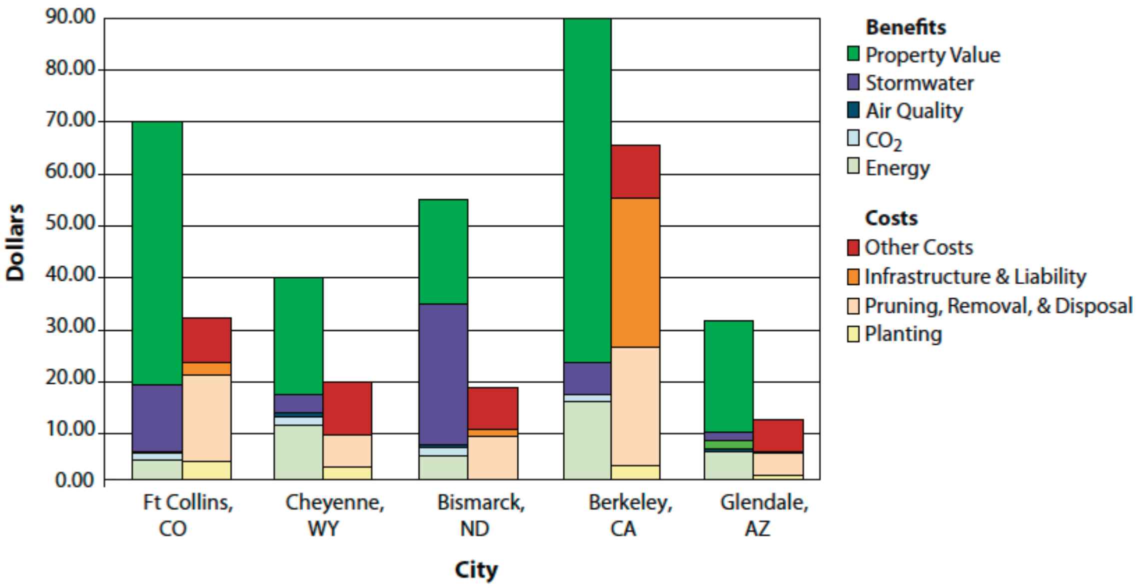


Fig. 8 - Total annual benefits versus costs (per tree) registered in a study in the USA (EPA, 2009)

5.1.3. Social benefits

Social scientists study another level of services that plants provide for urban residents. In fact, it was demonstrated that vegetation affect human moods, activities and emotional health whether being active in urban nature (planting trees, growing gardens) or passively encountering city green (such as a stroll through a park).

On a psychological level, plants can provide a calming effect as well as increase worker efficiency. It was found that people who only view nature after stressful situations show reduced physiological stress response, as well as better interest and attention and decreased feelings of fear and anger or aggression (Wolf, 1998).

Urban trees and vegetation have been also linked to reduced crime. Indeed, recent findings in urban residential areas have hinted that residents living in "greener" surroundings report lower levels of fear, fewer incivilities, and less aggressive and violent behaviour. A study conducted by Kuo and Sullivan (2001), e.g., used police crime reports to examine the relationship between vegetation and crime in an inner-city neighbourhood. Crime rates for 98 apartment buildings with varying levels of nearby vegetation were compared. Results indicate that although residents were randomly assigned to different levels of nearby vegetation, the greener a building surroundings were, the fewer crimes reported. Kuo and Sullivan also report that residents living in buildings surrounded by trees use more constructive, and less violent methods to deal with conflict. Residents with green views report using reasoning more often in conflicts with their children and significantly less use of severe violence. They also report less use of physical violence in conflicts with partners compared to those living in buildings without trees.

In the study related to the socio-environmental dimension in high-rise housing in Singapore provided with vegetated open spaces, Kong (2005) suggests that gardening, people, and environment form a triangle of interrelationships (Fig. 9), where one stimulates the other.

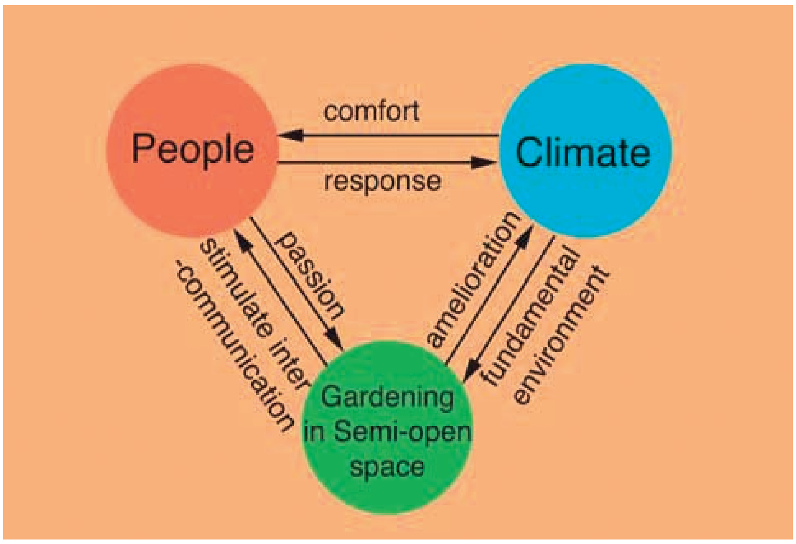


Fig. 9 - Interrelationships of gardening in semi-open space, people and climate (Kong, 2005)

5.2. Building-Integrated Vegetation: technical alternatives

In the last decades issues related to sustainability and energy consumption of existing buildings have suggested different solutions for retrofitting. Commonly they relate to the application on facades and roof of integrated systems, such as thermal coating or air cavity systems. However, Building-Integrated Vegetation (BIV) is witnessing a rapid growth in both research and market development as an effective system to improve the thermal performance of the building envelope. Building integrated vegetation systems consists of green roofs and vertical greening systems applied on both exterior facades and interior walls. Despite the recent advancement in this field, it is common knowledge that the integration of plants with building has remote origins.

As native vegetation is an expression of climate, since ancient times local traditional architecture have often seen a direct link between plants and construction techniques mainly in form of vertical gardens and green roofs. Pergolas and climbing plants are known to have been commonly used as the earliest form of green walls in the Mediterranean region more than 2000 years ago (Köhler, 2008) and the civilization of the Tigri and Euphrates River valleys are known to have developed great ornamental roof gardens, among which the Hanging Gardens of Babylon in the VII and VIII centuries B.C..

Photo 7 and 8 - Examples of plants integration in the façades of traditional buildings to provide shade and improve their aesthetic

Photo 9 and 10 - Examples of traditional buildings in Island (left) and in Denmark (right) with roofs covered by a vegetal layer to improve their thermal performance

Medieval and Renaissance Europe saw many buildings walls become covered with ivy or other plants essentially to improve their aesthetic while Scandinavian regions experimented several examples of green roofs between 18th-19th century to enhance their thermal insulation (Photo 9 and 10).

In the XX century, together with to the deep technological innovations brought by the Modern Movement, the five points of Le Corbousier had a great impact in the reconsideration of the role of vegetation in architecture in an attempt to "create an equilibrium between the man and the environment". According to his theory, Le Corbousier offered several examples of roof gardens as well as of vertical gardens, as in the case of the Mill Owners' Association Building of Ahmedabad in India.

In the fifties, the Brazilian architect Lina Bò Bardi consecrated part of her professional life to the research of innovative form of relationship between plants and built environment. During her career, she built or designed many small domestic buildings in a critical regionalist spirit, incorporating tropical vegetation into the concrete construction in novel ways: her Chame-Chame House (1958) in Bahia preserves a Jaca tree at the center of the design and, as in the Cirell house (1958) in São Paolo, combines stones, ceramic chips, and plants in the wall slabs creating vertical garden walls.

Photo 11 and 12 - The famous garden roof of Villa Savoye (left) and the vertical garden of the Mill Owners' Association Building of Ahmedabad (right), designed by Le Corbousier

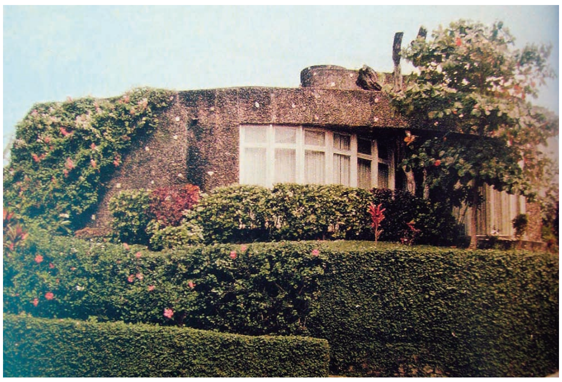


Photo 13 and 14 - The Chame-Chame house in Bahia (left) and the Cirell House (right) by Lina Bo Bardi

What is new is the recent research and application of systems and designs to optimize the benefits of vegetation on buildings without causing any harm to the building.

During the 1980s and 1990s research related to the use of vegetation applied onto the buildings, especially as for roof applications, saw the collaborative efforts of landscape architects, scientists, and private companies to find optimized solutions and analyse the energy behaviour of plants for creating more comfortable air temperatures inside and outside of buildings.

In recent times, finally, the French botanist Patrick Blanc became very popular for modernizing and popularizing the use of the so-called *Mur Vegetal*, which characterized and made well-known several architectural designs all over the world.

However, despite the diffusion of BIV in the last decades, unlike other "green" sectors such as solar photovoltaic or biofuels, BIV adoption is not yet driven by national-level policy measures, but entirely by city-level hyperlocal priorities (Ranade, 2013).

Specifically, the two major types of policy drivers for BIV are:

- building code requirements on storm-water discharge -such as those in London-, mandates for green roofs -such as those in Copenhagen-, and mandates for green walls -such as those in Shanghai-;

Photo 15 and 16 - Examples of Building-integrated Vegetation: green roofs in London (left) and in San Francisco (right)

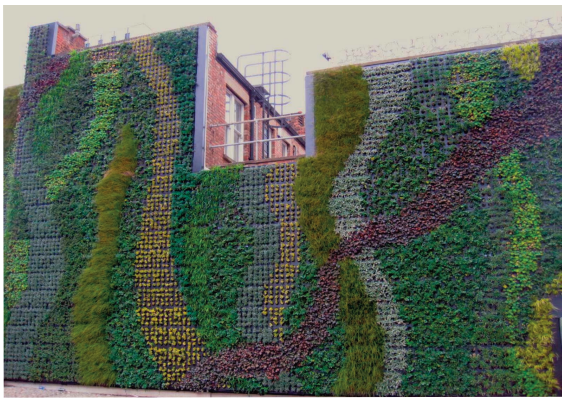


Photo 17 and 18 - Examples of Building-integrated Vegetation: living walls in London (left) and in Milano (right)

- financial incentives such as cash rebates for installing green roofs in Portland and exemptions in storm-water surcharge in London that shorten the payback period and the upfront capital expenditure. Nevertheless, the BIV growth forecast are very optimistics.

According to Ranade (2013) Europe has led the growth of green roofs market in the last two decades but markets - especially in Germany and Switzerland - are maturing and close to the saturation point[2]. Therefore, as seen in Fig. 10, Europe's share of new capacity decreases from 83% in 2011 to 36% in 2017. Still, cities such as Copenhagen and London will provide growth opportunities even in this shrinking geographical segment. American market is at an inflection point due to announced mandates or incentives for green roofs. In addition, this market segment is far from maturity, with green roofs occupying less than a fraction of 1% of flat roofs. As a result, North America's share of new installations will increase from 13% to 35%.

Eventually in Asia, the urgency to address urban environmental issues such as air pollution and storm-water management, will lead to ambitious targets for green-roof installations with a forecast of growth from 3% in 2011 to 28% in 2017.

Unlike the established green roofs market, green walls market is still in its infancy. Despite this, the market prevision shows dramatic growth also in this case, passing from 28,000 m_2 in 2011 to 1.02 million m_2 in 2017, with inflection point of growth in all regions.

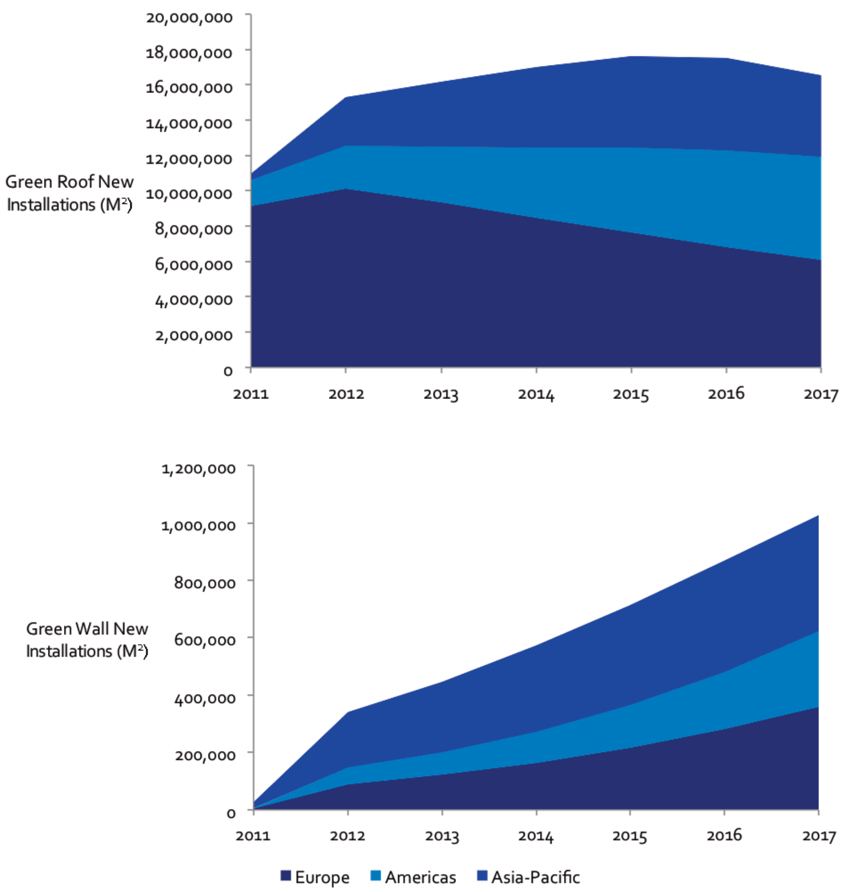


Fig. 10 - Forecast growth for Green Roof and Green Wall application within 2017 (Ranade, 2013)

5.2.1.Green walls

Green walls are walls covered with climbing plants or cascading groundcovers rooted in the ground or in containers positioned at different height from the ground, trained to grow onto and over specially designed supporting structures, anchored to the building façade.

Design, installation and maintenance considerations for green facades varies by system type selected and the conditions of the built and natural environment. Generally two primary types of green façades are distinguished: *modular trellis systems*, and *cable/rope wire systems* (GRHC, 2008). Both of these systems afford a high degree of design flexibility since they can be wall mounted, freestanding, or used as columns.

Modular trellis products can be installed vertically in either a wall mounted or freestanding application.

Cable/rope wire systems can span long distances, but special or complex designs may defeat the simplicity of the system.

However, for both systems green façade projects require that the following aspects have to be taken into consideration:

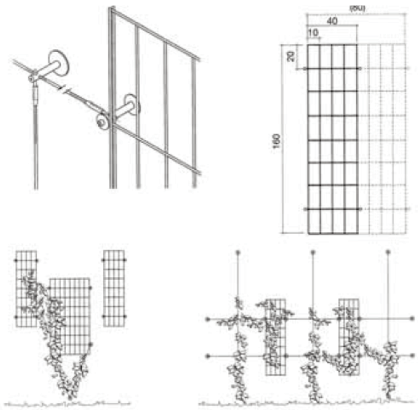
- attachment to building envelope - how the system will be secured to the building or freestanding structure;
- calculation of structural loads for larger systems, taking into account also loads such as snow, plants, and wind;
- plant selection for wind and light exposure, hardiness zones, and amenity context.
- realistic expectations related to plant aesthetics and growth – some systems require 3 to 5 years to become fully established;
- plant maintenance and/or long term maintenance plan to secure the health of these living systems, including proper soil and irrigation considerations;
- check with manufacturers who may have registered or specially trained installers that will be able to complete the project successfully;
- appropriate plant selection for the geographic region, correct plant spacing for desired coverage, and release from the temporary support structure used by the nursery.

Green walls can have negative effect on buildings façades if the vegetal species are particularly heavy and if the branches cause the deformation of the support structure and if the plants stay wet in winter provoking moisture on the wall.

Green wall technologies provide a wide range of options for designers. Following, some examples of products existing on the market are shown.

GITTERSYSTEME - Thomas Brandmeier – BegrUnungssysteme GmbH, Germany

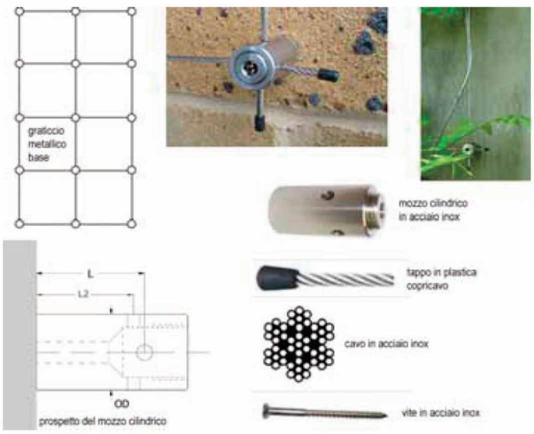
The system is constituted by one or more inox stainless steel rods anchored to the façade through special spacers, consisting in cylindric stainless steel elements fixed to the wall by means of plugs. The steel rods can be positioned with distance varying from 9 to 15 cm. Alternatively, modular elements fixed to the wall one next to the other can be installed. They are fixed through common spacers arranged regularly along the wall surface. The use of this combination of systems allows the greening of different multi-storey buildings.



Example of Vegetal species:
- Hedera Helix
- Jasminum officinale “Aureum”
- Trachelospermum jasminoides

“GREEN WALL” CABLE TRELLIS SYSTEM - S3i Ltd, UK

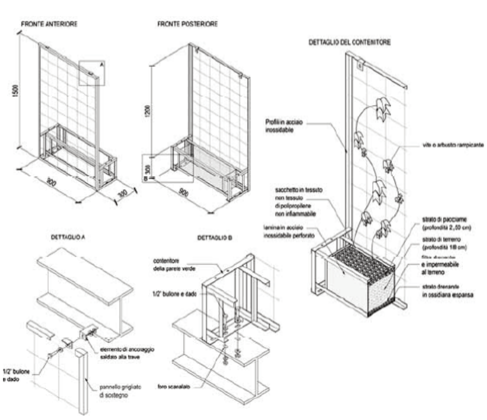
The 'Green Wall' stainless steel wire trellis system is made up of a stainless steel wire 'hub' allowing the crossing and partial tensioning of wires to form trellis sections. The hub are fit with screws directly into timber or into masonry with appropriate plastic screw plugs.
The cylindrical hubs have a central screw which can be tightened with an allen key to grip onto the 3mm diameter stainless steel wire. Hubs are placed at a distance of about 50 cm each other and are anchored punctually to the perimeter wall of the building through gusset with internal screw. This fixing can be reinforced with the addition of any chemical binder in the hole of the masonry in order to ensure a greater stability to the trellis.

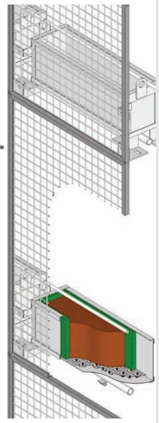


Example of Vegetal species:
- Akebia quinata
- Clematis orientalis
- Jasminum officinale “Aureum”

BASIC WALL SYSTEM - G-Sky Green Walls and Roofs, Canada

Basic Wall is a container system with vines trained over an integrated trellis that is attached to the building facade. Basic Wall is a cost effective solution for creating large outdoor green walls without a pattern. Basic Wall can be planted at the site or pre-grown for a minimum of 4 months at a nursery (depending on the time of year). If installed pre-grown, you will have a 80~90% full Green Wall at install, if not, it will take up to two years to fill in at the site.

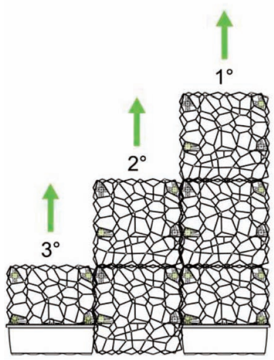




Example of Vegetal species:
- Clematis armandii
- Jasminum officinale “Aureum”
- Hedera Helix
- Parthenocissus tricuspidata
- Passiflora cerulea
- Thunbergia alata

WALL-Y - Geoplast, Italy

Wall-Y is a grid developed for the creation of green walls. The special texture created by the irregularly shaped cells is of great aesthetic value, decorating walls even before the vegetation cover has developed. The system is made of plastic which confere lightness to the grid.
The product consist in modular element of and very easy to install. The grid is permanently fixed to the wall to be covered with climbing plants by pressure blocks. Holes in the legs are used for the passage of the dowels.

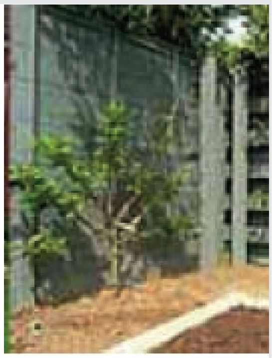


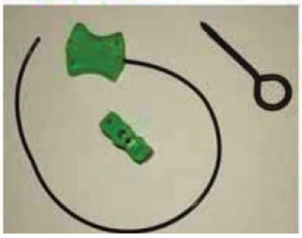
Example of Vegetal species:
- Rhincospermum jasminoides
- Clematis
- Jasminum
- Hedera-Araliaceae
- Rosacee
- Passifl oraceae
- Parthenocissus
- Lonicera caprifolium
- Wisteria sinensis

GRIPPLE - Gripple Limited, UK

The system is composed by glass fiber reinforced nylon clamps, where nylon threads are insterted and stretched to achieve a structure, which can be arranged horizontally or zig-zag. The nylon is UV stabilized so as not to deteriorate under direct sunlight. All parts of each clamp are made of corrosion-resistant material in order to allow its further reuse. The structure is anchored to façades through plugs with eye bolts.

Example of Vegetal species:
- Clematis “Frances Rivis”
- Jasminum nudiflorum
- Lathyrus odoratus
- Maurandella antirrhiniflora
- Wisteria floribunda

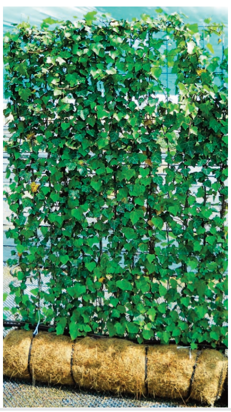




MOBICARE LIGHT - Poliflor, Italy

The system maximized the initial greenness immediately after its installation because it integrates a climbing plant cultivation panel system and a cultivation mattress where roots are contained.
The system includes:
- a structure to connect the vertical green system to the wall;
- a plant support made by non-woven-fabric geocomposite mat sewed in order to create many rooms with the function to contain the cultivation substrate. The mat is then covered with coconut fibre needle-felt geotextile;
- an instant living panel, assembled and made adherent to the mat through stainless steel tie-bands;

Example of Vegetal species:
- Hedera-Araliaceae
- Clematis orientalis
- Jasminum officinale “Aureum”






5.2.2.Living walls

Living walls are covered by plants which do not root in the ground, yet in modular elements where plants are rooted which entirely cover the wall surface. Modular elements are suspended on the wall through different support structures and are often made of stainless steel containers, geotextiles, irrigation systems, a growing medium and vegetation. The products currently present on the market are usually classified because of the types of growth media used: loose media, mat media and structural media.

Loose medium walls are "soil-on-a-shelf" or "soil-in-a-bag" type systems. It means that the growth media have their soil packed into a shelf or bag which are installed onto the wall. These systems require their media to be replaced at least once a year on exteriors and approximately every two years on interiors. This type of system is not generally used at big height or in very windy places, because they can easily have their medium blown away by wind-driven rain or heavy winds.

Mat type systems are usually applied for little and/or indoor installations. They could consist either in coir fibre or felt mats. Mat media are quite thin, even in multiple layers, and as such cannot support vibrant root systems of mature plants for more than three to five years before the roots overtake the mat and water is not able to adequately wick through the mats. This mat systems are particularly water inefficient and often require constant irrigation due to the thin nature of the medium and its inability to hold water and provide a buffer for the plant roots.

Structural media are growth medium blocks that somehow incorporate features of both loose and mat systems. The block that can be manufactured into various sizes, shapes and thicknesses. These media have the advantage that they do not break down for 10 to 15 years, can be made to have a higher or lower water holding capacity depending on the plant selection for the wall, can have their pH customized to suit the plants, and are easily handled for maintenance and replacements. They are the most common option for living walls for both exterior and interior applications. They are also the best choice in areas where high-winds, seismic activity or heights need to be addressed in the design. For their characteristics they do tend to be more expensive to install but have generally lower cost for the maintenance.

Likely green walls, the design and realization of living walls has to take into account several aspects such as:

- irrigation (establishing appropriate levels of watering and appropriate levels of nutrients);
- plants choice (according to hardiness zone, geographic location and specific microclimate);
- growing medium chouse.

Vegetation with high nutrient requirements generally requires a greater degree of care than those that have evolved from nutrient poor environments. The degree of maintenance may also be influenced by client expectations of the aesthetic qualities of a living wall installation and at what level flourishing vegetation needs to be maintained.

PATRICK BLANC'S PATENTED SYSTEM

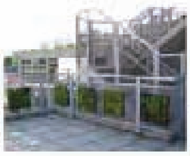
The system of vertical greening is constituted by interlocked rigid plastic (PVC) panels on which a polypropylene geotextile is positioned, followed by two layers of reinforced polyamide felt, between which polypropylene irrigation pipes are placed.
The external felt layer is provided with a series of pockets for the positioning of different plant species.

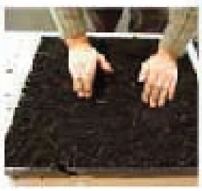
Example of Vegetal species:
- Acanthus mollis
- Artensia 'Powis Castle'
- Berberis darwinii
- Bergenia 'Bressingham White'
- Campanula portenschlagiana .
- Corydalis cheilanthifolia
- Delosperma nubigenum
- Epimedium acuminatum
- Iris japonica
- Sedum reflexum

ELT EASY GREEN™ LIVING WALL - ELT Easy Green, Canada

The system consists of of high density polyethylene modular panels, subdivided into cells in which growing medium is positioned. Panels can be combined with others to cover large wall surfaces and are fixed metal bands through a series of screws which are arranged in succession anchored to facades.
Each panel allows easy movement of the water flow without damaging the growing medium. It has a series of grooves that channel and make the water flow along its rear part, from top to bottom, from cell to cell and then to the panel below.

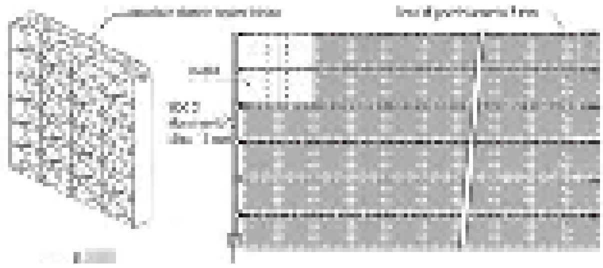
Example of Vegetal species:
- Ajuga
- Hedera Helix
- Liriope
- Sedum acre
- Sedum album
- Sedum reflexum
- Sedum sarmentosum





GREEN LIVING™ WALL - Barthelmes Manufacturing Company Inc., USA

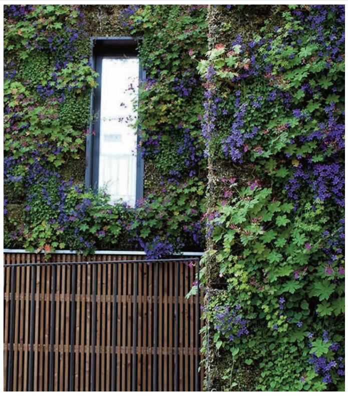
The system consists of lightweight panel made of recycled aluminum and stainless steel. The panel is internally divided into cells containing the growing medium. The fixing of the panel to the facade is made anchoring -by means of screws- the panel to linear metal profiles, arranged horizontally and vertically, and fixed to the facade. Each module is equipped on the top with a groove to house the drip irrigation tube, which is distributed linearly throughout the length of the plant. This irrigation system allows water to flow from top to bottom along the entire panel,ensure proper water supply to the plants.

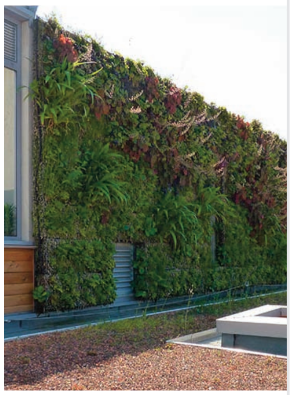


Example of Vegetal species:
- Delosperma nubigenum
- Sedum acre
- Sedum album
- Sedum reflexum
- Sedum sarmentosum

VEGETALIS® - Greenwall, France

The vegetal wall is composed by pre-cultivatedmodules constituted by galvanized steel cages (greenbox ®), where the growing medium is positioned. It is made of natural sphagnum moss which is lightweight and extremely permeable.
This substrate has a high water absorption capacity and allows a good rooting of plants. The metal cage is defined by a 30x30 grid made of 4 mm diameter wires. Each module is then mounted on a metal hooks through a special anchoring structure, defined by metal profiles fixed to the building by means of dowels and screws. A continuous and ventilated air gap between the wall of the building and the living wall.





Example of Vegetal species:
- Sedum acre
- Sedum caeruleum
- Sedum pulchellum
- Sedum roseum

FYTOWALL - Fytogreen, Australia

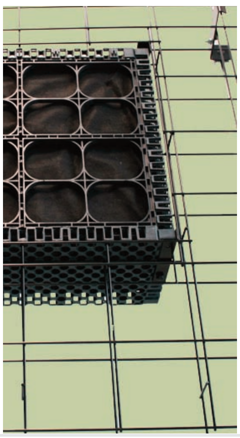
Fytowall is a vertical garden system specially design for Australian conditions to be robust, water efficient and sustainable without the need for constant replanting. It runs as a hydroponic system and uses as little a 5 litres per m_2 per day in summer and is compatible with tank water.
It consists of big modular panels, anchored to the existing building walls, containing a biodegradable foam as a growing medium, which is very water efficient. Between each layer of growing panels is a drip irrigation line that distributes water and nutrients via an automated control system.

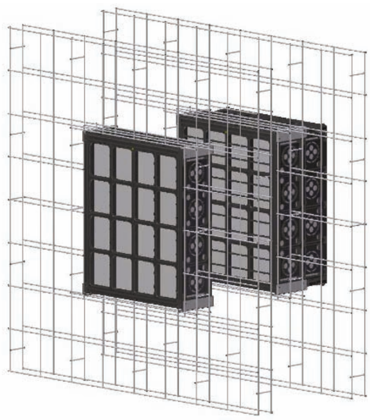
Example of Vegetal species:
- Leucothoe fontanesiana
- Jasminum officinale “Aureum”
- Trachelospermum jasminoides
- Mahonia gracilimus
- Pachysandra ‘Green Carpet’

VERTIGREEN HYBRID PRE-GROWN 3D TRELLIS - Tournesol, USA

The system consists of a recycled plastic plant growing module (VGM), set into a double-panel trellis system. The plants are grown in the module (either on its own or pre-installed in the trellis), and hung on the wall once the plants are rooted in. The trellis system mounts to the wall with a simple bracket. Either the plant growing module or the entire panel can be quickly removed for maintenance. The VGM® plant growing module has no internal baffles or separations, allowing the roots to fully develop and grow.
The double-panel trellis nurtures climbing plants and vines while it protects the underlying structure.

Example of Vegetal species:
- Hedera helix
- Hypericum perforatum
- Jasminum officinale “Aureum”





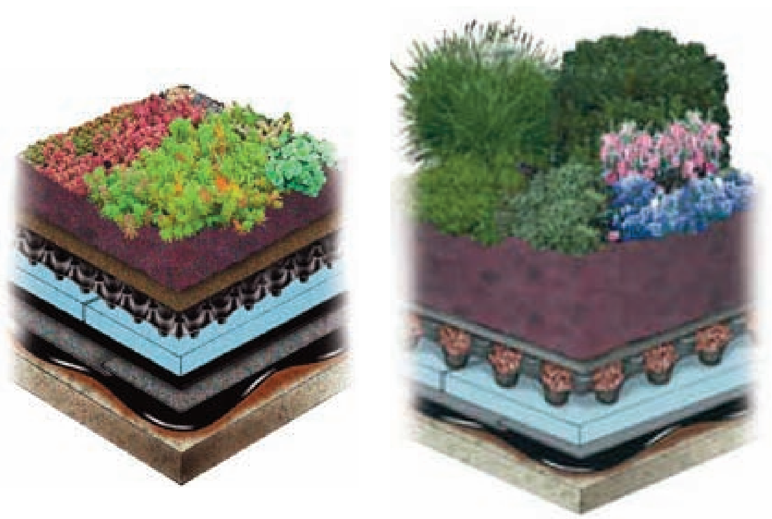
5.2.3. Green roofs

While the origins of the green roof date back to ancient Mesopotamia, it was not until the 1960s that it was recognized as an effective method to improve the quality of the urban environment. Though research in Germany and other parts of Europe supported the claims of environmental and economic benefits for both the private and public sectors, these technologies were rarely been applied until recently (Feller, 2011).

Based on the type of green roof, the recognized benefits provided include storm-water runoff reductions, reductions in urban heat islands, building heat and sound insulation, increased roof lifespan, water and air quality improvements, aesthetic attractiveness and increases in wildlife habitats. In particular, regarding the thermal performance, green roofs act as a thermal mass, slowly absorbing and holding energy from sunlight and releasing it when the ambient air cools. In this way, green roofs strongly contribute to reduces the heating and cooling demands within the building at certain times or seasons.

There are two major types of green roofs, *intensive* and *extensive* (Fig. 11). *Intensive roofs*, depending on their application, consist of a soil base-course that can be as shallow as 15-20 centimeters and as deep as 4.5 meters, though, they are typically less than one meter deep. Architectural features can include anything from pathways to water fountains and herbs to small trees. Intensive roofs typically are more costly than external roofs, require periodic maintenance, and require a more robust structural frame on the underlying building.

An *extensive green roof* consists of a base course that is less than fifteen centimeters deep and typically a lightweight growth medium in which sedums and other succulents can grow. These roofs are de signed to meet specific engineering and performance criteria. These structures are low cost because they require minimal, if any, added structural support for the underlying building. They are also low maintenance because the plant species are drought, disease, and insect resistant, while weeds and other invasive species cannot typically survive in the shallow soils without frequent rainfall.

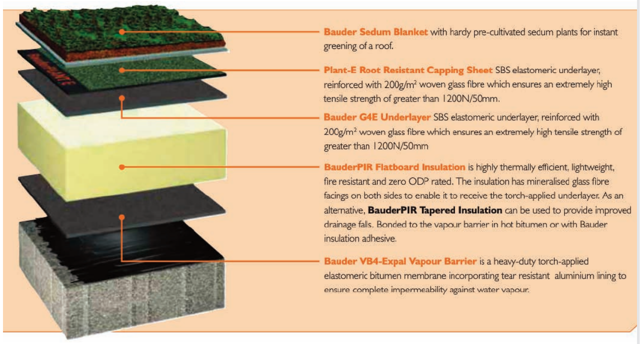


- Vegetation (Extensive/Intensive)
- Growing media
- Filter Fabric
- Drainage panel
- Insulation
- Roof barrier
- Protection course
- Waterproofing membrane
- Substrate

Fig. 11 - Typical composition of extensive (left) and intensive (right) green roofs

XERO FLOR - Bauder, UK

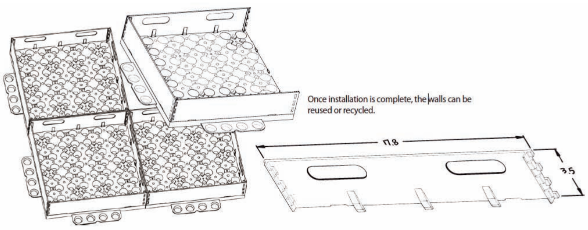
Bauder Xero Flor extensive green roof systems are constructed using a low maintenance sedums, grasses and herbs that provide excellent cover and increased protection to the waterproofing system. The plants are grown on a 'blanket' that is harvested like turf and installed by rolling out on top of the waterproofing and any other landscaping components required. The blankets are very lightweight, easy to maintain and provide instant greening to the roof.
The Xero Flor sedum blanket is a very versatile, exceptionally lightweight green roof system and is suitable for both new build and refurbishment projects.



Example of Vegetal species:
- Sedum acre
- Sedum pulchellum
- Achillea millefolium
- Linaria vulgaris
- Prunella vulgaris

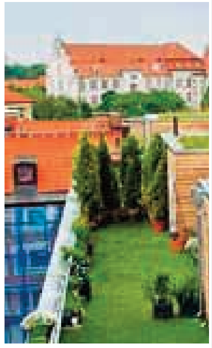
GROROOF SYSTEM, Metro Green Visions, Inc., USA

The system consists in pre-vegetated modular elements for the realization of extensive green roof. Once the modules are installed, the interlocking side panels are completely removed – providing 100% soil integration from day one the same as a grown in place system (competing modular systems give partial integration, or no integration at all). A specially blended lightweight growing medium composed of organic and mineral materials. The percentage of organic to inorganic material is dependent upon the type of vegetation planned for the green roof.

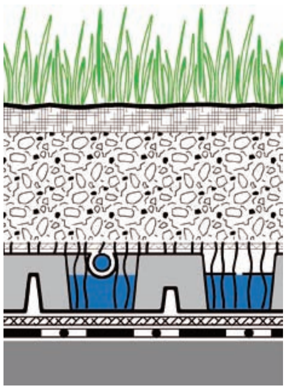


Example of Vegetal species:
- Sedum rupestri (reflexum)
- Sedum album - 'bella d' Inverno
- Centaurium erythrea
- Dianthus deltoides
- Nepeta fasseni
- Origanum vulgaris

SYSTEM BUILD-UP "SUMMER PLAINS" - ZinCo, Germany

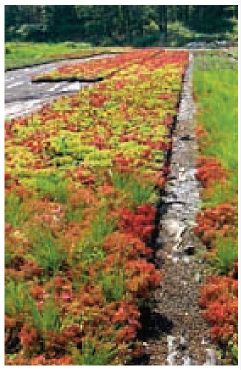



This is a light-weight solutions for intensive green roofs which allows the installation even on roofs with a low load bearing capacity. The basic principle involves the distribution and storage of water in the element cells which is then drawn upwards when required, through the wicks in the mat to the substrate layer. The water is fed through special dripperlines and the amount is controlled by an electronic irrigation system. Due to this sophisticated kind of irrigation, substrate depths can be reduced up to 50% which results in a lower system weight. The plants are grown on a 'blanket' that is harvested like turf and installed by rolling out on top of the waterproofing and any other landscaping components required.




Example of Vegetal species:
- Achnaterum calamagrostis
- Chamaemelum nobile "Plena"

GREENGRID SYSTEM - GreenGrid and ABC Supply Co., USA

Unlike layered-style and hybrid systems, 60x60 cm GreenGrid modules remain modular once they are installed. This allows for easy access to the underlying waterproofing system. Roof repairs are inevitable at some point along the life of the roofing materials. The advantage of being able to easily access the roof saves the cost of having to also repair the area of vegetation that must be disturbed to access the roof. GreenGrid modules can be removed, set aside, and replaced once repairs are made. The systems suits for extensive and intensive applications and for this reason is available in three depths (shallow 10 cm; intermediate 15 cm; and maximum 20 cm) to accommodate a variety of design goals.



Example of Vegetal species:
- Genus Sedum,
- Sempervivum,
- Talinum

5.3. Case studies

5.3.1. Centre of biotechnology Biopark, Paris

The Centre of biotechnology, designed by Valode & Pistre and realized in 2006, aims to adapt a building of the 1980s to contemporary criteria. The structure of this imposing building, witness of its time, remains unchanged. The intervention reframes, restructures and redefines the form to integrate it better into the city and connect it with the new university district built on the banks of the Seine.

The built volumes are split to make way for a new road system irrigating the heart of the urban block freed of its former slab and transformed into square place.

The cut gable ends are dressed in a metal trellis, forming a support for vegetation which gives its colour to the change of usage. Formerly austere, the heart of block becomes a green environment in facades stepped into terraces, doubled by a generous wave-like pergola over which grows roses, bellflowers, acanthuses and clematises.

In a limited budget, the operation fits explicitly in what exists and brings a welcome breathing to this small island in second rank on the Seine.

Photo 19 and 20 - Views of the Centre of biotechnology in Paris

Fig. 12 - Front view of the building (Valode et Pistre architectes. http://www.v-p.com)

5.3.2. Leyteire Square, Bordeaux

The project regards the requalification of a square in the historical centre of Bordeaux University. The spaces designed by the landscape architecure studio Debarre Duplantiers Associésare turn into a lively heart of the University, where intermingling can take place. The initial meaning of "campus" can be retrieved through an intense central green space.

This series of courtyards becomes a network of interactive spaces, as well as a part of the city: a number of facilities animate the center of the square (museum, café, amphitheaters) and contribute to its urban value. The addition of planted elements lends a human scale to the existing landscape by providing shade, delineating paths, and acting to filter air, sound, and light that enters the space.

This, in turn, combats the Urban Heat Island Effect, providing more pleasant interior spaces during the hot summer months.

In plan, a certain hierarchy is established between the wide-open center, and more intimate spaces along the space's edges. This variety of spaces invites a wide range of activities common for a university campus, from eating lunch in the sun, to meeting with colleagues and professors, to hosting celebrations and festivals.

Fig. 13 - New layout of the square

Photo 21, 22 and 23 - Views of the Leyteire square

5.3.3. Bosco Verticale, Milan

Bosco Verticale is a project of urban reforestation designed by BOERISTUDIO that aim to contribute to the regeneration of the environment and urban biodiversity without the implication of expanding the city upon the territory. The project consists in two residential towers of 110 and 76 meters height in the Porta Nuova district of Milan, for a total of 400 condominium units. As defined by the architects Bosco Verticale is "a model of vertical densification of nature within the city", able to create a model of building linked between nature and city within the territory and within the cities of contemporary Europe. The buildings will host 900 trees (each measuring 3, 6 or 9 m tall) apart from a wide range of shrubs and floral plants. The amount of vegetation corresponds, for each tower, to an area of 10.000 sqm of forest. In terms of urban densification the equivalent of an area of single family dwellings of nearly 50.000 sqm.

Moreover the building is conceived as a system that optimizes, recuperates and produces energy. Plant irrigation will be produced to great extent through the filtering and reuse of the grey waters produced by the building. Additionally Aeolian and photovoltaic energy systems will contribute, together with the aforementioned microclimate to increase the degree of energetic self sufficiency of the two towers. The management and maintenance of vegetation will be centralised and entrusted to an agency with an office counter open to the public.

Photo 24 and 25 - Views of building during the construction

Fig. 14 - Drawings of the design (http://www.stefanoboeriarchitetti.net)

5.3.4. Flower Tower, Paris

The tower, completed in 2004, arises from a design project of Edouard François with the collaboration of Patrick Blanc and embodies the expression of desire for nature in the city.

Containing 380 pots of bamboo on ten stories, the building itself is almost invisible behind its herbaceous curtain. It is situated on the edge of the jardin Claire Motte in the 17th arrondissement, and was designed to be a vertical extension of this space, both for those in the garden and those living in the building. The pots cannot be moved and are fixed to an automatic watering system (using recycled rain water) to ensure the maintenance of the plants.

Bamboo was chosen because it is a hardy and fast growing plant, but also because it makes a noise in the wind, "giving the impression to those inside that they are sleeping in a tree". Bamboo were also positioned with the aim to mitigate the microclimate and to act as a light filter by the foliage.

The plants cover three sides of the building that receive most of the solar radiation, while the northern face displays a plain concrete “unfinished” surface. According to the architect, this was a deliberate choice as he wanted to create a “ying and yang” effect between the attractive and the ugly, and also to provide something raw that would make the plants look more glamourous in contrast.

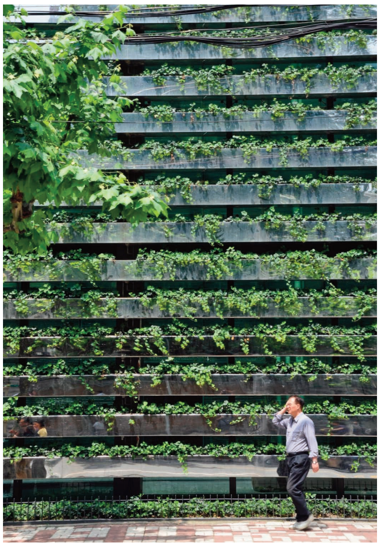


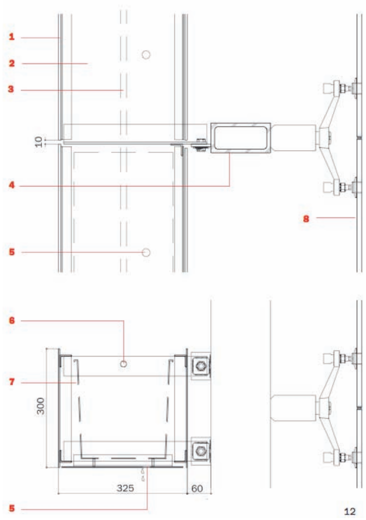
Photo 26, 27 and 28 - Views of the Flower Tower in Paris

5.3.5. Z58 Building, Shanghai

Z58 is a building that encompasses office and a showroom for Zhongtai, a leading lighting company in China. It arises from the refurbishment of an existing watch factory of Shanghai. The architect Kengo Kuma in this project shows a great attention in the research of a dialogue between the building and the context. In particular, for the main façade of the building, stainless steel horizontal elements are integrated with ivy for the creation of a vertical garden. The horizontal planter boxes are named "the green louvers". These green louvers are fixed to the steel pipe with brackets. Using the same steel pipe as the strut, glass panes with DPG (Dot Point Glazing) connection fixtures are mounted inside. The green louvers are in dual structure, consisting of 3mm-thick stainless panel with mirror finish, and U-shaped planter box with excellent waterproof performance made of FRP (Fiber Reinforced Plastic). Supporting structure consisting of L-angle steel is inserted between these two layers. An automatic water-supply system is employed (in order to maintain the vegetation), in which water runs through the pipe of 20 mmΦ, and the water from the drainpipe drips on the louver underneath.

Moreover, by applying steel wires to the existing concrete wall, a four-storey atrium is set up to create a transition space acting as a buffer zone between outside and inside and where visitors can experience communication as well as enjoying the space where natural light is filtered by the vegetation.





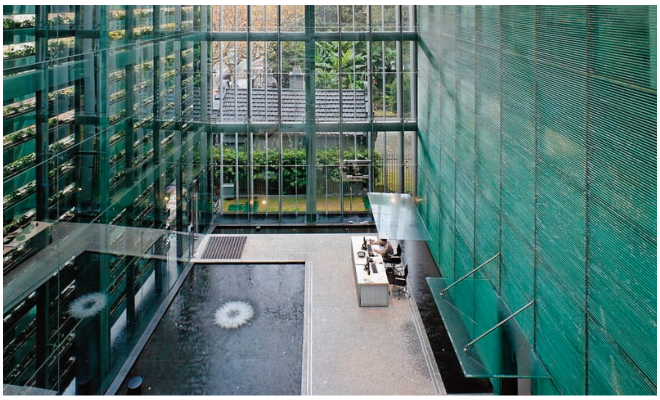



Photo 29, 30, 31, 32 - Clockwise from top left: façade with green louvers; a detail of the façade structure; an internal niew and an overall view of the building. On top right: Fig. 14 - Constructive detail of the green façade

5.3.6. Oasis d'Aboukir, Paris

The Oasis of Aboukir is a 25-metre-high green wall by botanist and researcher Patrick Blanc, which covers a building facade in the second arrondissement of the city.

The wall features plants from 237 different species and appears to grow up the facade in diagonal waves. It was planted in the spring and covers the previously raw concrete facade on the corner of Aboukir Street and Petits Carreaux street. The vertical garden decorates the façade of a historic building in the heart of the city, a five-storey Parisian block, with waves of 7600 plants.

The designer's original sketch shows a jungle-link pattern across the host building's vacant façade, so the team chose varying colours of plants to make the desired texture and pattern. Deep greens, yellows and reds all converge together to make up the lush vertical garden that was ready in only 7 weeks.

Starting one story above street level, the vertical garden's pattern reaches diagonally, as if toward the sun. Before the garden was installed, the side of the building was an eyesore, with uneven paint and random graffiti scrawled across the surface. The vertical garden not only transformed the side of the building, but also reactivated the small pedestrian triangle below it, where the Aboukir and Petits Carreaux converge.





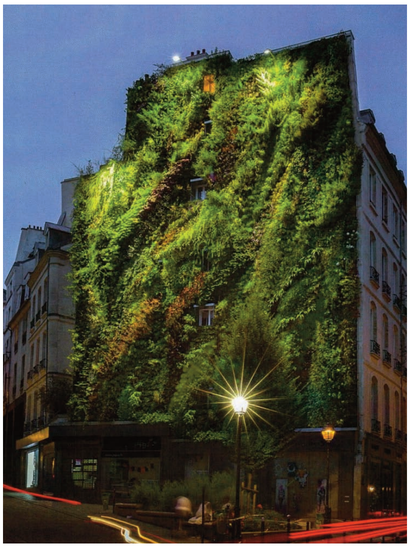


Photo 33, 34, 35, 36 and 37 - Clockwise from top left: The façade before the intervention; views of the façade after the installation of the living wall (others)

5.4. Software tools for the evaluation of the benefits provided by vegetation in the built environment: ENVI-met ®

One reason for the very limited number of field studies on outdoor thermal comfort in relation to street design is certainly the huge number of urban variables and processes involved. In this respect, numerical modelling has a distinct advantage over comprehensive field measurements and is, therefore, a powerful alternative for urban climate issues.

ENVI-met is a three-dimensional non-hydrostatic model for the simulation of surface-plant-air interactions not only for but especially inside urban environments. It is designed for microscale with a typical horizontal resolution from 0.5 to 10 m and a typical time frame of 24 to 48 hours with a time step of 10 sec at maximum. This resolution allows to analyse small-scale interactions between individual buildings, surfaces and plants.

The architecture of the software is constituted by 5 modules:

- Atmosphere, which develops parameters related to wind, turbulence and turbulent kinetic, temperature and humidity;
- Soil System, which is related to temperature and water flow inside soil and water bodies;
- Vegetation, which is related to foliage temperature, heat, water and vapor exchange within canopy air, water interception and transport;
- Surfaces, which is related to ground surface energy budget, wall/ roof surface temperature and heat exchange;
- Biometeorology, which is related to comfort assessment using the PMV model;

The files needed and produced by ENVI-met are distinguished between Input-Files (defining a specific simulation), Database Files (collecting information for all simulations) and Output Files (created by ENVI-met);

Input data are entered through two main components of ENVI-met interface:

- Configuration File (Fig. 15);
- Area Input File (Fig. 16).

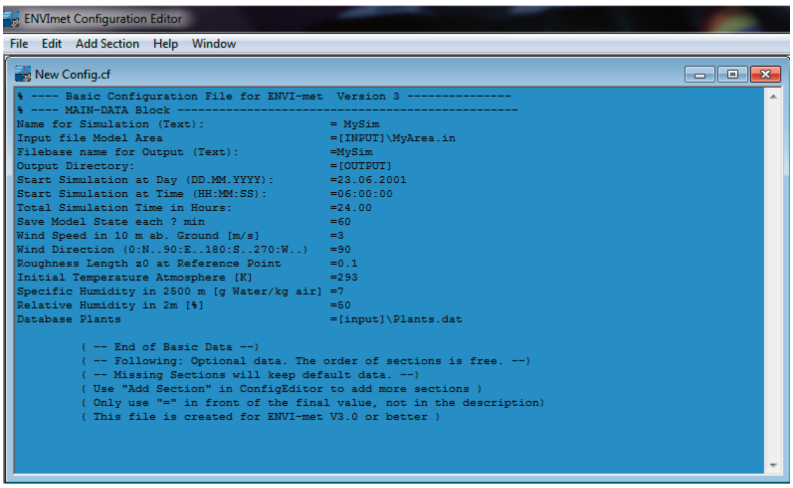


Fig. 15 - The ENVI-met interface “Configuration file” (http://www.envi-met.com)

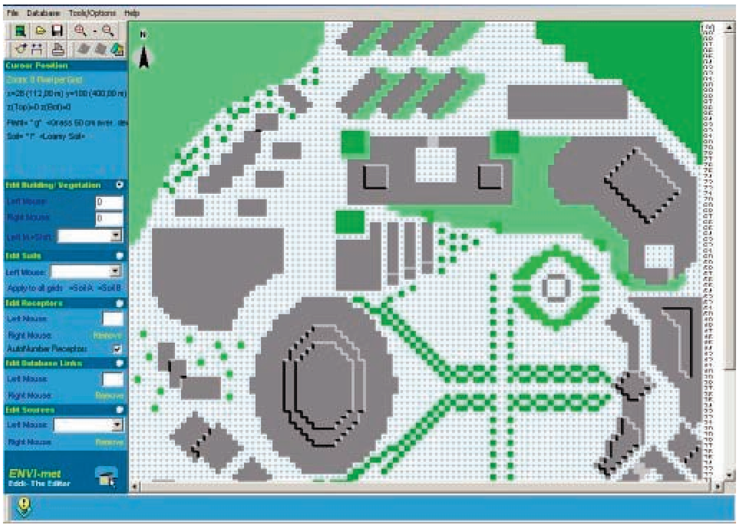


Fig. 16 - The ENVI-met configuration "Area input file" (http://www.envi-met.com)

The Configuration File defines the settings for the simulation to run, for example the name for the area input file, the name of the output files or the meteorological settings.

Area Input Files specify the geometry of model environment such as buildings, plants or soils in detail. Information stored in the Area Input files include:

- position and height of buildings;
- position of plants;
- distribution of surface materials and soil types;
- position of sources;
- position of receptors;
- database links;
- geographic position of the location on earth;

Through the area input file the model domain is also organised as a rectangular area which extends in x-, y- and z- direction.

Besides the two basic files needed for each simulation ENVI-met specific information need to be entered about the surfaces, plants or emission sources. As for plants, the model allows to define any kind of plant entering the following information:

- CO_2 fixation plant typology;
- Leaf diameter and aerodynamic properties;
- Minimum stomata resistance of the plant;
- Short-wave albedo of the plant leaf;
- Height of the plant;
- Total depth of the root zone in positive values;
- Leaf Area Density (LAD) in m^2/m^3 for 10 data points;
- Root Area Density (RAD) in m^2/m^3 for 10 data points.

As for LAD, ENVI-met database provide some profiles based on some reference profiles that can be taken into account for the simulations. However, the database can be improved with new information. If Leaf Area Index (LAI) of a certain plant is known, it is possible to model the plant by distributing it over the (normalized) height. In practice, the LAI value is divided in 10 parts that represent the LAD layers of the plant.

The output files generated can be separated in four groups:

- Main Data Files, which contain the complete state of the 3D model, including the atmosphere, the surface and the soil;
- Receptor Files, which are generated in relation to defined receptors inside the model area to watch specific points;
- Model Files, which contain the vertical profile data of the one-dimensional model in ENVI-met in ASCII-format and are mostly used for cross-checking or for finding problems;
- BOTworld Files, which provide climate data for the BOTworld model.

ENVI-met generates several data for every simulation which can be read by different programs. Some of the output files are simple ASCII-files which can be read by specific software tools. Others, mainly the main output files are binary files must be read with the program XTract (ASCII- output) or LEONARDO (graphical output).

LEONARDO is a graphical interface for displaying and analysing numerical data which make easy to turn simulation results into 2D or 3D data maps.

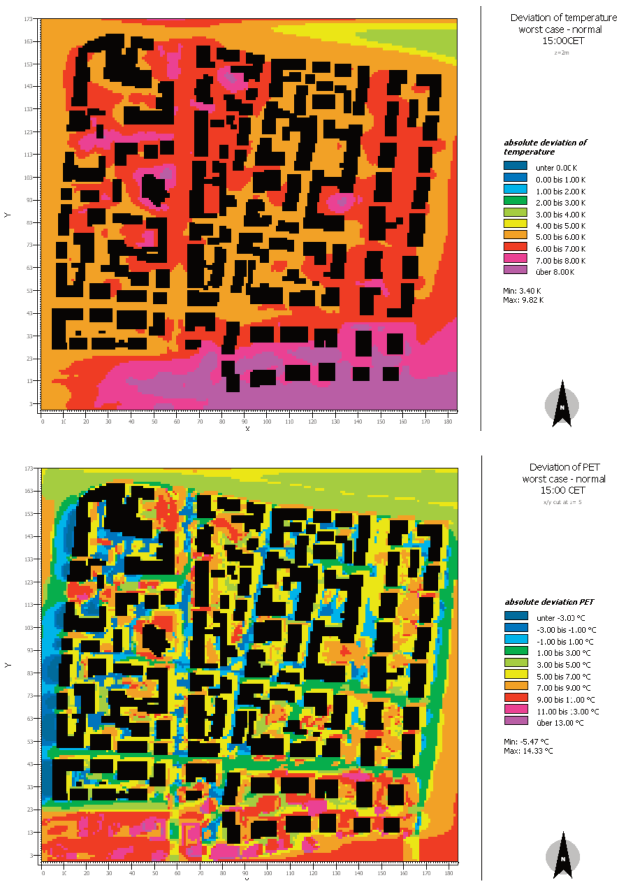


Fig. 17 - Example of graphical outputs generated with LEONARDO (Huttner et al. 2008)

Notes

1) The National Center for Ecological Analysis and Synthesis (NCEAS) was established in 1995 as a research center of the University of California, Santa Barbara, helping create a large community of scientists from multiple disciplines, eager to collaborate to answer some of the toughest environmental questions facing society.
2) Germany alone commands a staggering 86 million m_2 of installed green roofs, out of a cumulative 104 million m^2 in 2011. However, markets in Germany and Switzerland are maturing and close to the saturation point. In Germany, 10% of all flat roofs are green roofs already. In Switzerland, the most prominent city with green roof mandates, Basel is already at 70% of its stated target for green roof installations.

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Photo References

Photo 1 - Photo of the Author

Photo 2 - U.S. Environmental Protection Agency

Photo 3 - http://www.huffingtonpost.com

Photo 4 - http://www.flickr.com

Photo 5 - Photo of the Author

Photo 6 - http://www.greening.gov.hk

Photo 7 - http://www.casascirocco.it

Photo 8 - Photo of the Author

Photo 9 - http://thenetworks.co.za

Photo 10 - Photo of the Author

Photo 11 - http://www.socialdesignmagazine.com

Photo 12 - http://www.pinterest.com

Photo 13 - http://www.archdaily.mx

Photo 14 - http://www.tu-cottbus.de

Photo 15 - http://www.greenroofs.com

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Photo 17 - http://www.cnplus.co.uk

Photo 18 - http://www.landscapeme.wordpress.com

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Photo 20 - Valode et Pistre architectes. http://www.v-p.com

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Photo 33 - http://www.murvegetalpatrickblanc.com

Photo 34 - http://www.decorationofhome.net

Photo 35 - http://www.murvegetalpatrickblanc.com

Photo 36 - http://www.homedsgn.com

Photo 37 - http://www.lifestyle-and.me

PART II

CHAPTER 6
Sustainable Social Housing

6.1. European challenges of Social Housing in times of crises

In The European Union, the right to housing is an international obligation incumbent on every Member States. Indeed, this right is recognised in the United Nations Universal Declaration of Human Rights, which lays down that «...Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services...»[1]. The Council of Europe's revised Social Charter states that «...With a view to ensuring the effective exercise of the right to housing, the Parties undertake to take measures designed to promote access to housing of an adequate standard, to prevent and reduce homelessness with a view to its gradual elimination and to make the price of housing accessible to those without adequate resources...»[2]. The European Commission also recognized that implementation of the right to housing determines the achievement of other fundamental rights such as the right to human dignity, the protection of family life, water, health, energy, etc. and that all these factors are essential for individual integration into society.

Nevertheless, Social Housing in the European Union is characterised by the wide diversity of national housing situations, conceptions and policies across member states. A variety of approaches are implemented across the EU, in terms of size (Fig. 1), tenures, providers, beneficiaries, and funding arrangements within this sector (Pittini, 2012). And, although the right to housing is incorporated into many Member States' constitutions, it has been reported that access to decent housing is no longer affordable for many EU citizens.

This is more true today, considering that the economical crisis that Europe and North America are experiencing brought a series of social transformation that wiped out some false certainties such as job security and home ownership. In fact, the explosion of the financial and real estate bubbles primarily affected the middle classes and those who had made investments by drawing on loans to be repaid with future earnings (Pozzo, 2012). In this framework, the countries that made the greatest investments in real estate and with the greatest rate of first home owners (Greece, Spain, Portugal and Italy), have suffered the most from the effects of the crisis and from the effects of household debt, which adds to the high level of public debt.

In 2010, despite the undertaking in the revised Council of Europe Social Charter to prevent and reduce homelessness with a view to its gradual elimination, 5.7% of Europe's population suffered from housing deprivation, 17.86% lived in overcrowded or unfit accommodation, and for 10.10% of households, housing costs absorbed more than 40% of their disposable income (EESC, 2012).

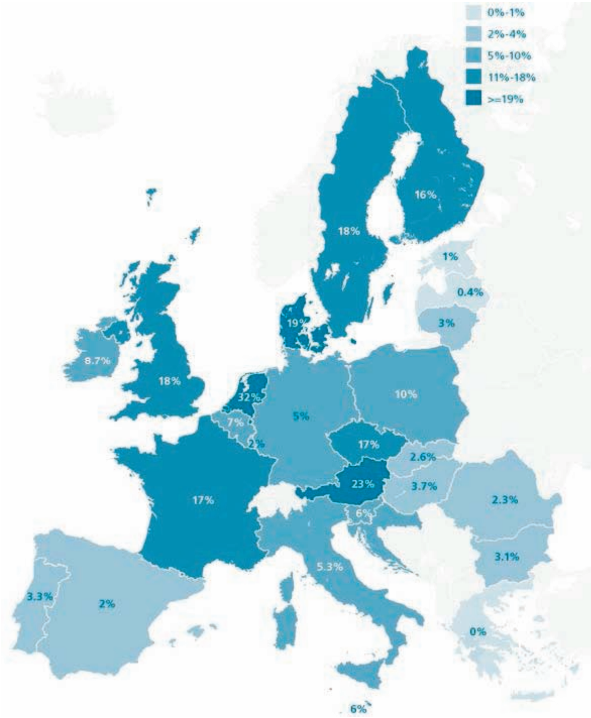


Fig. 1 - Social rental housing as percentage of total housing stock (Pittini, 2012)

This situation has been calling the emphasis on the necessity to provide adequate funds and sources for the construction of new social dwellings and the renovation the existing buildings stock. In this regard, it must be said that Social Housing has experienced an increasing diversification of its finance mechanisms and sources over the last two decades. In fact, there has been a tendency to involve private and not-forprofit initiatives through a wide range of social agencies, albeit with continuing large-scale government subsidies and financing housing programming and sector regulation (Fig. 2). Despite the differences existing among the EU Member States, today it can be assumed that, in practice, we find a combination of actors involved, with public provision (usually by municipalities, either directly or through dedicated publicly owned companies) often coexisting with a growing private sector, mainly consisting of specialised non-profit or limited-profit bodies (Pittini, 2012).

However, in a context of widespread collapse of financial institutions, large-scale state aid to private banks and high unemployment in many European countries, important questions arise regarding the sustainability of funding for the construction and the renovation of social and affordable housing. For this reason, EU directives are helping to undermine the practices of cooperation and poling of resources needed to modernise public housing, to ensure its proper management and to strengthen its local consolidation, also in a perspective of Europe 2020 goals achievement. Indeed, as stated by the European Economic and Social Committee (EESC) in 2012, Social Housing actively contributes to achieving a number of the Europe 2020 strategy's goals, regarding support for the strategy to boost the growth and attractiveness of regions, the investment generated and the creation of jobs that cannot be relocated, combating poverty and social exclusion and the commitment to the fight against climate change and energy poverty.

In 2011 The Eu Commission published proposal on the European Regional Development Fund (ERDF) and the European Social Fund (ESF) regulations, which consist of providing 2014-2020 Structural Funds to finance energy-efficient renovation of Social Housing, integrated measures to ensure sustainable urban development, access to high-quality and affordable Social Housing for marginalised communities and support for social enterprises. Such measures are considered necessary for the provisions of the European Commission's proposed directive on energy efficiency, which requires social housing agencies to improve the energy efficiency of 4% of the social housing stock each year. This type of obligation must be flanked by specific measures for financing investment, through the ERDF in particular but also by setting up an investment fund at the European level.

According to the European LiaisonCommittee for Social Housing - CECODHAS (2009), within 2020, an amount to 800,000 dwellings will be upgraded to the highest standards each year, creating 200,000 jobs per year with a 0.7 multiplier effect of indirect jobs creation at local level meaning an additional 140,000 jobs.

COUNTRY	TYPE OF PROVIDER(S)					
	CENTRAL GOVERNMENT	LOCAL AUTHORITY	INDEPENDENT PUBLIC BODY/ PUBLICLY OWNED COMPANY	CO-OPERATIVE	OTHER PRIVATE NON-PROFIT	PRIVATE FOR-PROFIT
Austria		X	X	X	X	X
Belgium		X	X		X	
Bulgaria		X				
Cyprus	X					
Czech Republic		X		X*	X*	X*
Denmark		X		X	X	
Estonia		X				
Finland			X		X	
France			X	X	X	
Germany						X**
Greece			X			
Hungary		X				
Ireland		X		X	X	
Italy		X	X	X	X	X
Malta	X				X	
Lithuania		X				
Latvia		X				
Luxemburg		X	X			
Netherlands					X	
Poland		X		X***	X	
Portugal		X	X	X	X	
Romania		X				
Slovenia		X			X	
Slovakia		X				
Spain		X	X	X		X
Sweden****						
United Kingdom		X	X	X	X	X*

* = can apply for funding to provide social housing within certain funding schemes
** = they also include municipal companies, which are considered as part of the private sector
*** = depending on the definition used
**** = there is officially no 'social housing' in Sweden, despite the existence of a municipal publicly owned sector, cooperative housing in the form of tenant ownership, and a system of negotiated rent setting for the whole rental sector

Fig. 2 - Social Housing providers in Europe (Pittini, 2012)

6.1.1. The issue of Housing in Italy: from Public Housing to Social Housing

Italian policy foreseens three main types of publicly supported housing[3]: Subsidised Housing (Edilizia Sovvenzionata), Assisted Housing (Edilizia Agevolata) and Agreed Housing (Edilizia Convenzionata). The development of a social housing policy in Italy followed a progressive decentralization in terms of investments and management. The most significative legislative events that led to the development of the Social Housing in Italy are summarized as following:

1903 The law n. 251/1903 introduced the IACP - Istituti Autonomi per le Case Popolari (Autonomous Institutes of Public Houses) as public bodies responsible for the realization and management of the public housing stock. This measure was part of a wider social policy that, at the beginning of the XX century, spread out in the country with new forms of financial bodies and the intervention of the government in favour of the lower class. In this phase the IACP interventions for public housing operated through existing bodies, such as municipalities and cooperatives.

1938 With the royal decree n. 1165/1938 new actors were involved in the management of Social Housing construction such as INCIS - Istituto Nazionale per le Case degli Impiegati dello Stato (National Institute for State employees houses), charity bodies, cooperatives etc. The municipalities were moved to the background, confering funds and available areas to the new bodies involved. Private investments were bestowed mostly in forms of charity donation, expect for INCIS the IACP were obliged, in most cases, to appeal to credit forms to carry out their projects.

1949 After the war, due to the necessity of reconstruction of parts of the cities, the government to actualize a large-scale plan, resorting two important measures: the *Piano Fanfani* (Fanfani Plan) and law Tupini n.408/1949 which introduced the INA-Casa Plan and the principles of the whole legislation aimed at the regulation of the Public Housing. The system of financing was also modified: no external credit was allowed and the government, and the INA institute (National Insurance Institute) and the enterely participated to the financing of the constructions. The IACP became the instruments of esecution and management, operating in position that not always compensated the cost of services.

1962 The law 167/1962 introduces the PEEP - Piani per l'Edilizia Economica e Popolare (Plans for Economic and Popular Housing), as tools for the urban planning in relation to the construction of Public Housing. The aim is to estimate, through a systematic plan, the real housing need for the next 10 years, subtracting the intervention to the casuality of the construction bodies. Cities with population above 50.000 inhabitants must provide a PEEP indicating the areas destined for housing and those for public services, including green public areas.

1963 The fund GESCAL - Gestione Case per i Lavoratori (Management for employees' houses) was introduced to raise money destinated to the construction of employees' houses. It respresented the substitution of the INA-Casa Plan.

1971 The **law 865/1971** tranformed the **IACP from economic public bodies to non-economic public bodies** that implied a concentration of the activities on the welfare and social aspects related to housing. The law reorganized the competences in the field of management and financing of public housing. The **CER** - Comitato per l'Edilizia Residenziale (Committee for the public housing) was introduced as the responsible actor for the distribution of funds provided by the government.
According to the law the IACP had to be the only institutes acting in this field and, consequently, GESCAL, INCIS and other public bodies were suppressed and their estates were transferred to IACP or sold to the tenants.

1977 The **decree 616/77** actualized the transfer of mandates from State to the **Regional level**.

1978 The **law 457/1978**, known as "**Piano decennale per l'edilizia residenziale**" (Ten-year plan for residential building), new competences are attributed to the regions, in relation, e.g., to the funding raise issue and the control on the respect of procedures and economic and technical obbligations. The ten-year plan forcasted for the first time a series of activities for the recovery of the degraded existing buildings through the PdR - Piani di Recupero (Plans of Recovery).

1992 The **law 179/1992** introduced measures for the urban requalification by means of **PII - Piani Integrati di Intervento** (Intergrated Plans of Intervention) and **Programmi di Riqualificazione Urbana** (Programs for Urban Requalification).

1993 The **law 493/1993** introduced the **PRU - Programmi di Recupero Urbano** (Programs for Urban Recovery) resting on the ex fund GESCAL.
The **law 560/93**, allowing the sell of large part of the public housing estate, gave rise to funds to be reinvested in the renovation of the existing building stock.

1996 The article 2 of the law 662/1996 proposed the allocation of funds for the **Contratti di Quartiere** (Neighborhoods Agreements), as new instruments aimed to enable and govern local development in an integrated and sustainable way through the involvement of local communities and the coordination of projects and resources shared by the signatories to the agreement. This measure is related not only to the physical but also to the social recovery of poor and degraded urban areas.

2008 Under the **Ministerial Decree of 04.22.2008** (Article 1, paragraph 2) the term *Edilizia Residenziale Pubblica* (Public Housing) has been replaced by *Edilizia Residenziale Sociale* (Social Housing). A new National Housing Plan *(Piano Casa)* was approved with the **decree 112/2008**[3] (art. 11) which aims to address the housing problem in a direct and holistic way. Among the main aspects of the plan are the assumption that Social Housing provides an opportunity to overcome traditional forms of public housing, and the definition of Social Housing and urban regeneration as strategic for the country.

As it can be observed, in Italy the public sector is mainly represented by the IACP, that today act as autonomous public agencies with different legal statutes. However, different providers are also involved in different housing schemes: subsidised housing provision is a competence of the public sector (municipalities and public housing agencies), assisted housing are managed by cooperatives, and all private and public providers, especially building firms and cooperatives, engage in the provision of agreed. Central government are responsible for macroprogramming and co-financing of projects through housing allowances, co-funding of urban renewal programmes and programmes to support social rental housing.

Despite a great growth of the public sector in the post war period, where over a million dwellings were built, the public social rented sector never grew significantly larger later.

In addiction, starting in the mid 1990s, the real estate market has witnessed a general increase in prices corresponding to a relatively small increase in family income, generating tensions in the housing market (especially in the metropolitan areas), to which the traditional instruments of Public Housing (Edilizia Residenziale Pubblica - ERP) have difficulty finding adequate responses (Fig. 3).

Housing demand in Italy has changed over time, becoming more complex and diversified, and is currently characterized by the presence of “atypical” housing demand (strong increase in singles, single-parent families, immigrants, temporary workers, off-campus students and others) and the extension of the housing emergency into intermediate segments of the population who until recently were untouched by such difficulties (FHS, 2010).

Nevertheless, the housing system in Italy has been experiencing a phase of change in re-

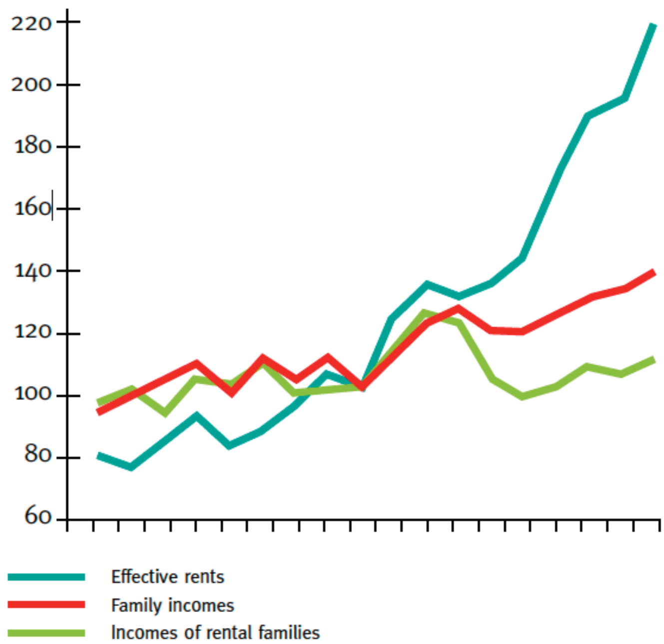


Fig. 3 - Evolution of rents and incomes in Italy (index number, 100=1986) (Banca d’Italia, 2007)

cent years and a growing interest in Social Housing, whose complexity was immediately manifested in the search for a working definition. The "Alloggio Sociale" (Social Lodging) definition, introduced by the Ministerial Decree of 04.22.2008, partially ensures that any public allowances in this area would not be considered "state aid" as defined in Articles 87 and 88 of the EC Treaty. This definition, as well as that proposed by the CECODHAS[4], stresses the need for a multidimensional approach to the issue of housing, addressing the real estate components together with social and other intangible components relating to services. Construction projects were thus flanked by programs to support, guide and facilitate community development, with the overarching objective of enhancing the sustainability of local communities. On the other hand, the introduction of a new National Housing Plan (*Piano Casa*) has foreseen the provision of a Integrated Real Estate Fund System (*Sistema Integrato di Fondi immobiliari-SIF*), consisting of a national fund and a network of local funds primarily devoted to Social Housing, aiming to promote and test innovative financial instruments and methodologies that enable participation by a wide range of social and financial categories - mainly Foundations for Social Housing development created by the bank Foundations in partnership with Regions, Municipalities and other private investors - who are capable of contributing and integrating planning, design, and financial resources on behalf of Social Housing projects. This is possible thanks to the fact that the Integrated Real Estate Fund System provides for the implementation of the Fondo Investimenti per l'Abitare - FIA (National Housing Investment Fund) managed by Cassa Depositi e Prestiti S.g.r. (Cash Deposit and Loans, the Italian public bank based on the management of the postal savings, an investment management company) facilitates the establishment of a series of local funds dedicated to local initiatives of social and public interest by contributing up to 40%. Composed of strategic public and private investors, the national fund plays the role of co-founder and guarantor, ensuring that the initiatives are appropriate to the effective accomplishment of Social Housing projects (FHS, 2013). Amongst the main features of this 'Fund of funds' are a minimum amount of €1 billion to €3 billion, lasting at least 25 years, earning objectives in line with comparable market financial instruments, adequate territorial diversification of investments, ensuring adequate representation to investors by the composition of the Fund's organs, defined criteria for participation in local investment, and acquiring minority shares up to maximum 40% by the Cassa Depositi e Prestiti. The objectives of the Fund are to increase the rental stock managed by the funds at an average rent of approximately 50% of the market rental price and to increase the supply of low cost home ownership. The anticipated target group are people or families not having the requirements to obtain social housing, but unable to meet the market price.

6.1.1.1 Innovative examples

After the introduction in Italy of the Integrated Real Estate Fund System, dedicated to Social Housing projects, the initiative launched by private funations have been decisive for the progression of the sector. The Fondazione Cariplo, e. g., since 2004 has been experimenting innovative models based on sustainability and ethical investment to expand the range of planning instruments and seek to involve in its initiatives other public and private institutions. The initiative thus took concrete form in the Social Housing Programme and the Fondazione Housing Sociale (FHS), instituted to implement the Programme itself. The work of FHS developed along three main axes:

- The promotion of ethical financing initiatives, and in particular, real estate funds dedicated to SH;
- The testing of innovative, no-profit management models;
- Development of project design instruments to be shared among all sector operators;
- A public-private partnership to develop the initiatives in a manner coordinated with and supplemental to existing public housing policies.

Currently, within the Integrated Real Estate Fund System (SIF), FHS actively manages the promotion and organization of more than thirty local real estate funds managed by different investment management companies throughout Italy (the most active regions being Lombardy, Piedmont, Veneto, Trentino Alto Adige, Emilia Romagna, Liguria, Tuscany, Marche, Abruzzo, Lazio, Campania, Basilicata and Sicily). The objective is to implement Social Housing initiatives in the respective territories, flanking capital with local resources[5] coming from local banking foundations, cooperatives, private individuals (builders, landholders) and/or local administrations, which generally play a decisive role in making the projects possible as well as promoting and guiding them.

The multidimensional, interdisciplinary approach implicit in Social Housing initiatives, which combine urban, architectural, real estate, financial, and social planning, depends on the cooperation of various public and private agencies, finding its maximum expression in the network of activities, relations, and exchanges.

Fig. 4 - Casa Crema+, one of the project currently undergoing supported by FHS

According to a recent monitoring made by Eire (Expo Italia Real Estate), in recent years Italy assisted to an increase of projects for the development of housing characterized by energy efficient and low-impact constructive systems.

The project Casa 100k, designed by the Italian architect Mario Cucinella represents one of the first examples of low-cost and low-impact house in the country. Developed with the collaboration of Fondazione Symbola and Legambiente, the design project refers to a 100 m^2 zero energy house able to combine the pleasure of living with the pay back of the investment cost with the energy that it can produce. The house is designed as a technological kit, where photovoltaics integrated with the architecture. The use of solar energy-capturing surfaces for the winter months, internal air circulation for summer and all manner of available passive strategies makes the building a perfect bioclimatic machine.

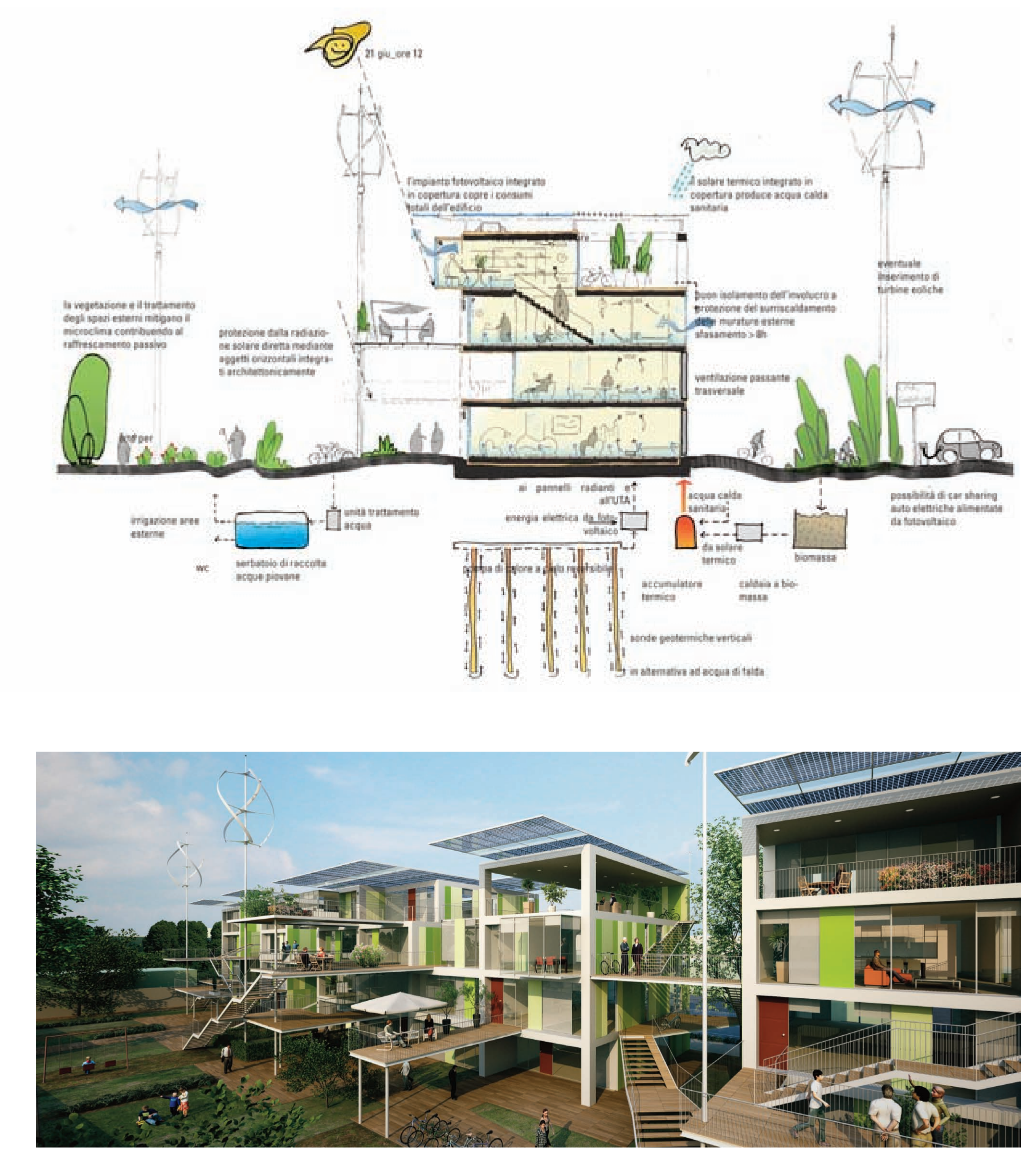


Fig. 5 - The Casa 100k design project by Mario Cucinella (http://www.mcarchitects.it)

The new collective eco-friendly building in Motta di Livenza (Treviso), designed by the architectural firm Matteo Thun & Partners, is another example of building based on the challenge of combining efficiency and good design at affordable costs. In fact, the building arises from an innovative and low-cost Social Housing design using traditional construction methods, responding to the needs of public administration to find innovative solutions in the field of subsidised buildings or council houses. In fact, the cost for this three-story structure with twelve apartments located in a residential area not far from the city's historic center is in accordance with Italian laws regulating Social Housing (which prescribe a cost of less than 1,000 euros per square meter).

Designed with a technique employing timber combined with other materials (concrete and brick for the ground floor and prefabricated wooden panels for the upper floors), it explores solutions that, in terms of both form and construction, are innovative compared to the typical range of urban Social Housing projects.

The residential core, which is rectangular in plan, is a reinterpretation of the traditional, low-cost urban building type based on external walkways. The ground floor features a large colonnade that leads to the internal courtyard. Designed as an evergreen garden, it gives breath to the internal rooms overlooking at it. The building is organized over three floors. The time-tested distribution system allows optimal rationalization of the spaces and functions, avoiding the presence of blind corridors and stairwells and ensuring double exposure for all housing units.

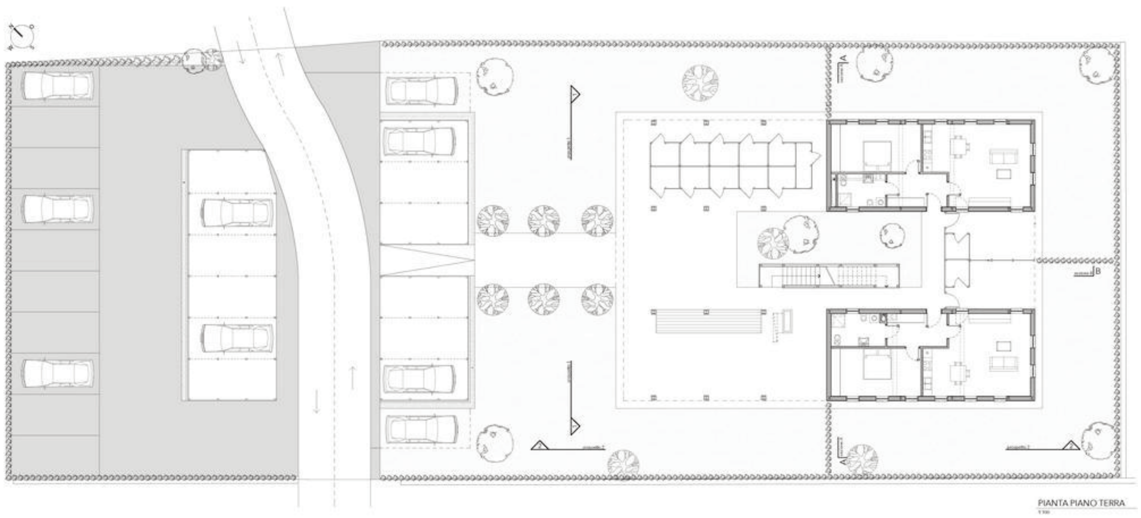


Fig. 6 - Ground floor layout of the collective eco-friendly building in Motta di Livenza (Treviso), designed by the architectural firm Matteo Thun & Partners (http://www10.aeccafe.com)

Using the classic technology of concrete and brick buildings for the ground floor, the other levels have a wood structure and pre-fabricated panels. A second layer of wooden plates covers the whole building and acts as a brise- soleil.

The prefabricated system of modular wooden panels used for the floors and internal partitions ensures maximum durability and flexibility. Insulated wooden panels also form the outer walls and the roof. "Intelligent" plywood walls provide a host of cost-cutting benefits, including a reduction of the time required for construction, installation, and site management. Furthermore, they guarantee better energy performance, durability over time, and an optimal level of comfort, well-being, and health, all of which contributes to an idea of a quality of life that can only be achieved through a sustainable approach to design. This wood construction system also influences the formal solutions. The continuous system of wooden brise-soleils acts as a sun-screen and gives clarity and continuity to the entire complex. The project is an essential synthesis of form and function.

Photo 1, 2 and 3 - The collective eco-friendly building in Motta di Livenza (Treviso), designed by the architectural firm Matteo Thun & Partners

6.2. *Habitação social* in Brazil

By the 1980s, several trading barriers highly prevented Brazil's economy growth in term of international market competition. During the '90s, as a consequence of a trade liberalization process and of the stabilization plan of 1994 Plano Real, significant economic advances were carried out in an effort to bring down inflation and achieve higher levels of growth. Since that time, the Brazilian economy went through several, macroeconomic cycles that created important political and social changes, as the increase in education, a progressive reduction of inequality among population besides «…the progressive consolidation of democracy…» (Beghin, 2008) and a consequent increasing of organised civil society participation in making and monitoring public policies[6].

Today, the country is considered one of the emerging forces in the worldwide economy, with low inflation and high product growth that entailed an unemployment rate stabilization around 4,9% and the rise of average worker incomes, with a higher increase for the lowest-income segments (IBGE, 2012).

With the intention of gradually advancing to adhere to the increasingly important global standards for a sustainable development, Brazil has been experiencing improvements in recent years of legislative and administrative frameworks to face, among other things, one of the issues that historically constituted a criticality of the country: the urbanization of slum areas, known as *favelas*.

As a matter of fact, despite the effort made during the last decade, a huge percentage of the urban population - 43,2% in 2009, according to IBGE (2010) - is still living in inadequate conditions, with inexistent or precarious access to housing, infrastructures and public equip-

Photo 4 - An image of the city of São Paulo: typical urban scenario of Brazilian metropolis ment, which means that slum areas, together with overall distribution of public services, keep on being a critical urban reality. Moreover, we need to consider that the poverty issue in the country has exacerbate also because, while the flow of internal migration resulting from the strong attraction that industrial jobs hold for residents of Brazil's poor regions has drastically diminished and industrial enterprises are being distributed more homogenously over the nation's territory, large numbers of poor people are still concentrated in major Brazilian metropolises such as São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, and Recife. A large portion of this population, particularly the poorer segment, remains in the cities despite exclusion from a formal labour market that demands skilled labour (Herling, 2009).

Starting from these assumptions, since the last decade, Brazil has been making considerable efforts to generate concrete responses for a more efficient and sustainable social housing policy. This intention is nowadays translated in a strong increase of federal, state and municipal investments, as well as the growth of private sector participation in low-income housing, in order to finally propose noteworthy urban and architecture design project of social interest.

Considering the increasing demand for housing and the massive rate of greenhouse gases emission derived from building and construction sector, initiatives on sustainable building techniques have become a prior challenge of Brazil governance. The State of São Paulo, and the metropolitan area of the city of São Paulo in particular, became in the last years an experiment laboratory where administrations engagements, in all levels, are producing a robust and efficient development programme that will serve as reference model for future social house planning of other cities of the country.

Photo 5 - A typical view of *favela* in Brazil

6.2.1. The state of São Paulo as laboratory of sustainable practices

Brazil has 57 formally created Metropolitan Regions and also three Integrated Regions of Development, which include 482 cities and 8.6% of the national total. The population is strongly concentrated in these regions, representing 87% of the total[7].

The State of São Paulo has a wide range of spatial forms and distinct scales of urbanization, constituting a very complex urban network. These phenomena are a result of the process of urbanization, internalization of the economic development and population sprawl of the Metropolitan Region of São Paulo, process that have consolidated the so called São Paulo Macrometropolis, a region structured under a network of flows and relations that assembles 173 cities with intense functional integration. These cities are located in 200 km radius from the city of São Paulo. It shelters 30 million people, or 73.3% of the population of the State (95% residents in urban areas), 22% of Brazil's total population, and generates 82.5% of the Gross Domestic Product (GDP) of the State of São Paulo and more than one third of the Brazilian GDP.

Despite the high concentration of wealth, the state of São Paulo still has social, urban and environmental problems, that make investing in quality of life and improving territorial functions of São Paulo one of the greatest challenge, not only to ensure the cities' development, but also their economic. For this reason, at the state level, several initiatives have been launched for the (re)urbanization of the most degraded areas of the cities and to offer concrete responses to the big demand for housing.

The Housing Secretariat (Secretaria da Habitação), responsible for the development of a the housing policy of the State of São Paulo, for example, has recently launched the programme *Casa Paulista - Agência Paulista de Habitação Social*, to make operative some funds destined to Social Housing programmes such as the Fundo Paulista de Habitação de Interesse Social (FPHIS) and the Fundo Garantidor Habitacional (FGH), in order to involve private subjects in the construction of affordable houses.

From 2012 to 2015, by means of the *Agência Paulista de Habitação Social* and of the *Companhia de Desenvolvimento Habitacional e Urbano* - CDHU (Housing and Urban Development Agency of the State of São Paulo), the state government is investing R$ 7,9 billions (around € 2.6 billions) to realize 150,000 new houses and to implement actions for the urbanization of favelas. These interventions are developed with joint actions carried out by the State, financial agents, municipalities, landowners, civil organizations and building companies (GESP, 2013).

Moreover, over the last few years, Social Housing initiatives have been often supported by non-governmental organizations such as The Cities Alliance, the United Nations Environment Programme (UNEP) and the UN-Habitat, which aim to improve the aspects of sustainability related to the construction or the recovery of affordable dwellings in the metropolitan areas of the country.

6.2.1.1. UNEP SUSHI Project- Sustainable Social Housing Initiative

In 2008 the United Nations Environment Programme (UNEP) launched the project called SUSHI (Sustainable Social Housing Initiative), with the objective to create guidelines for the inclusion of sustainable elements in Social Housing projects in Brazil.

The government's Social Housing programme, considered in the SUSHI project, prioritizes families with an income between 1-3 minimum wages but also provides housing for the population earning up to 10 minimum wages.

As Andrade and Pileggi (2006) stated, even if there are no official statistics, it is known that a large number of dwellers, pressed by lack of resources, sell their right to housing and return to squatter settlements, because of the insufficient income to cover gas, water and electricity bills, besides mortgage and regular family expenses. In these cases, subsidies to instalment payments are not enough to solve the problem of access to housing and therefore sustainable Social Housing projects, able to bring to effective users' economic savings, could actually make a difference.

For this purpose, the state of São Paulo has been chosen by SUSHI project as the "pilot site" for the development of a local approach to promote sustainable technologies and strategies in low-income dwelling projects, taking into account all stakeholders involved in this process, such as consumers, suppliers and, especially, project developers. This multi-stakeholder approach allows to achieve several objectives on different levels: the economic level (business opportunities, "green" jobs), the government level (reduced healthcare costs), the society (wealth generation, pollution reduction), financial agents field (new financing opportunities, better guarantees, reduced risk of premature obsolescence of the building) and last but not least for the final user, the families that will live in buildings that provide a higher quality of life.

The SUSHI project is conducted in partnership with the - CBCS (Brazilian Council of Sustainable Construction) - and the CDHU. Furthermore the project created a network of partners to discuss the aspects of sustainability in Brazilian Social Housing by involving several national institutions that have renowned experience in Social Housing, energy efficiency, thermal comfort and rational water use such as, the Polytechnic School of the University of São Paulo, the Federal University of the State of Santa Catarina, the State University of Campinas, besides the *Caixa Econômica Federal* (National Bank) for the economic support.

An important aspect of this experience was the involvement of private companies interested in the application of their technologies in Social Housing, that sponsored the pilot projects offering their systems and equipments to directly evaluate their performance and challenges.

Although sustainable design and construction encompasses the study of a multitude of aspects, the project focuses on the themes of rational use of water and energy saving, taking into account the national norms that regulate thermal comfort and energy efficiency performance of buildings in Brazil.

The SUSHI project was carried out in three phases[8]:

1) *Evaluation of the sustainable solutions available on the market.*

Since 2009, several documentary researches have been carried out by CBCS team, in order to identify available technologies and strategies to improve energy efficiency and water management in Social

Housing designs and construction in the State of São Paulo. The result of this first phase was a mapping of the sustainable solutions available on the market and potentially applicable to Social Housing projects by means of the analysis of costs and benefits related to the local context.

2) *Assessment of the strategies in "pilot project".*

The strategies previously evaluated were tested in Social Housing projects chosen as "pilot projects" in order to understand their success or failure, verify whether these actions could be replicated, and identify potential improvements for future implementation.

3) *Evaluation of the results.*

The benefits and main difficulties encountered during every pilot experience were described in apposite reports, considering technical aspects (implementation, maintenance, generated costs and social impacts) as well as the main challenges for the adoption of the solution as a public policy and what could be improved in its application in other CDHU housing developments. In some cases, CDHU was successful in implementing new technologies, but in others, it experienced some difficulties and opted for no longer use them.

Selected design solutions for energy efficiency and thermal comfort include:

Passive systems:

- Standardization of ceiling height;
- Orientation;
- Proper use of building materials and products for thermal insulation (lining, low-absorptance glazing, windows frames);
- Shading devices.

Active systems:

- Solar panels;
- Solar-electric hybrid heater;
- Photovoltaic panels;
- Efficient appliances;
- Remote and individual metering of energy and water inputs.

Selected design solutions for water use efficiency include:

- Rainwater harvesting;
- Water reuse through phyto treatment, or in-situ sewage treatment;
- Water management solutions (individual consumption metering, use of water-saving appliances);
- Land-use solutions (e.g. permeable pavement).

Among the passive systems experimented, the use of lining systems in pilot projects gave satisfying results in the matter of thermal comfort. The use of a roof lining is needed to create a thermal isolating layer that separates the environment occupied by the user from the heat radiated through the roof during the day and to partly reduces heat losses during the night, so as to increase the thermal resistance of the house covering. Previously, single-family units used to be designed and built up just with a roofing tiles covering supported by a timber structure, without slab lining. Since 2007 CDHU has been evaluating possible application of lining systems to significantly improve dwellings' thermal and acoustic insulation. The CDHU team evaluated the application of different material of roof lining such as plaster, wood, PVC or roofing slab (layer of reinforced concrete). Roofing slab can be a mixed slab with bricks, EPS or concrete slab. According to Brazilian ABNT NBR 15220-3[9], CDHU team evaluated different constructive solution for the covering system, among which: clay roofing tile covering with no lining; clay roofing tile covering with air gap and 12 cm - mixed slab lining; clay roofing tile covering with 1 cm - wood lining with or without polished aluminium sheet acting as thermal insulator.

For bioclimatic zones 3 to 5, where most of the CDHU projects are situated, the ABNT NBR 15220-3 recommends values of thermal transmittance as the followings:

$U < 2.30$ if $\alpha < 0.6$
or
$U < 1.5$ if $\alpha > 0.6$
and where:
U is the thermal transmittance of the roof, and
α is the solar radiation absorbance of the roof.

As shown in Table 1, thermal transmittance does not vary significantly when clay roofing tiles are used with either a mixed slab or wood lining.

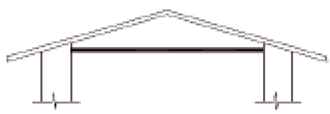
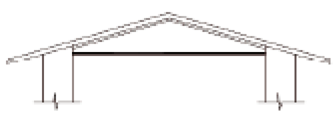
	U [W/(m2K)]	4.55		U [W/(m2K)]	2
	TC [kJ/(m2K)]	18		TC [kJ/(m2K)]	32
Clay roofing tile covering (1cm) with no lining	ϕ[hours]	0.3	Clay tiles covering (1cm) with air gap and wood lining (1cm)	ϕ[hours]	1.3
	U [W/(m2K)]	1.92		U [W/(m2K)]	1.11
	TC [kJ/(m2K)]	113		TC [kJ/(m2K)]	32
Clay roofing tiles covering (1cm) with air gap and mixed slab lining (12 cm)	ϕ[hours]	3.6	Clay roofing tile covering (1cm), polished aluminium sheet and wood lining (1cm)	ϕ[hours]	2

Table 1 - Comparison of transmittance, thermal capacity and thermal delay of different coverings with or without lining systems (ABNT NBR 15220-3)

Actually, the use of mixed slab lining does not translate into significant improvements in the thermal performance of the building and moreover its greater thermal capacity causes an excessive heat storing during the day returning it at night, which is not desirable for most part of the year. On the contrary, the thermal transmittance of the covering lowers significantly when clay roofing tiles are used with a wood lining and a polished aluminium sheet, because of the low conductivity of the thermal insulating material. In this case low thermal capacity is also achieved.

Starting from these considerations, since 2007, CDHU has used slab lining in its housing projects and, currently, all the typologies are delivered with slab lining, to improve not only the thermal comfort of users but also the "aesthetic" of the dwelling. In fact, the use of slab or lining represents a good solution for hiding components such as tiles, wiring, plumbing etc. contributing to create a more pleasant environment for residents.

In regards to active systems to improve energy efficiency in Social Housing, an important contribution was given through the application of solar panels for domestic water heating. This system has been usually integrated with an electric shower head (manually or automatically adjustable), as a backup system for days of little sunshine. Cafelândia C was the first site where CDHU installed solar water heating systems in horizontal residential developments (Photo 6).

Cafelândia C is a low-income residence built in the town of Cafelândia, located in the northwest region of the state of São Paulo and with about 16,000 inhabitants. The Social Housing project counts 136 dwellings, originally built by the community. Dwellings already existed when solar heating systems were installed. The system applied was composed of a solar collector, a thermal reservoir, installed under the roof inside the building and a backup system using an electric shower head, configuring a solar-electric hybrid system. The *Instituto de Pesquisas Tecnológicas do Estado de São Paulo* - IPT (Institute of Technological Re-


Photo 6 and 7 - Solar panels installed in a social housing complex in Cafelândia (left) and in Mogi Mirimim (right) search), was hired to monitor the results of the implementation of solar systems in the pilot project development, showed that the electricity consumption for water heating decreased and that great results were obtained in user satisfaction. After using the solar heating system, users declared they would even agree to pay a little more to permanently acquire the system, due essentially to the great reduction of the electricity bill.

The results obtained in Cafelândia, in terms of energy saving and user comfort improvement, were so significant that CDHU decided to establish the use of solar heaters as standard procedure in its projects. By 2009, over 15 thousand housing units had already received solar heating systems from CDHU and an energy saving of about 45% has been estimated (Neto, 2010). On the other hand, solar systems installed in vertical housing developments (more than two-storey houses), did not lead to appreciable results essentially because of the problems with the supply of hot water to the lower floors and also in the individualized water metering. For this reason, other systems were tested in vertical houses and, so far, natural gas heaters offered best results.

With regard to photovoltaic systems application in SUSHI pilot project, CDHU first experiment was made in 2002, in five indigenous dwellings in the village of Terra Indígena Guarani do Ribeirão Silveira, in Boracéia, municipality of São Sebastião, with the sponsor of Companhia Eletrobrás Furnas, the main company for the supply and distribution of electricity in the Southeast, South, Centre-west and North regions of Brazil.

Even if the program led to satisfactory results in terms of energy savings, the cost for implementing this technology was very high and CDHU initially set this program aside. Nowadays the main challenge for this action consists in achieving competitive prices comparing to other energy efficient systems. However, CDHU reports state that more tests will be done in other housing developments to refine the application of this technology and better evaluate its benefits.

Photo 8 and 9 - Solar panels installed in a social housing complex in Mogi das Cruzes (left) and in Rubens Lara (right)

6.2.1.2 Innovative Social Housing design projects in the city of São Paulo

The city of São Paulo, together with the adjacent metropolitan region, represents the basin of the economic development of the whole Brazil, with one third of Gross Domestic Product and 19,6 millions of inhabitants. According to CDHU data, in 2008 the housing deficit of the metropolitan area of São Paulo was about 620,000 units, representing almost the 10% of the country. In particular, the peripheral areas of the City concentrate a number of environmentally vulnerable situations where it is possible to observe a high degree of co-incidence between the risk areas and the informal settlements. In these areas, mostly constituted by favelas, more than half of the households have no access to sewerage facilities and are greatly exposed to environmental problems causing also disease and health hazards.

The Strategic Master Plan of the city, approved in 2002, defined four categories of Zones of Special Social Interest (*Zonas de Especial Interesse Social, ZEIS*) as shown in Fig. 7. Despite a still existing spatial segregation, the coexistence of wealth and poverty is nowadays producing an urban phenomenon that «…creates a productive energy that as no equal in the world, which is also expressed in the intense cultural and above all architectural production…» (Anelli, 2011).

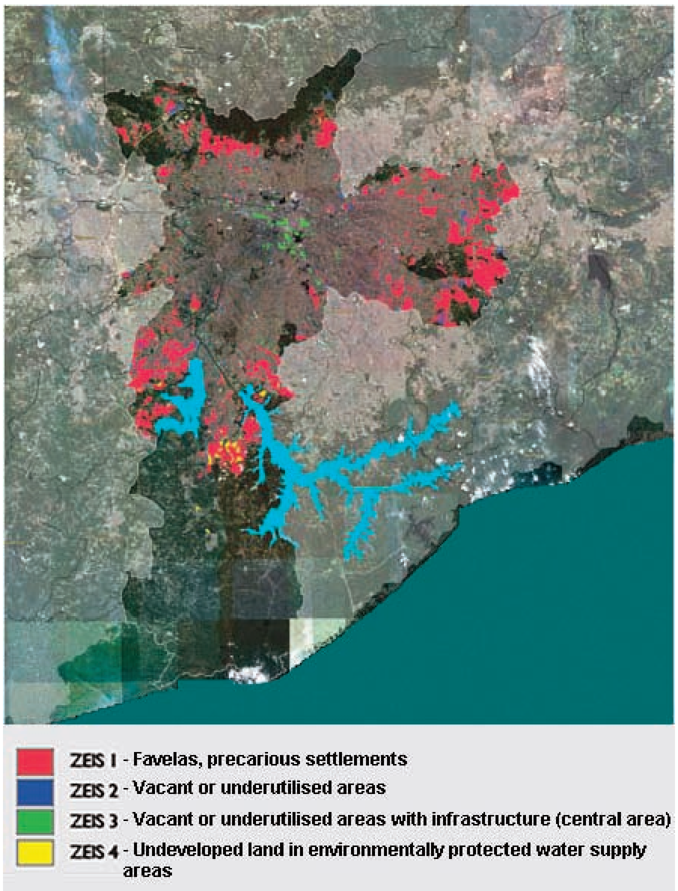


Fig. 7 - Zones of Special Social Interest (ZEIS) in the city of São Paulo (HABISP, 2008)

The challenge of combating poverty and promoting a sustainable growth of the city is continuously supported by the contribution and funding from all three levels of government: local, state, and federal. In particular, the city government over the past 30 years launched various programs to provide the population a decent quality of life in these areas. Sporadic initiative to install infrastructure were followed by complete slum upgrading programs, most of which entailed building new housing units on the same site.

Since 2005 the *Secretaria Municipal de Habitação* - SEHAB (Housing Secretariat from the city of São Paulo) has been carrying out the largest favelas urban program of the country. Through a project called "*Estratégias para o Planejamento, Financiamento and Implementação Sustentáveis da Política Habitacional e de Desenvolvimento Urbano*" (Strategies for Planning, Financing, and Sustainable Implementation of Housing and Urban Development Policy), the SEHAB and the Cities Alliance with support from the World Bank, developed a project whose aim was to establish a strategic planning process that would be supplemented by specific studies in order to address the reality that is undergoing transformation. The final results achieved helped the agency's technical staff to formulate the Municipal Housing Policy, adopted as a starting point for the total (re)urbanization of São Paulo slum areas within 2024, as recently stated by the local administration. Under this initiative, strategic, continuous and systematic planning has been established within SEHAB to make it possible to learn more about the demand for housing and to redirect human, financial, institutional, and legal resources toward the execution of programmes most likely to meet that demand[10].

To reach both aims of facing such a large housing volume and at the same time producing good quality architecture, the city administration for the first time outsourced or subcontracted several national and international professionals in the field of architecture and urban planning and gave birth to a complex programs network, including also top academic institutions from all over the world, local administration and the community people -not in the form of "petitioners" but as active involved citizens- to engage a debate about the informal city and to offer sustainable upgrading proposals.

The urban and building plans aims to convert the city into spatial solutions, where the society can have equal access to housing, employment, technology, services, education, and resources, that is, a more sustainable way of living.

One of the consequences of these inedited purposes and of the intense production of interrelated contributions was, for example, the use money coming from the selling of Carbon Credit to finance the development of social and environmental projects areas. This is the case of the favela of Bamburral (Photo 10), the first precarious settlement to be urbanized with such funds. The slum, situated in the region of Perus -north of São Paulo city- is settled in a very problematic area from an environmental point of view. Because of the proximity of a landfill used for solid waste dump, that generates methane able to provide electricity to 700 thousands people, the local administration succeed in selling carbon credits by auction, earning an amount of 71 million Reais.

Brasil Arquitetura was the design team chosen to develop the urban and architecture project of the area. The intervention includes infrastructure, stream channelling and the construction of five blocks of affordable houses that will receive 260 families that currently live in the district.

According to the preliminary geotechnical studies, that individuated four areas of risks (from very high risk to low risk), all the precarious constructions staying on unstable soil were removed. This area is currently being converted in a linear park for the community leisure and the construction of a deck over the stream will allow safe movements of residents (Fig. 8).

Photo 10 - The community of Bamburral before the intervention

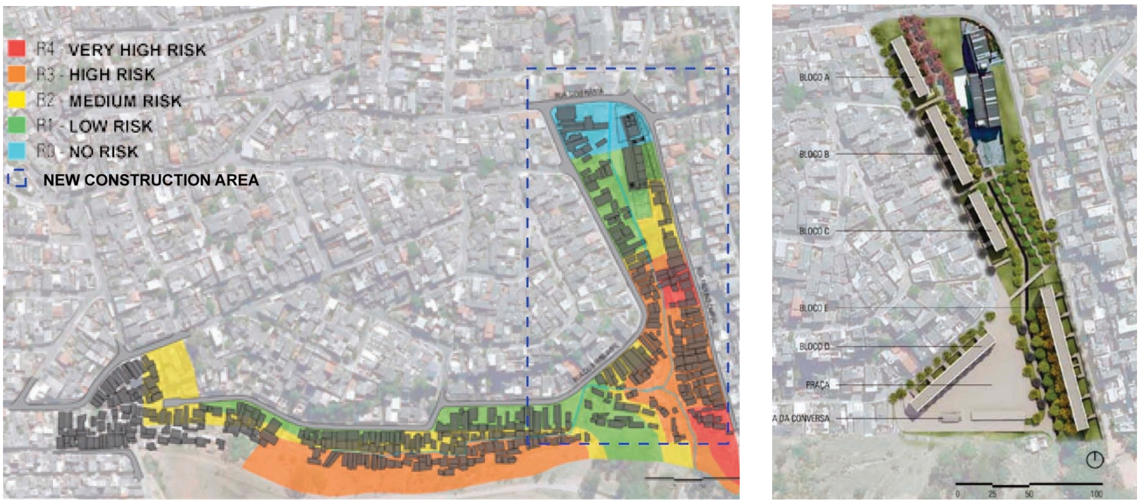


Fig. 8 - The intervention area with risk evaluations (left) and the new masterplan (right) (by courtesy of Brasil Arquitetura)

The dwellings consist in max seven-storey buildings on pilotis where the ground floor is destined to receive social spaces for the community. The use of pilotis not only releases open public space but also separate the dwellings from the particularly humid soil of the area, improving thermo-hygrometric comfort of dwellers (Fig. 10). At the same time this solution allows the adaptation of the buildings to the natural soil conformation. The choice of leaving the open-topped stream and providing an abundant vegetation of the surrounding would also contribute to maintain more pleasant temperatures for most time of the year (Fig. 11).

Fig. 9 - Photomontage of the new buildings in the community of Bamburral (by courtesy of Brasil Arquitetura)

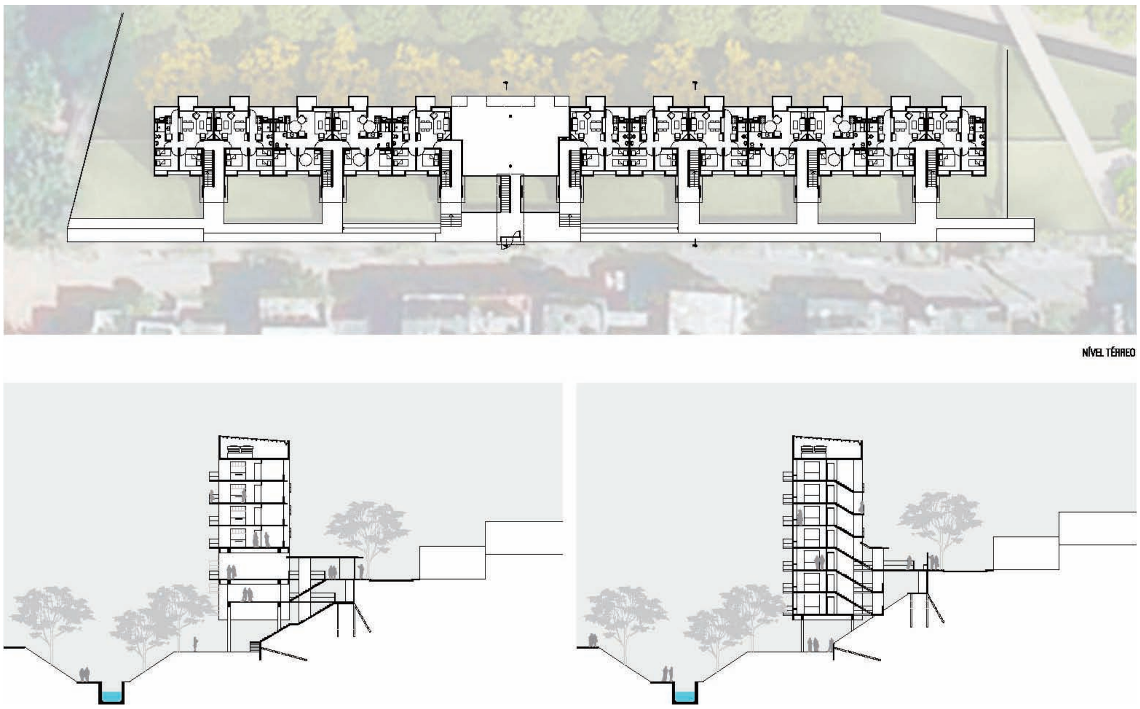


Fig. 10 - Groundfloor layout and sections of on of the blocks (by courtesy of Brasil Arquitetura)

The apartment unit, despite the maximal standard of the area adopted (around 50 m^2), presents a rational distribution of the spaces that ensures adequate living levels. Natural lighting and transversal ventilation are provided by big openings placed on opposite façades, while Cobogó, common ceramic perforated tiles traditionally used in modern Brazilian architecture, is used as a shading device (Fig. 12).

For the domestic water supply, the design team opted for individualized water metering systems to ensure performance and effectiveness of the systems, providing efficiency and reliability for consumers. In order to guarantee sustainable economy of the intervention, the building structure consists of typical local constructive systems: reinforced concrete and structural masonry. The community accompanied the whole design and building process and together with designers and social workers was engaged in a constructive debate from the beginning of the action to the execution of the project.

Fig. 11 - Rendered images of the Bamburral social housing complex (by courtesy of Brasil Arquitetura)

Fig. 12 - Typical apartment layout of the new building (right) and rendered images of the Bamburral social housing complex (left) (by courtesy of Brasil Arquitetura)

The SEHAB has been also promoting several initiatives to implement the debate about the requalification of favelas by involving different institutions, mainly belonging to the academic field, inside and outside Brazil. Since 2007 the São Paulo Architecture Experiment has been launched by the SEHAB in collaboration with the S.L.U.M. Lab (Sustainable Living Urban Model Lab) from Columbia University's Graduate School of Architecture, which proposes a reconsideration of the minimal habitation in dense urban space in an attempt to involve top academic institutions from all over the world, to build up an architectural debate about residences in informal cities.

Among the proposals related to the city of São Paulo, the S.L.U.M. Lab research suggests a new land-water interface, combining vegetation and built environment to create a new "living" system. For example, in the area of Grotão, Paraisópolis, a proposal of a "infraagriculture" concrete rooftops panning system was foreseen, where the tectonic and process of generational growth follow the informal nature of the favela organization (Fig .13).

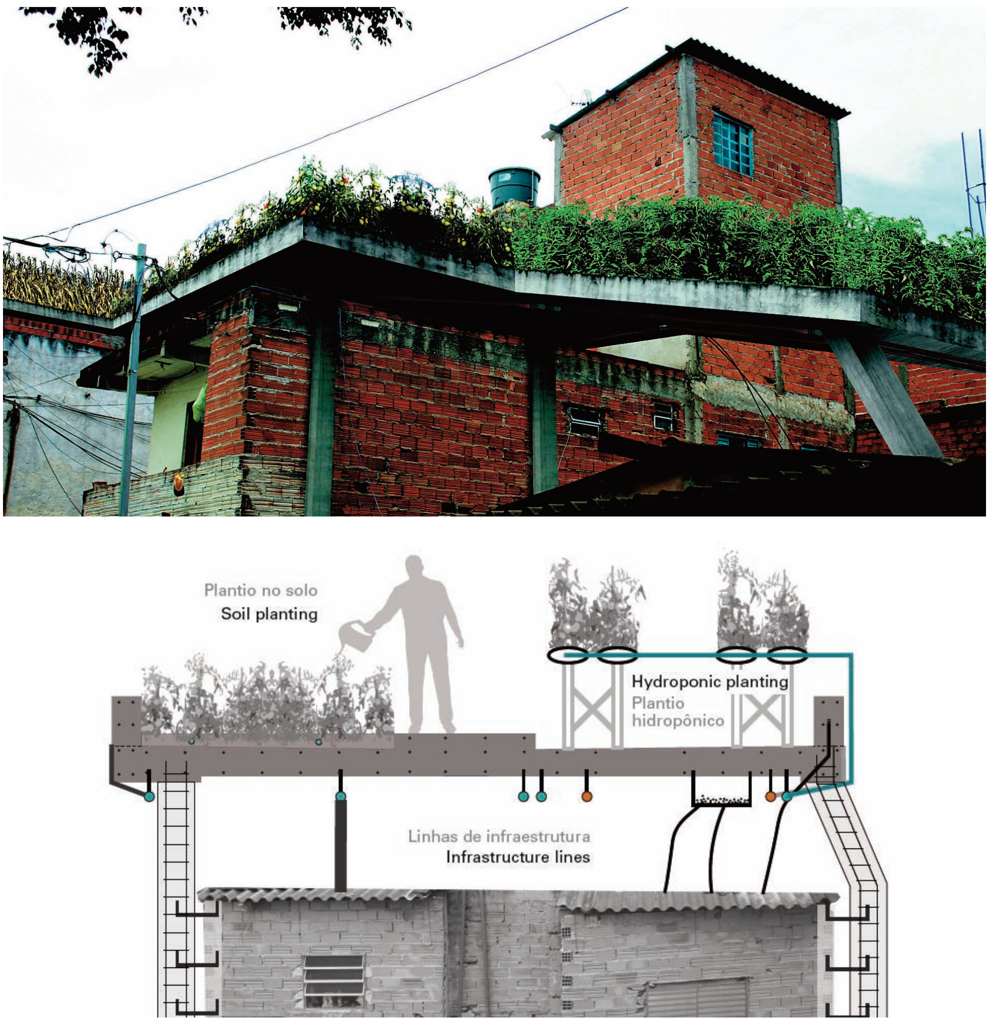


Fig. 13 - Hypoteses of integration of vegetation into the built environment in order to create a new "living" system inside the community of Grotão (Tamayo et al., 2010)

The system would operate in a largely decentralized strategy, which promotes the integration of the system with a large number of interconnections in the community in order to enhance the erosion control system, the agricultural production and the social life of the community (Fig. 14). The connection paths are based on the existing house attributes, seeking the implantation of the public services to the houses without running water or sewage links, besides negotiating slope, density, and water runoff paths.

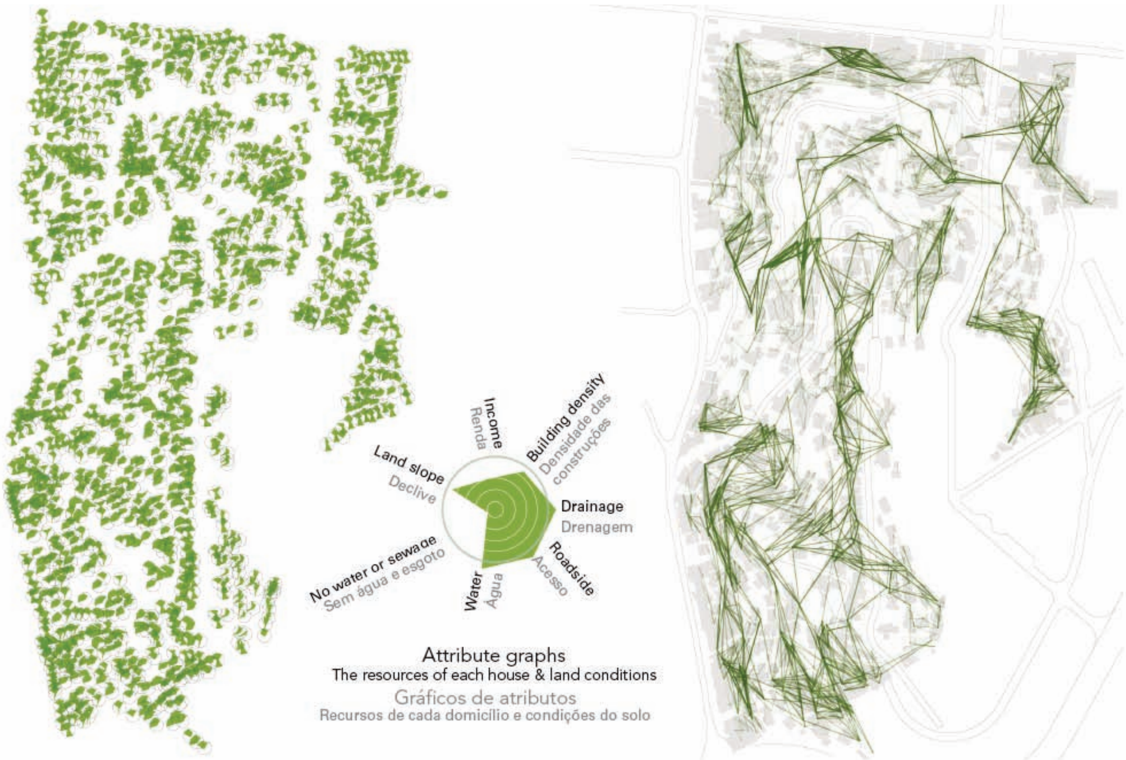


Fig. 14 - Conceptual scheme of the role of vegetation to promote a system of physical and social interconnection inside the community of Grotão (Tamayo et al., 2010)

Through the program “Concurso Renova SP”, a design competition launched on June 2011, SEHAB appealed once again to important name inside the Brazilian architecture scenario to continue the reurbanization process of 209 favelas, for a total of 55,642,278 m^2 of the city, the largest SEHAB’s urban intervention ever done (Barda and França, 2011). What came out from the competition are, in most cases, interesting design projects that aim at the regeneration of the city, embracing the possibility of social intervention and responsibility in areas of precarious conditions moving between different scales: housing and urban planning. As for the area called “Cabuçu de Baixo 5”, the winner design team MSA+PMA in collaboration with “MAS Urban Design ETH Zürich” proposed a complex masterplan that focuses on the need for a concept and strategy that respect the existent local qualities whilst solving the community problems.

The territory of Cabuçu de Baixo, indeed, consists in an extensive area located in the North of São Paulo, which is currently facing high levels of landslide risks, flooding, high density, polluted streams, poor infrastructures and lack of cultural and social services. The direct response for that foresees two ways of interventions: linear or punctual.

Linear housing structures, alongside the stream, resemble the dorsal spine of the plan by concentrating on areas under severe depression and giving birth to a new urban front (Fig. 15). This grid is accompanied by public spaces which allow the decrease in density caused by this new implementation and the creation of open spots. The target of these structures is to stimulate this area and define a new consolidated core.

Fig. 15 - Planivolumetric plan of the project for the reurbanization of area "Cabuçu de Baixo 5"(Barda and França, 2011)

On the lower part of Cabuçu de Baixo 5, in a highly polluted creek area an underground sewage system treated as a green linear park for a greater part of Brasilandia is also foreseen. 30% to 100% relocated units in the neighbouring and the most dense areas are proposed to be replaced with new Social Housing projects, forming perimetric linear residence with a parallel intention to introduce public squares, commercial activities, public facilities all along the creek and the main roads. New streets and public space network in the south of the dump are implemented to serve as a new residential area for the nearby relocations. (Fig. 16).

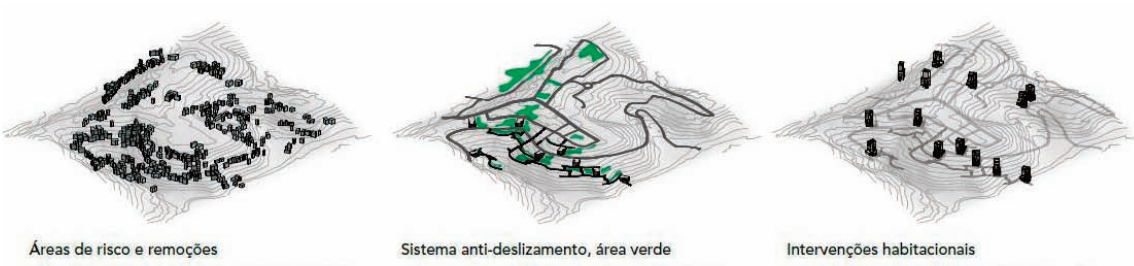


Fig. 16 - Sectors of intervention for the reurbanization of area "Cabuçu de Baixo 5" (Barda and França, 2011)

The other method, punctual intervention, reduces occupancy rate by proposing an increase in vertical construction. They consist in residential towers which act as reinforcement elements located on the hillside by also creating new public spaces within a linear perimeter that gathers housing, social facilities and commercial areas along the stream. The general picture is to create exceptional vertical buildings for housing whilst creating empty spots on land destined for public spaces (Fig. 17 and 18).

Fig. 17 - Volumetric section of the design project for the reurbanization of area "Cabuço de Baixo 5" (Barda and França, 2011)

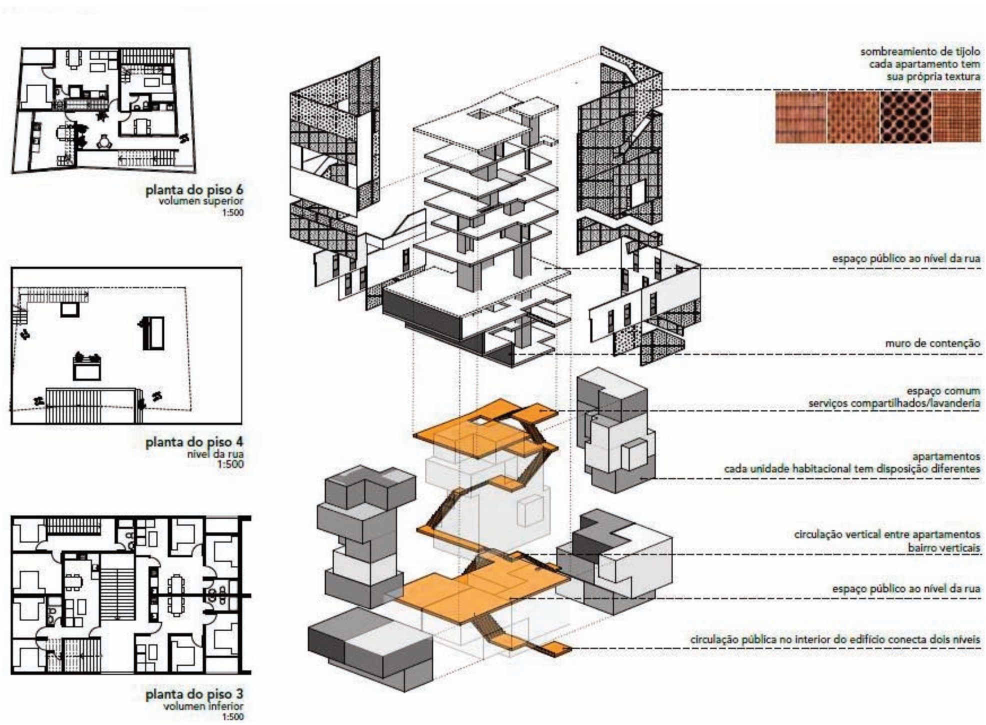


Fig. 18 - Exploded 3D of a typical residential tower for the area "Cabuço de Baixo 5"(Barda and França, 2011)

Also for the area called "Cordeiro", the proposal of the design team leaded by the architect Carolina Haguiara Cervellini, starts from the assumption that the renovation of the favela begins from the reconfiguration of its public spaces. Then the plan aims to integrate environmental and urbanistic regeneration working on the consolidated built environment of the area, the surrounding geomorphology and powerless mobility.

One of the opportunity to exploit was represented by the fact that this area of the city suffered less real-estate speculation than other areas nearby. This allowed to widely act at the neighbourhood level as well as at the scale of the buildings. Several interventions are proposed for the requalification of the open spaces such as the reconfiguration of the vehicular and pedestrian paths. The use of plants and vegetation is also considered for the enhancement of the area and the reduction of storm-water runoff jointly with the canalization of a stream, taking into account the local vegetal species, as shown in Fig. 19 and 20.

Fig. 19 - Masterplan for the urban renovation of the area "Cordeiro"(Barda and França, 2011)

Fig. 20 - Sketches for the urban renovation of the area "Cordeiro" (Barda and França, 2011)

Vegetation is also considered for its integration with the new houses which consist in the assembly of reused containers that constitute the envelope of the buildings (Fig. 21). Green walls grow all around the lateral surfaces of these containers conferring them a new aspect. Climbing plants grow up on cages containing recycled stones to increase the thermal mass of the building walls (Fig. 21). Solar collectors on the top of the building, acting also as sun shading for the rooftop terraces, would guarantee the energy autonomy of the dwellings.

In addiction, the apartments layout is designed to facilitate a cross ventilation inside the houses.

Fig. 21 - Rendered images of the new housing blocks in the area "Cordeiro" (Barda and França, 2011)

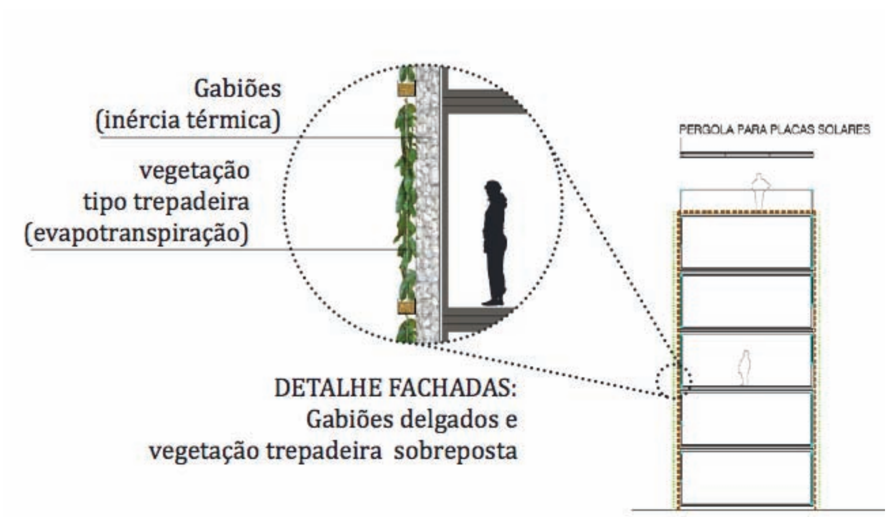


Fig. 22 - Detail of the façade system of the building in the area "Cordeiro"(Barda and França, 2011)

Notes

1) Article 25 (1) of the Universal Declaration of Human Rights (UDHR), adopted by the United Nations General Assembly on 10 December 1948 at Palais de Chaillot, Paris. The Declaration arose after the Second World War and represents the first global expression of rights to which all human beings are inherently entitled.
2) Article 23 of the European Social Charter , adopted in 1961 by the Council of Europe. Revised in 1996, it came into force in 1999 with the aim to set out human rights and freedoms and establish a supervisory mechanism guaranteeing their respect by the States parties.
3)Transformed into Law 133/2009.
4) An official definition of Social Housing in Italy has been provided for the first time in 2008 by CECODHAS Housing Europe (European Federation of Public, Cooperative & Social Housing) as "mainly of dwellings rented on a permanent basis; also to be considered as Social Housing are dwellings built or rehabilitated through public and private contribution or the use of public funding, rented for at least eight years and also sold at affordable price, with the goal of achieving social mix".
5)The Integrated Funds System currently consists of a national fund of funds, the *Fondo Investimenti per l'Abitare* - FIA, managed by *Cassa Depositi Prestiti e Investimenti* (CDPI Sgr), which invests in local real estate funds to build social housing units at affordable prices, intended for families unable to meet their housing needs on the marketplace, but with incomes higher than those which would entitle them to public housing.
6) With the end of the military dictatorship, in the mid-1980s, Brazil passed through a phase of redemocratization with the adoption of a new Constitution in 1988, that established the Rule of Law and a Social State, defining the right of citizens to social protection and leading to a progressive participation of organised civil society in making and following up on public policies.
7) Data of 2010, http://world.bymap.org (accessed December 2013).
8) Each of these actions was discussed in detail in a specific report called "lessons learned" in the fields of water management and energy savings (CBCS, 2010).
9) Cf. Chapter 2, Paragraph 2.3., p.47.
10) In order to achieve this goal an important managerial information system, called HABISP (*Sistema de informações para Habitação Social na cidade de São Paulo*), was adopted. It is updated regularly and includes information about residents of precarious settlements of various kinds – *favelas*, informal land subdivisions, slum tenements, hazardous areas – and of government housing developments. Gathering the data made it possible to update the characteristics of those settlements and classify them in order to obtain a comprehensive view of all the various types. It also permitted the setting of priority criteria for interventions based on the different programmatic lines adopted.

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Photo References

Photo 1 - Daniele Domenicali, published on http://europaconcorsi.com

Photo 2 - Daniele Domenicali, published on http://europaconcorsi.com

Photo 3 - Daniele Domenicali, published on http://europaconcorsi.com

Photo 4 - http://www.domusweb.it

Photo 5 - By courtesy of Brasil Arquitetura

Photo 6 - By courtesy of CDHU

Photo 7 - By courtesy of CDHU

Photo 8 - By courtesy of CDHU

Photo 9 - By courtesy of CDHU

Photo 10 - By courtesy of Brasil Arquitetura

CHAPTER 7
Examples of Social Housing retrofit in Europe

As highlighted in Chapter 6, social housing in the European Union shows a wide diversity of national policies across member states, characterized by different approaches and situations, in terms of size, tenures, providers, beneficiaries, and funding arrangements for the construction of new social dwellings and the renovation of the existing buildings stock.

In this sense, EU is committed to foster practices of cooperation and to explore new ways to achieve the necessary resources to modernise public housing and to ensure its proper management, also in a perspective of Europe 2020 goals achievement.

This chapter provides a series of significant examples of social housing retrofit interventions that were analysed in order to identify technical alternatives for buildings renovation as well as different finance mechanisms put in use in different countries.

The examples chosen are described in synthetic data sheets that put an emphasis on the solutions adopted for the upgrading of buildings envelope and systems, the possible use of vegetation and landscaping for the retrofit of the external spaces, funding mechanisms and overall outcomes of renovations.

The retrofitted social housing complexes belong to continental and temperate climates. In particular, 2 examples were chosen for Austria, 1 for Bulgaria, 1 for Denmark, 3 for Germany, 1 for Sweden, 2 for France, 3 for Italy and 3 for Spain. Depending on the climate context, the technical strategies used for the building retrofit are different.

Among the most common technical solutions applied, it can be mentioned the introduction of sunspaces, present in many examples situated in cold zones. The diffusion of this technical solution must be sought in the fact that it represents a relatively cheap opportunity to increase, at the same time, the surface area by creating a comfortable environment throughout the year and to decrease the power demand for heating, since the thermal comfort during the coldest days is totally or partially provided by passive solar gain.

Another very diffuse solution is the thermal coating, which, in the case of temperate countries, is usually integrated with ventilated façades or other systems able to also increase the thermal mass of the building envelopes.

The most common strategy, used indifferently in all climatic zones, is the replacement of the existing windows (frames and glazing) with high-performance ones.

The use of renewable resources, in particular photovoltaic and solar collectors, is also widespread. They are usually integrated with condensing boilers that ensure a significant reduction of energy consumption due to their high efficiency.

Mechanical ventilation with heat recovery is usually adopted in cold areas while natural ventilation is encouraged in temperate and warm areas, especially during night hours.

The use of vegetation and the requalification of the outside spaces turns out to be still not considered as integral part of the retrofit process. Nevertheless, some significant examples demonstrate that a certain interest in this sense is starting to spread out. In this regard, the case of Hedebygade district, in Copenhagen, can be recognized as one of the most emblematic and pioneering examples.

Last, but not least, the case sheets provide also some information about the new dynamics that have started to be adopted in the last decade in term of actors involved in rehabilitation projects of social housing. Despite the differences existing among the countries, from the examples analysed, it can be observed an increasingly frequent tendency to involve private and public subjects, albeit often with continuing large-scale government subsidies and financing housing programming and sector regulation.

Year of construction: 1980
Year of renovation: 2008
Location: Dornbirn
Client: VOGEWOSI
Architectural design: Helmut Küess
Structural design: Büro Hagen
Electrical systems: Peter Häm-merle
HVAC systems: E-plus

Data:
Number of dwellings: 54
Number of floors: 3
Surface: 4460 m^2

Energy Performance:
Requested Primary Energy:
before: 250 kWh/m^2y
after: 20 kWh/m^2y
savings: 92%

Costs:
Total Cost: 4,194,000 €
Cost per m^2: 940 €/m^2

7.1. RESIDENTIAL COMPLEX WIEDEN 90-98
Dornbirn, Austria

The residential complex Wieden 90-98 was built in 1980. It consists of 54 dwellings distributed in five three-storey buildings.
In 2008, VOGEWOSI, a no-proft real estate company, owner of the complex, commissined a project fot the renovation of the complex in in order to enhance the energy efficiency of the buildings.

BUILDING ENVELOPE
The retrofit intervention considered several passive house solutions. An 120 mm insulating layer made EPS was applied to the basement ceiling as well as to the roof of the top floor apartments where a new waterproofing layer was also provided. The external walls, originally made of brick mansonry with 30 mm central insulation layer, have been covered with 250 mm EPS thermal coating. Old windows have been subsituted with triple glazed windows, positioned in correspondance to the insulation layer of the external walls. Moreover, balconies have been turned into winter gardens, acting as buffering zones to guarantee thermal comfort both in winter and in summer.


Photo 1 and 2 - Glazed balconies applied on south façades


Photo 3 and 4 - The residential complex after the retrofit intervention

SYSTEMS

A central ventilation system with heat recovery (efficiency > 85%) was installed in the attic floor of each building. Autonomous regulation system for each apartment was provided.

Before the intervention the heating systems consisted in three gas boilers with a total power of 210 kW per building.

After the retrofitting, each building requires just one 45 kW condensing boiler. Moreover 150 m^2 solar collectors on the south-facing roof were installed, achieving an annual solar fraction of 60% for domestic hot water preparation and 17% for space heating. The heat distribution uses existing piping.

BENEFITS PROVIDED

After retrofitting, the results obtained in terms of energy saving were higher than those expected, with reductions of the energy supply, including space and water heating and electricity, from 250 to 20 kWh/m^2a, equal to 92% less. This assessment was conducted according to the Passivhaus-Projekterungspaket (PHPP) standard.

SUMMARY OF MAIN INTERVENTIONS:
- 250 mm EPS thermal coating applied to external walls;
- 120 mm insulation of basement ceilings and attic roofs;
- New waterproofing layer of the roof with 40x40 cm fibre cement tiles;
- New triple glazed windows (North façade);
- New central ventilation system with heat recovery;
- Substitution of gas boiler with condensing boiler (45 kW);
- Solar collectors for space and water heating.

TRANSMITTANCE VALUES (W/m^2K):

	Before	After
Ext. walls	0.30	0.11
Bas. ceilings	0.80	0.19
Roof	0.40	0.11
Windows	2.80	0.90

Photo 5, 6, 7 and 8 - South façade of the residential complex before (left) and after (right) retrofitting

Year of construction: 1957-58
Year of renovation: 2005-06
Location: Linz
Client: GIWOG
Architectural design: ARGE Gerhard Kopeinig, Ingrid Domenig-Meisinger

DATA:
Number of dwellings: 50
Number of floors: 5
Surface: 3106 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 179 kWh/m^2y
after: 14.4 kWh/m^2y
savings: 90%

COSTS:
Total Cost: 2,446,000 €
Cost per m^2: 787 €/m^2

FUNDS:
47% - Private
13% - Federal Government
40% - Mortgage with Regional Government

7.2. RESIDENTIAL COMPLEX MAKARSTRASSE 30-40
Linz, Austria

The residential complex Makarstrasse 30-40 was built in 1957-58 in Linz and includes 50 dwellings distributed on five floors.
Between 2005 and 2006 the complex underwent a retrofit intervention launched by GIWOG, a social housing association, and co-sponsored by the Federal and Regional Government.
The main reasons for the renovation were complaints by tenants regarding poor usability of the balconies because of the strongly increased traffic frequency on the street below. Additionally, the building was due to renovation, high energy costs and the wish to do a pilot project to collect experience for other projects also were part of the motivation.

BUILDING ENVELOPE
Prefabricated large-format elements were chosen for the renovation, which helped to considerably shorten the construction time. They consists of special GAP-solar façade panels in grey and red which, besides improving the thermal and acoustic insulation of the external walls, confer the building a new aspect. The panels provide high insulation levels throughout and the closure of the balconies, eliminating all thermal bridges.
The ground floor slab was also provided with 100 mm rock wool insulation, reducing its transmittance value from 0.70 W/m^2K to 0.21 W/m^2K.
Existing windows have been substituted with triple glazed windows.

SYSTEMS
The installation of a controlled ventilation system contributed to a clear im-

Photo 9 and 10 - Holes for the ventilation of the new façades (left) and the installation of the GAP-solar panels (right)

provement in interior air quality as well as providing better protection against exterior noise. Moreover it guarantees heating recovery up to 70%.
Another measure was the switch from gas boiler to district heating which in Linz is partly produced by biomass.
New elevator have been also installed in each building with 4 floors.

BENEFITS PROVIDED
After retrofitting, the apartments offer a much higher user comfort, also due to a new elevator, the enlargement and glazing of the balconies and the mechanical ventilation with heat recovery for each room.
Three meetings were organized for the tenants, where they were informed about the renovation measures.
Energy savings led to a significative reduction of bills, passing from 40.8 €/month to 4.73 €/month.

FUNDS
The retrofit intervention was realized for the 47% through private investment, for the 13% through Federal funds and for the 40% through a mortgage stipulated between the GIWOG and the Regional Government.

SUMMARY OF MAIN INTERVENTIONS:
- Insulation of facades, floors, roofs;
- Very high insulation of the outside walls by using a "GAP-solar façade";
- New triple glazed windows, including anti-glare shield;
- Mechanical ventilation with heat recovery for each room;
- Substitution of gas boiler with district heating (biomass);

TRANSMITTANCE VALUES (W/m²K):

	Before	After
Ext. walls	1.2	0.08
Bas. ceilings	0.70	0.21
Roof	0.90	0.09
Windows	2.50	0.86




Photo 11, 12, 13 and 14 - The residential complex on Makarstrasse before (left) and after (right) retrofitting

Year of construction: 1947
Year of renovation: 2004
Location: Sofia
Client: Association of Flats Private Owners
Architectural design: Arch Plus design team

DATA BEFORE RETROFITTING:
Number of dwellings: 13
Number of floors: 3
Surface: 1100 m²

DATA AFTER RETROFITTING:
Number of dwellings: 15
Number of floors: 4
Surface: 1160 m²

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 194.7 kWh/m²y
after: 105.6 kWh/m²y
savings: 46%

COSTS:
Total Cost: 52,375 €

FUNDS:
Mortgage by the Association of Flats Private Owners

7.3. BUILDING FOR APARTMENTS N°10
Sofia, Bulgaria

This building dates back to 1947 and originally included 13 apartments. The aim of the retrofit intervention was to renovate the building and provide the maintenance interventions in order to reduce the energy consumption and increase tenants' comfort inside the apartments.

BUILDING ENVELOPE
Before the retrofitting, the roof and the common spaces of the attic were in very degraded conditions, the external walls were not insulated and the timber frame windows raddled. With the intervention, thermal coating was provided for the external walls and the roof. A waterproofing barrier was also applied and the windows have been substituted with new PVC frame windows, reducing its transmittance value from 2.9 W/m²K to 2 W/m²K.

SYSTEMS
The building was connected to a teleheating grid with high-insulated tubes of distribution.

BENEFITS PROVIDED
After retrofitting, the life of the building has been prolonged for about 40 years and a reduction of energy up to 46% was achieved, corresponding to a decrease of CO_2 emission of 63%.
The building has been certified with class A of the Bulgarian standard. This enables the exclusion for 10 years of the building from the payment of property tax.

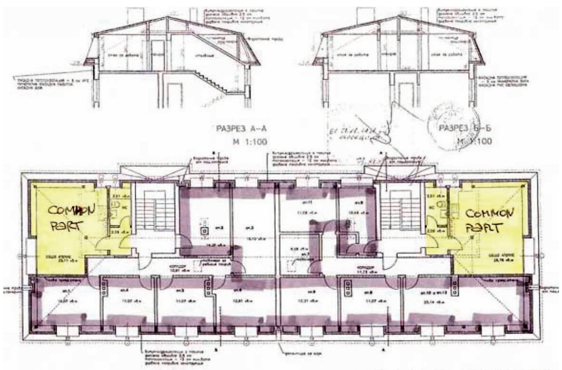


Fig. 1 - Layout and sections of the building

Photo 15 - Thermal insulation of the attic during retrofitting

FUNDS

The main difficulty encountered at the beginning of the project was the lack of private funds, considering that the dwellings were inhabited by low-rent tenants. For this reason the owners decided to constitute into the first registered Bulgarian Association of Flats Private Owners" in order to obtain special conditions for bank loans.

Besides the optimization of the energy performance, the attic floor was completely demolished and re-built in order to obtain two new apartments, whose rent has been used to pay part of the mortgage to the bank.

SUMMARY OF MAIN INTERVENTIONS:
- Thermal coating applied to external walls;
- Insulation of the attic roof;
- Waterproofing layer of the roof;
- New PVC windows;
- Teleheating system;
- Substitution of gas boiler with condensing boiler (45 kW);
- Reconfiguration of the area of the attic floor.

TRANSMITTANCE VALUES (W/m²K):

	Before	After
Ext. walls	Unknown	0.52
Bas. ceil.	Unknown	0.52
Roof	Unknown	0.50
Windows	2.90	2.00




Photo 16, 17, 18 and 19 - The building before (left) and after (right) retrofitting

Year of construction: 1884 ca.
Year of renovation: 1996-2004
Location: Copenhagen
Client: Copenhagen Municipality
Architectural design: Various

Data before retrofitting:
Number of dwellings: 150
Number of floors: 5

Data after retrofitting:
Number of dwellings: 115
Number of floors: 5

Energy Performance:
Requested Primary Energy:
before: 8.5 kWh/y pro capite
after: 5.9 kWh/y pro capite
savings: 30%

Water Consumption:
before: 49.6 m^3/y pro capite
after: 42 m^3/y pro capite
savings: 16%

Costs:
Total Cost: 50,400,000 €

Funds:
10.5% - Government

7.4. HEDEBYGADE DISTRICT
Copenhagen, Denmark

The renewal of the Hedebygade Block was part of a wider renewal of Vesterbro, a central district of Copenhagen. It has been a working-class district since 1850 and one of the first town districts built outside the ramparts of the old city.

The Urban Renewal Company (SBS) published a proposal for the renewal of Hedebygade Block in June 1995. Various action plans were considered and taken up in the ensuing years, until a proposal acceptable to both the residents of the buildings and the City Council resulted in a plan for renewal of the Hedebygade block in the spring of 1996. This renewal plan coincided with an increased focus by the city in urban ecology, supported by public sentiment.

This led to a grant of 5 Million Euros by the city government to assist with demonstration projects as part of the renewal of Hedebygade, which would showcase Danish innovation, technology, and knowledge within the field of ecological and sustainable building, construction, and planning.

As a part of the urban renewal of the Hedebygade block, 11 out of 12 different projects of urban ecology have been completed. This includes projects in 9 buildings, and 2 projects covering the whole block. Each project dealt with a different subject: *prism*, *flora*, ‘*green’ kitchen*, *sun wall*, *flexible facades*, *integrated ecological renewal*, *sun in the urban renewal*, *waste sorting, shared courtyard and community house*, *house end project*, and *measurement of consumption*.

The municipal plan which was developed for the area stated that existing houses had to be preserved with regard to environment, architecture and social life.

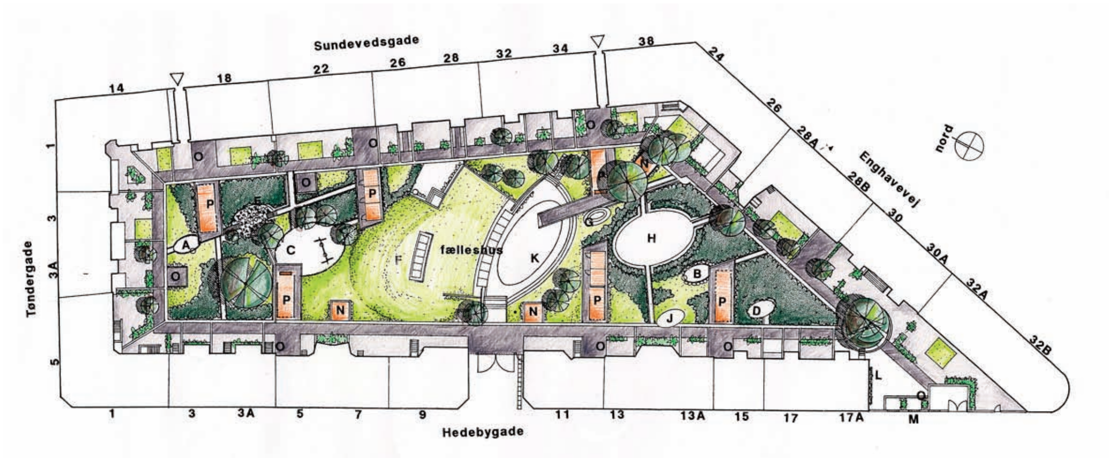


Fig. 2 - Layout of the retrofitted area

BUILDING ENVELOPE

Many different technical solutions have been tested, among these several innovative ones. The facade solutions were the most significant such as the sun walls with solar cells and heat exchanger, and the energy saving facades demonstrated in the subprojects 5, 6, 7 and 8.

Subprojects 6, 8 and 11 are examples of the successful integration of photovoltaics into the facade. Some of the more interesting solutions applied to the building envelope were: Project 5, which utilized passive solar techniques combined with solar air collectors on the roof, added insulation, low-e glazing, and heat recovery; and the Project 6, where PV's and low-e glazing are added to the facades and balconies.

Flexible facades consisting of covering facades and balconies with glazing elements combined with the use of solar cells and other kinds of plate elements are also used in order to obtain sunspaces while increasing the area of the apartments. All the elements used for sunspaces were dry assembled and have an independent load bearing structure.

Moreover, 150 mm insulating rock wool panels have been installed in correspondence of walls and 250 mm insulating rock wool panels have been installed on roofs.

Low-e glazing windows have been installed at the place of the original ones.

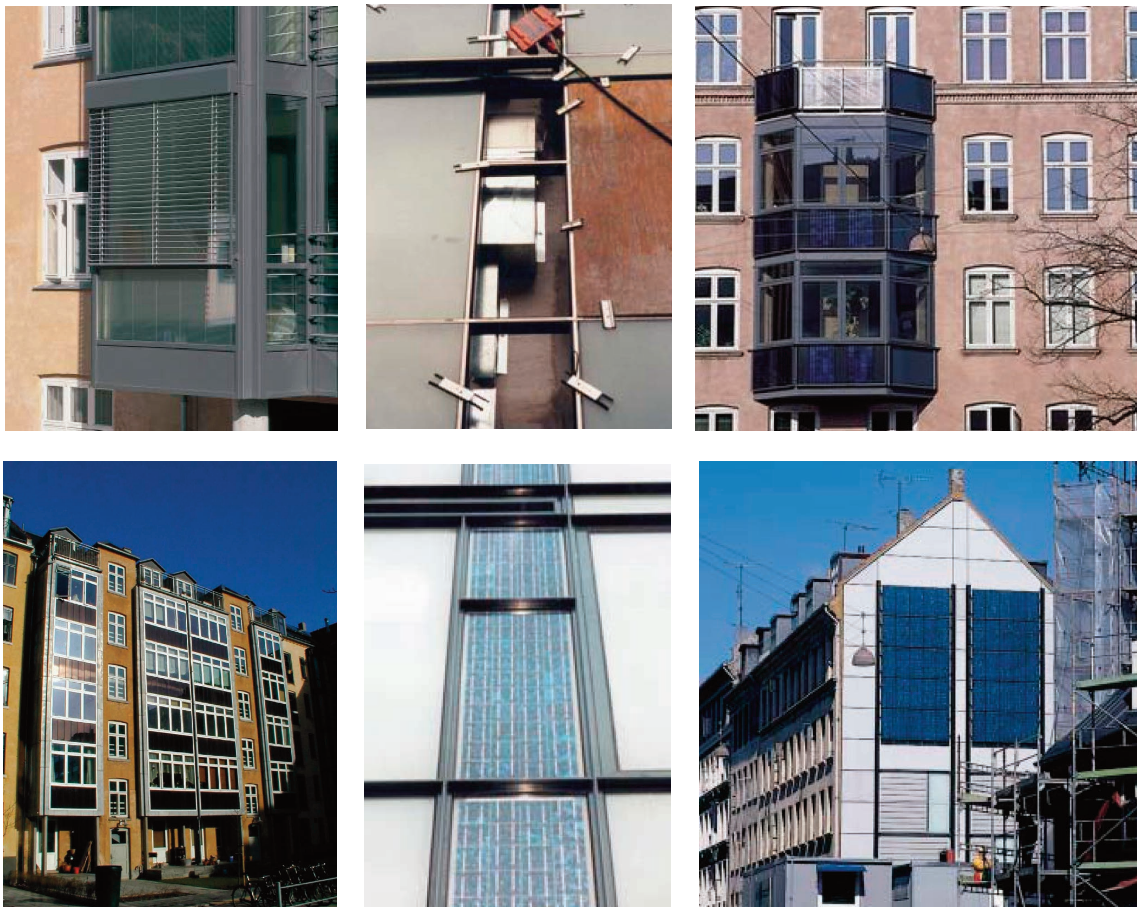


Photo 20, 21, 22, 23, 24 and 25 - Flexible façades constituting by sunspaces (left), solar walls (centre) and PV panels applied on railings and walls (right)

SYSTEMS

120 m^2 of solar cells have been integrated into roofs, railings and walls. PV also works as trombe walls and have been implemented with heat recovery systems: the air passing behind the modules is pre-heated and successively channeled into the ventilation system.
Moreover, 35 m^2 of solar panels have been installed on two buildings roofs.
To optimise the daylight, a heliostat was provided to canalised the sunlight into the building through the roof.

VEGETATION AND LANDSCAPING

The renovation of the district was not only limited to the buildings. Great attention was given to the design of the external spaces: ecologically courtyard have been arranged for recreational purposes,and vegetation was introduced in order to optimize the microclimate and to promote environmentally friendly planting.
On the same wall where PV panels are installed, a vertical garden was also grown.
The use of vegetation is also encouraged inside the sunspaces and the balconies of the apartments. Rainwater collectors, cabins for waste sorting have been also provided. The community house, located in the middle of the courtyard, is fitted out with a community room, kitchen facilities and a common laundry.

Photo 26, 27 and 28 - Use of vegetation for the renovation of the external spaces (top), inside the residential units (left) and applied in form of vertical garden (right)

BENEFITS PROVIDED

Following the concept of Eco-accounting (Environmentally accounting) improved by the Danish Building and Urban Research, five indicators for the extent of sustainability are used. These "urban ecology indicators" are heat consumption, electricity consumption, water consumption, waste production and CO_2 emission. All indicators are based on annual accounting and related to the amount of residents'. An additional indicator makes up the heat account in relation to the area being heated.

While two of the buildings do achieve a lower energy consumption than the goal, it has been pointed out that this does not result in less carbon emissions. This is due to the fact that the district heating system emits less CO_2 than the electricity required to power the heat recovery ventilation and other systems that partially replaced the demand on the district heating.

Water consumption per person was reduced to 89-120 l/per, where the average for Copenhagen is 126 l/per and the goal is to have 110 l/per. Household waste was increased from 279 hk/per year in 1996 to 300 kg/per year in 2003, where the average for Copenhagen for the mentioned years rose from 231 kg to 241 kg.

It was calculated that extra investment in urban ecological solutions will return the whole investment within a period of twenty years – a period that could be shortened considerably by increased energy prices.

FUNDS

The total cost was 50 million euro. The Ministry of Housings granted a total of 40 million DKK (app. 5.3 million €) for the greening of the buildings. The funding came from the national campaign "Project Renovation", where a number of different renovation processes and technologies were tested and developed.

SUMMARY OF MAIN INTERVENTIONS:
- Thermal coating applied to external walls;
- Solar walls;
- Sunspaces;
- Building integrated PV;
- Ventilation system with heat recovery;
- Solar collectors for space and water heating;
- Eliostat;
- Use of vegetation for microclimate enhancement and external landscaping;
- Water recovery systems;
- Cabins for waste sorting;
- Individual metering.

Photo 29 and 30 - The eliostat installed on the top of a building to canalise the sunlight (left) and a residential unit (right)

Year of construction: 1964
Year of renovation: 1998
Location: Engelsby, Flensburg
Client: BIG Heimbau AG
Architectural design: Staermose & Isager architects
Construction Company: Esbensen Consulting Engineers

DATA:
Number of dwellings: 40
Number of floors: 8
Surface: 2850 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 123 kWh/m^2y
after: 46 kWh/m^2y
savings: 63%

COSTS:
Total Cost: 1,400,000 €

FUNDS:
21.4% - EU

7.5. RESIDENTIAL BUILDING IN MOZARTSTRASSE 31
Flensburg, Germany

The building consists of a two similar eight-storey towers built in 1964, containing a total of 40 apartments.
In 1998 the BIG Heimbau AG, owner of the building, jointly with Flensburg municipality, decided to start a renovation process of the block and launched a design competition, won by Staermose & Isager architects.
The project was about the energy retrofit of the building and the partial redistribution of the layout in order to realize new spaces for seniors.
The retrofit project was included in the EU project Solar Housing through Innovation for the Natural Environment (SHINE).

BUILDING ENVELOPE
Most of the interventions regarded the retrofit of the building envelope. The external walls were originally constructed with sand limestone and Eternit cladding. First of all, a new Eternit rain-screen cladding with 120 mm external insulation was provided.
In some flats with one external facade, glazed balconies have been inset into the building, while the remaining 60% of flats had externally attached balconies, with three external faces. Thermal modelling showed that while glazed balconies could save 20-40% of the flats energy consumption, there was also a potential risk of energy use increasing if they were too heated. To avoid this problem, argon filled double glazing with low-e coating was used for the inset balconies, with a potential energy saving of 40% and a potential risk of a 10% increase. However for external balconies, the potential saving was lower and the risk far higher, because of the three exposed faces. Therefore external balconies were made with single glazing and air leaky, which

Photo 31, 32 and 33 - One of the tower building before (left) and after (center and right) retrofitting

combined with careful choice of surface finishes makes it impractical and unlikely that they will be heated. Balconies also provide an amenity space and a significant benefit in terms of thermal buffering and ventilation pre-heat, providing 85% of ventilation air to the flats.
Narrow glazing bars and translucent white glass have been used for the lower part of the glazing, to provide privacy, without excessively reducing light transmission inside the apartments. Even so the flats in the north west corner of the building had little daylight coming through, and to overcome this problem, new windows have been created at the back of each room.

SYSTEMS
53 m^2 of south facing solar panels, have been mounted on the roof and connected to a 2800 litre thermal store to provide domestic hot water. To improve indoor thermal comfort, a mechanical ventilation system was introduced with relative humidity control.
Heating is provided from a coal fired, city-wide, district heating system.

VEGETATION AND LANDSCAPING
The design also included external landscaping, rainwater collection into ornamental ponds, greening of car parking areas and provision of local re-cycling points.

BENEFITS PROVIDED
Thanks to the strategies used, primary energy due for water heating was reduced for the 63% and the indoor comfort greatly increased.
Because of the high benefits provided, the project was awarded with the German Messer Preis Solar '99.

FUNDS
The 21% of the total cost (1,400,000 €) was financed by EU.

SUMMARY OF MAIN INTERVENTIONS:
- Glazed balconies to the south, east and west elevations;
- New eternit rain-screen cladding with 120mm external insulation and 200mm insulated roof.
- Ventilated solar walls;
- Improved day lighting with highly glazed walls and roof;
- New low-e windows;
- Low energy central heating;
- Solar collectors;
- Demand controlled humidity regulated extract ventilation system;
- External landscaping.

	Before	After
Ext. walls	1.20	0.29
Bas. ceilings	1.60	1.60
Roof	0.85	0.21
Windows	5.10	2.20

TRANSMITTANCE VALUES (W/m^{2}K):

Photo 34, 35 and 36 - Glazed roof and balconies (top and left) and the solar panels installed on the roof (right)

Year of construction: 1971
Year of renovation: 2010
Location: Halle-Neustadt
Client: GWG Halle-Neustadt
Architectural design: Arch. Stafan Forster
Structural design: Stroh & Ernst
Systems: AIG Beraten &Planen

DATA BEFORE RETROFITTING:
Number of dwellings: 125
Number of floors: 5
Surface: 3160 m^2

DATA AFTER RETROFITTING:
Number of dwellings: 81
Number of floors: 5
Surface: 3160 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 135 kWh/m^{2}y
after: 55.5 kWh/m^{2}y
savings: 41%

COSTS:
Total Cost: 7,700,000 €

FUNDS:
20% - Federal State of Saxony

7.6. SOCIAL HOUSING OLEANDERWEG
Halle-Neustadt, Germany

This conversion of existing prefabricated building in Halle-Neustadt resulted from the city reconstruction for the International Architectural Exhibition (IBA) in 2010. Originally, 2 or 3 apartments per floor were arranged around 11 staircases. By reducing the staircases to 6 and removing the associated corridors, the design project has allowed for the extension and rearrangement of the apartments and the renovation of the external spaces, which also entailed structural interventions.

BUILDING ENVELOPE
A high thermal insulating coating was applied to the original envelope. Walls have been insulated with 140 mm EPS panels and covered with resin, while roofs have been provided with 240 mm EPS panels and waterproofing barrier. All ceilings of the apartments have been also insulated.
Existing windows have been substituted with PVC frame and double glazed windows.

SYSTEMS
Interventions on the building systems were related essentially to heating. Since 2006 Oleanderweg is connected to a teleheating grid of the town. The operation regarded the substitution of tubes and the installation of autonomous connections to the power station.

VEGETATION AND LANDSCAPING
Outdoor spaces have been formed by removing alternating sections of the 3rd and 4th floorplates, creating large outdoor terrace spaces. The ground floor accommodation comprises of 10 "Townhouses" each

Photo 37 and 38 - Vegetation integrated with buildings: private gardens (left) and new terraces (right) with separate entrances and private gardens which are assigned directly to the homes and defined by a continuos ground level plinth.

BENEFITS PROVIDED

Because of the high benefits provided, the project was awarded with the German Messer Preis Solar '99. Thanks to the strategies used, primary energy due for water heating was reduced for the 63% and the indoor comfort greatly increased.

FUNDS

The cost of intervention implies substantial investments, 21% which was provided by the Federal State of Saxony.

SUMMARY OF MAIN INTERVENTIONS:
- New layout of the apartments;
- Thermal coating on walls ceilings and attic roofs;
- New waterproofing layer of the roof;
- New double glazed windows;
- New autonomous heating systems;
- External landscaping.

TRANSMITTANCE VALUES (W/m²K):

	Before	After
Ext. walls	1.61	0.45
Roof	1.61	0.45

photo 39, 40, 41 and 42 - The building in Oleanderweg before (left) and after (right)retrofitting

7.7. BLAUE HEIMAT HOUSING COMPLEX
Heidelberg, Germany

Year of construction: 1927 (1st phase); 1951 (2nd phase)
Year of renovation: 2004
Location: Heidelberg
Client: Heidelberg GmbH
Architectural design: Arch. Johannes Gerstner
Structural design: Stroh & Ernst
Systems: AIG Beraten &Planen

DATA BEFORE RETROFITTING:
Number of dwellings: 56
Number of floors: 4
Surface: 2890 m^2

DATA AFTER RETROFITTING:
Number of dwellings: 40
Number of floors: 4
Surface: 3375 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 438 kWh/m^2y
after: 100 kWh/m^2y
savings: 80%

COSTS:
Total Cost: 4,800,000 €

FUNDS:
Heidelberg GmbH

The Blaue Heimat complex is positioned in the Handschuhsheim district of the city of Heidelberg and was realized in two phases: a first part was developed in 1927 and a second part in 1951. It presents a court configuration including 155 dwellings and 10 semi-detached houses situated inside the court. In 2004 the German institute for housing, Heidelberg GmbH, owner of the building, started a "pilot" process of requalification aimed at a new layout configuration and at a energy efficiency improvement of 56 apartments.

BUILDING ENVELOPE
The focus of the energetic redevelopment was the toughening of the building shell. On roof, ceiling and external walls rockwool panels have been applied and old windows have been replaced with triple glazings. On south façades window spaces have been enlarged to optimize daylighting inside the apartments.
New construction of balconies thermally separated from the building (south side) were also considered to enlarge the living space and increase the indoor comfort.

Fig. 17 - Aerial view of the housing complex

Photo 43 and 44 - Part of the residential complex before (left) and after (right) retrofitting

SYSTEMS

During the retrofit process, the replacement of the building technology with energy-saving components was also taken into account. In particular, heating supply is provided by a CHP (50 kWel/80 kWth), combined with two peak load boilers (each 92 kW) and three water storages (each 1000 litres). The supply system is based on natural gas and the distribution heat pipes are strongly insulated (200%). Moreover, an individually operable ventilation system with heat recovery was provided. Electricity production from RES was also considered by integrating photovoltaic modules on the roof top.

BENEFITS PROVIDED

After redevelopment, the basic rent became higher than for comparable living space, but the lower running costs have a permanent, cost-reducing effect. In fact, the planned energy savings were achieved in the first two years after the modernisation of the building. The primary energy use (heating and electricity) fell from 438 kWh/m^2 per year to just 100 kWh/m^2 per year. The annual heating requirement, in particular, was reduced as a result of the measures taken by 87% to around 21 kWh/m^2 per year.

In 2007 the entire building complex has been certified as a "ZeroHaus"(Zero Building) in a multi-stage certification process.

SUMMARY OF MAIN INTERVENTIONS:

- Roof, ceiling and external wall insulation;
- Installation of triple glazing;
- Enlargement of the window spaces facing south;
- New construction of balconies thermally separated from the building (south side);
- Installation of a block heat and power plant;
- Individually operable ventilation system with heat recovery;
- Integration of regenerative energies by installing photovoltaic modules.

TRANSMITTANCE VALUES (W/m^{2}K):

	Before	After
Ext. walls	unknown	0.15
Bas. ceil.	unknown	0.17
Roof	unknown	0.13
Windows	unknown	1.20

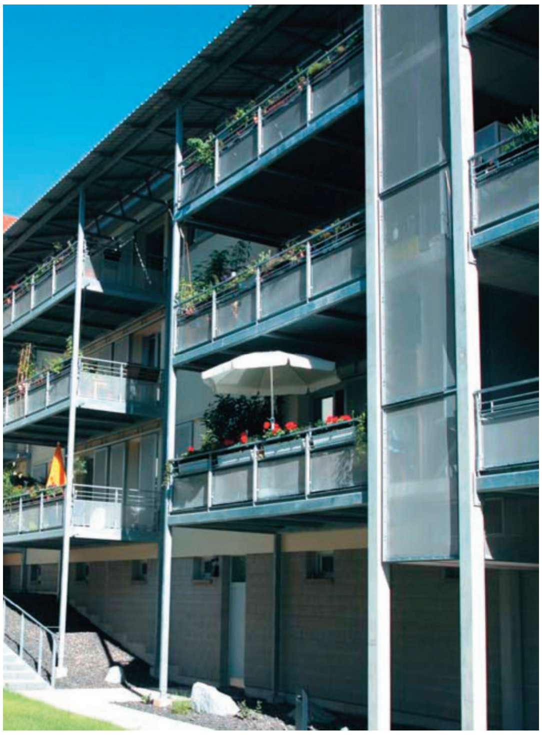


Photo 45, 46 and 47 - Insulation applied on an apartment ceiling (top left), photovoltaics panels installed at the top of the balconies (bottom left) and the new balconies with indipendent structure (right)

Year of construction: 1963-1973
Year of renovation: 2004
Location: Göteborg
Client: Gårdstenbostader
Architectural design: CNA architects
Energy consulting: Andersson and Hultmark AB
Monitoring: Jan Olof Dahlenbäck, CIT Energy Management AB

DATA:
Number of dwellings: 255
Number of floors: 3.7
Surface: 18,720 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 270 kWh/m^2y
after: 146 kWh/m^2y
savings: 45%

COSTS:
Total Cost: 11,700,000 €

FUNDS:
94% - Gårdstenbostader
3.4% - EU
2.6% - Swedish Energy Agency

7.8. GÅRDSTEN SOCIAL HOUSING COMPLEX
Göteborg, Sweden

The Gårdsten area was built during 1963-1973 and comprised 3,000 multifamily dwellings and 200 villas. The design of the area was influenced by the planning fashion of the time and built at the same time as several similar housing areas in Gothenburg. It was physically isolated from other neighbourhoods based on so called ”neighbourhood planning”, and the different traffic means were separated having one circular road, smaller feeder roads and traffic free courtyards and paths for pedestrians.The east side of Gårdsten consisted of two parallel lines of buildings, one side with three stories and the other with eight, stretching up to one kilometre. The housing in the west side of Gårdsten were gathered around 11 large square courtyards, with one side dominated by one six-storey building and the others with three-storey buildings. The north side of the area was developed with three-storey high slab blocks.
In the ‘80s the housing in the north part was converted to cooperative apartments and Gårdstensbostäder -incorporated into the municipally owned group of housing companies- became the only owner of the complex.
In the late ‘90s the problems with maintenance had become obvious and led also to social problems such as criminality and segregation.
In 1996, the city authorities started a process of social and physical regeneration of the estate and this retrofit project, started in 2004, was the first renovation project carried out in that process.
Architects and contractors involved were obliged to take residents into concern in their work. Residents have been part in working groups together with professionals such as architects, also including board members and employees at Gårdstensbostäder.

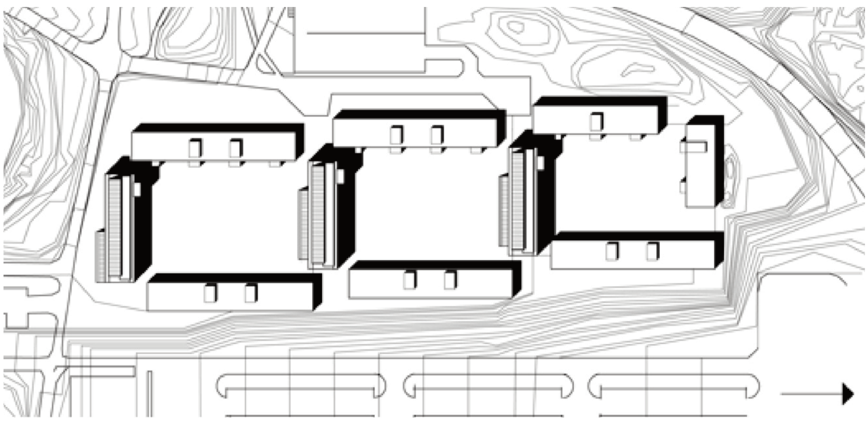


Fig. 3 - Layout of the complex

BUILDING ENVELOPE

The internal layout of the individual apartments was not altered, although they have been upgraded with new windows, finishes and appliances after discussions with individual residents.

Thermal coating made of 100 mm rock wool panels was applied to the external walls.

On north façades and an innovative solar air double envelope system was also used for solar air heating: heat is stored in the thermal mass of the original concrete façade elements. The joints between the elements, which before renovation resulted in large heat losses, now allow the warm air into the apartments. When the cooler air reaches the bottom of the wall cavity, it is returned to the solar collector to be reheated.

On the south façades glazed surfaces have been enlarged and sunspaces have been created.

SYSTEMS

Prefabricated solar collector roof modules have been installed to provide pre-heating of domestic hot water.

Photo 48, 49, 50, 51 and 52 - Views of the complex after retrofitting

VEGETATION AND LANDSCAPING

Common greenhouses have been built on the ground floors of the blocks, providing an opportunity for social interaction as well as production of a wide range of fruit, herbs and vegetables. Composting and recycling facilities have been also installed for each courtyard.

BENEFITS PROVIDED

The housing company has increased rental income as all apartments are currently occupied and its operational costs for energy and water have been reduced by 40 per cent. The flats are now warmer and do not suffer from condensation with a corresponding improvement in the health of the residents. Reduced energy costs, better facilities and greater opportunities for social interaction have all led to an overall improvement in quality of life.

Energy and water use are monitored and charged to individual apartments so creating greater awareness of consumption. All waste is now sorted on site and organic waste is fed into special composting

Photo 53, 54, 55, 56 and 57 - Views of the complex atfer retrofitting

units in the community greenhouses. Public awareness of the need to save energy and water has been raised as a result of the demonstration aspects of the project.
The courtyard design has been specifically carried out to create greater opportunities for community interaction and integration.

FUNDS
The total cost of the project was €11.7M. Costs relating to the energy/sustainable building elements were €2.2M. The cost was primarily met by the housing company (€11M) with €400,000 coming from the EU and €300,000 from the national government.

SUMMARY OF MAIN INTERVENTIONS:
- Thermal insulation of external walls;
- Installation of new windows;
- Enlargement of the window spaces facing south;
- sunspaces(south side);
- Individually operable ventilation system with heat recovery;
- Solar collectors for water heating;
- External landscaping and common spaces to improve social life.

Year of construction: 1962
Year of renovation: 2010-11
Location: Paris
Client: Paris Habitat
Architectural design: Fréderic Druot, Anne Lacaton and Jean Philippe Vassal

DATA BEFORE RETROFITTING:
Number of dwellings: 96
Number of floors: 16
Surface: 8900 m²

DATA AFTER RETROFITTING:
Number of dwellings: 100
Number of floors: 16
Surface: 12460 m²

ENERGY PERFORMANCE:
Requested Primary Energy (only for heating):
savings: 50%

COSTS:
Total Cost: 11,200,000 €

FUNDS:
Paris Habitat

7.9. TOUR BOIS-LE-PRÊTRE
Paris, France

The 17-storey Tour Bois-le-Prêtre, was originally designed by French architect Raymond Lopez, containing 96 apartments in the northern outskirts of Paris. It was conceived as a low-cost social housing block as most of spread out in Europe at the time. Twenty years ago it underwent a façade renovation that eliminated much of the character of the building, cutting off much of the natural light and views.
After 60 years of ageing and neglect the building needed a significant overhaul to bring the accommodation up to modern standards. Rather than absorbing the cost of demolition and reconstruction, the Paris housing authority gave the go-ahead to save the building through a retrofit process. The program of many of the 96 apartments was tweaked to reconfigure the floor plan. The apartments themselves were minimally disturbed by the additions, which meant that residents did not have to move out during construction.

BUILDING ENVELOPE
Architects designed a prefabricated extension to each apartment creating lightweight sunspaces and balconies hang off the original walls and supported by steel posts. In this way the building gained about 2/3 more square footage at minimal costs. The building's existing façade was replaced by sliding floor-to-ceiling glass doors which separate the apartments from the new terraces to let more natural light into each residence.
The new windows and balconies are interspersed by a facade of corrugated aluminium clads that characterised the new exterior of the tower.



Photo 58, 59 and 60 - The building before (left) and during retrofitting (center and right)

BENEFITS PROVIDED

The modular prefabricated additions, supported by steel posts added to the structure's perimeter, increased the total living space in the tower from roughly 96,000 square feet to more than 134,000 square feet and greatly improved views. The new layout organisation and the technical improvements made it possible to adapt the rental offer while meeting families needs, allowing the access to all the residences during the retrofit, and reducing the consumption of energies of more than 50%, mainly by the addition of the sunspaces.

FUNDS

The public office for housing, Paris Habitat, owner of the building, totally incurred the cost of the project, that was of €11.2m.

SUMMARY OF MAIN INTERVENTIONS:
- Prefabricated extension to each apartment/sunspaces;
- New windows;
- Improved natural ventilation and daylighting;
- Instalation of a new elevator;

Photo 61, 62, 63 and 64 - Views of the building and of the apartments after retrofitting

Year of construction: 1969
Year of renovation: 2008-09
Location: Hoenheim
Client: Habitat des Salariés d'Alsace
Architectural design: AGM Architecure

DATA:
Number of dwellings: 72
Number of floors: 4-8
Surface: 7173 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 243 kWh/m^2y
after: 103.9 kWh/m^2y
savings: 60%

COSTS:
Total Cost: 3,367,667 €

FUNDS:
75% - Bank loans
25% - State and regional grants

7.10. SOCIAL HOUSING IN RUE DU WALDECK
Hoenheim, France

Built in 1969, the complex consists in two residential buildings of 4 and 8 floors, for a total of 72 dwellings.
In 2007, considering their state of obsolescence and degrade, the Habitat des Salariés d'Alsace, institute owner of the block, decided to commission a renovation design project which could take into account the contemporary standard on energy regulation in buildings.
On the occasion of the public competition launched by the French agency for the environment and energy (Agence de l'Environnement et de la Maîtrise de l'Energie - ADEME) to finance innovative and energy efficient retrofit project, a proposal for the social housing in rue du Waldeck was presented and awarded at the end of the competition.

BUILDING ENVELOPE
A 120 mm fiberglass insulating layer was applied on external walls to improve the thermal performance of the building. In some parts, the façades are finished with wood boards.
Double glazed PVC windows have been installed to substitute the original ones. The design also aimed at the optimization of daylighting in common areas in order to lower electrical consumptions.

SYSTEMS
130 m^2 of solar panels have been installed on the side of the Rue du Waldeck for the production of hot domestic water.
Heating is provided by a central district grid distribution. In each apartments radiators with individual regulation system have been installed.
A mechanical ventilation system with humidity control equipment was also considered.

Photo 65 and 66 - Views of the buildings after retrofitting

BENEFITS PROVIDED

After the retrofit operations, the primary energy requested in the building fell down for more than 50%, passing from 243 kWh/m^{2}y to 103.9 kWh/m^{2}y, which entailed a reduction of bills for about 60%.

The building has been certified with class C, according to the BBC-effinergie Alsace standard.

FUNDS

The total cost of the intervention was of about 3,400,000 €. To incur these expenses the owner appealed to bank loans for the 75% while the rest was covered by national and regional grants.

SUMMARY OF MAIN INTERVENTIONS:
- 120 mm fiberglass insulation;
- Wood boards finishing;
- New double glazed PVC windows;
- New central ventilation system with heat recovery;
- Solar panels for water heating.

TRANSMITTANCE VALUES (W/m^{2}K):

	Before	After
Ext. walls	unknown	0.3
Windows	unknown	1.6

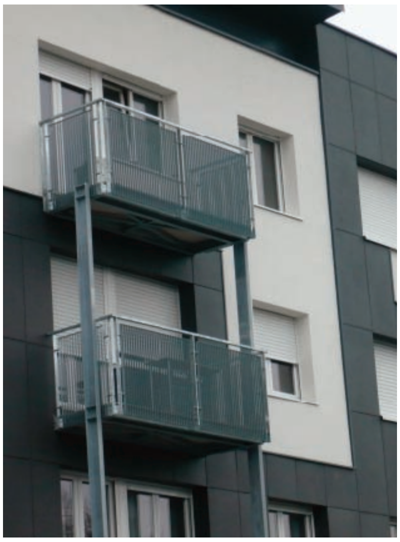


Photo 67, 68 and 69 - Views of the buildings after retrofitting

Year of construction: 1976-78
Year of renovation: 2005-07
Location: Bressanone
Client: Istituto per l'edilizia sociale della provincia di Bolzano
Architectural design: Arch. Walter Brida and Christian Moser

DATA BEFORE RETROFITTING:
Number of dwellings: 44
Number of floors: 5
Surface: 5017.70 m^2

DATA AFTER RETROFITTING:
Number of dwellings: 66
Number of floors: 5
Surface: 12460 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 243 kWh/m^{2}y
after: 103.9 kWh/m^{2}y
savings: 60%

7.11. SOCIAL HOUSING IN VIA WOLKESTEIN
Bressanone (Bolzano), Italy

The social housing complex situated in via Wolkenstein was designed by the architect Rudi Zingerle and built between 1976 and 1978. It is made of a high north-south oriented building, and two terraced houses with duplex apartments. 30 years after its construction the complex presented evident signs of disrepair and structural weaknesses. Moreover it was mainly inhabited by seniors who found the apartment oversized for their needs. For these reasons, in 2005, the institute for social housing of Bolzano (Istituto per l'edilizia Sociale della provincia di Bolzano) commissioned to the architects Walter Brida and Christian Moser a project of renovation. The buildings energy performance have been improved and the apartments layout modified. 14 new dwellings were obtained, four of which handicap accessible.

BUILDING ENVELOPE
External walls and the basement ceiling have been insulated with 120 mm mineral fibre panels.
Roof insulation has been improved through the addiction of a 200 m thermo-insulating layer.
New double glazed windows have been installed with insulated rolling shutters.

SYSTEMS
Solar panels have been installed on the roof for the production of hot domestic water. Heating is provided by the central grid of the town. The retrofit of the systems also regarded the renewal of the electrical system and appliances.

Photo 70, 71 and 72 - Views of the buildings before retrofitting

BENEFITS PROVIDED

After the retrofit intervention, the primary energy request decreased of 44% (from 155 kWh/m²y to 69 kWh/m²y).

In 2006 the project was awarded with the a special prize for energy efficiency conferred by the municipality of Bolzano.

SUMMARY OF MAIN INTERVENTIONS:
- Thermal coating applied to external walls, roofs and basement ceilings;
- New double glazed windows;
- New electrical system;
- Teleheating system;
- Solar panels for water heating.

TRANSMITTANCE VALUES (W/m²K):

	Before	After
Ext. walls	0.89	0.11÷0.35
Bas. ceilings	0.71	0.23÷0.26
Roof	0.90	0.14÷0.18
Windows	1.30	0.89

Photo 73, 74 and 75 - Views of the buildings after retrofitting

Year of construction: 1970
Year of renovation: 2004-11
Location: Savona
Client: Savona municipality and ARTE Savona
Architectural design: Arch. Giacchetta, Bronzin & Magliocco

DATA:
Number of dwellings: -
Number of floors: 4
Surface: -

ENERGY PERFORMANCE:
Requested Primary Energy (only for heating):
savings: 60%

COSTS:
Total Cost: 3,847,672 €

FUNDS:
82% - Region of Liguria
18% - Savona Municipality

7.12. SOCIAL HOUSING IN PIAZZALE MORONI
Savona, Italy

The complex -one of the first social housing example of Savona- suffered of several architectural and urban negligences, such as the lack of appropriate infrastructure and low quality technological features of the buildings.
15 buildings of the big districts were object of intervention, which took into account not only the renovation of the buildings but also the requalification of the open spaces.

BUILDING ENVELOPE
For the insulation of the building envelope the design team opted for cork, cellular glass and flakes of cellulose derived from waste of paper and inserted in the air gap of the brick masonry (160 mm) of external walls. On 3 of the 15 buildings other passive systems such as sunspaces -obtained by closing the balconies with glazing- and solar walls were considered. New balconies have been created using independent load bearing structures. New shading devices have been anchored to the external walls to avoid overheating during hot hours.

SYSTEMS
Photovoltaics panels have been mounted on the roof for a total peak power of 20kWp (1kW for each apartment).

VEGETATION AND LANDSCAPING
Pedestrian areas and open spaces for the community have been also ameliorated in order to provide opportunities for social interaction. New plants have been grown. Composting and recycling facilities have been provided as well as water collectors.

Photo 76 - Aerial view of the Piazzale Moroni district in Savona

BENEFITS PROVIDED

After the retrofit intervention, the primary energy request decreased of around 60%, especially thanks to the passive strategies used.

FUNDS

This intervention arose from the Contratti di Quartiere (cf. Chapter 6 of this thesis) related to innovative programs for urban renovation. In 2003 the municipality of Savona, in collaboration with the regional agency for buildings (Agenzia Regionale Territoriale per l'Edilizia - ARTE) promoted one of the 7 projects later approved by the region, receiving a grant of about 5M€.

SUMMARY OF MAIN INTERVENTIONS:
- Thermal coating applied to external walls, roofs and basement ceilings;
- Solar spaces on existing balconies;
- Solar spaces on new structurally indipendent balconies;
- Solar walls;
- Shading devices;
- Photovoltaic panels;
- External landscaping

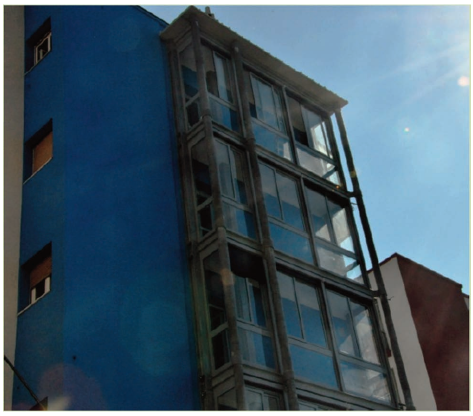
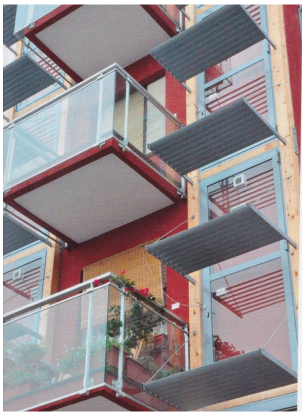




Photo 77, 78, 79, 80 and 81- Sunspaces, and shading devices (top), the building before (bottom left) and after (bottom right) retrofitting

Year of construction: 1930
Year of renovation: 2008-11
Location: Senigallia
Client: Senigallia municipality and ERAP Ancona
Architectural design: Dierna & Orlandi

DATA:
Number of dwellings: 82
Number of floors: 1-2
Surface: -

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 204 kWh/m²y
after: 38.82 kWh/m²y

COSTS:
Total Cost: 3,990,000 €

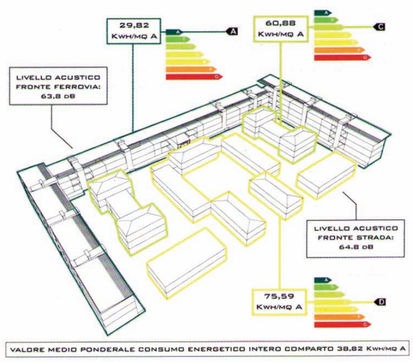
FUNDS:
41% - ERAP Ancona
40% - Ancona Municipality
19% - Private investment

7.13. VILLA AOSTA DISTRICT
Senigallia (Ancona), Italy

The renovation of Villa Aosta district was coordinated by the Department ITACA (Istituto per la Trasparenza, l'Sggiornamento e la Certificazione degli Appalti) of the University La Sapienza of Rome. Built in 1930 the complex includes 82 residential units, 40 of which owned by the regional institute for social housing of Ancona (Ente Regionale per l'Abitazione Pubblica della Provincia di Ancona -ERAP). The district is surrounded by a railway and a busy road which cause high levels of noise and air pollution.
The aim of the project was the radical inversion of the use of energy resources in an attempt to go back to traditional passive system for heating and cooling. Moreover the demolition and reconstruction of the two L shaped blocks has been considered.

BUILDING ENVELOPE
Since the buildings have a historical value and are, in some cases, hedged by the local department for historical buildings, the energy retrofit was conducted maintaining their original architectural characteristics.
80 mm wood fibres thermal coating highly reduced the transmittance of the external walls, also eliminating possible thermal bridges. New ventilated roofs have been provided as well as new low-e windows.
In the new L blocks, sunspaces have been also designed.

SYSTEMS
Photovoltaics panels have been mounted on the roofing of the car park for a total peak power of 15kWp. Furthermore, the complex has been provided with a new thermal power station (80 kW) connected to the district teleheating grid. New LED appliances for artificial lighting have been installed.



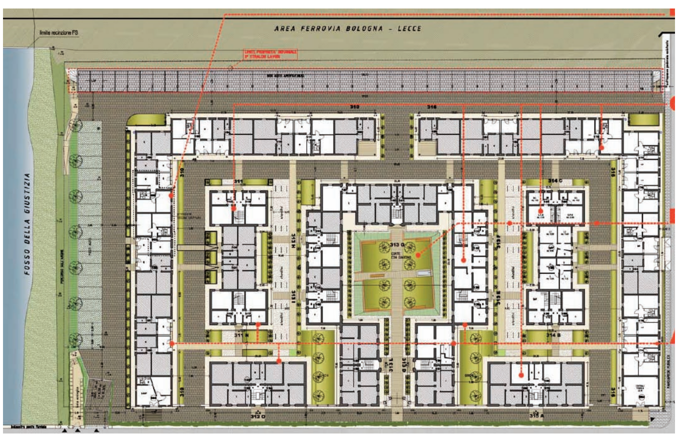


Fig. 4 and 5 - Tridimensional view and layout of Villa Aosta district in Senigallia

VEGETATION AND LANDSCAPING

For the recovery of the outside spaces, a 2m high vegetation has been planted all around the district, to act as a noise and wind barrier and contribute to mitigate the microclimate of the area.

Natural ventilation is provided thanks to wind catchers integrated in the green barrier which catch the air at a height of 5m and channel it, through buried pipes, to the apartments.

BENEFITS PROVIDED

Through software simulations, the primary energy request has been calculated before and after retrofitting: respectively 204 kWh/m^{2}y and 38.82 kWh/m^{2}y.

FUNDS

The total cost of intervention was of around 4M €. The investment was made only for the 19% by private funds. The rest was covered by the Ministry of Housing and Zaragoza municipality.

SUMMARY OF MAIN INTERVENTIONS:
- wood fibres thermal coating applied to external walls;
- Ventilated roofs;
- Wind cather and wind towers;
- New low-e windows ;
- New thermal power station;
- Photovoltaic panels;
- Vegetation applied for noise and air pollution reduction and mitigation of microclimate;
- LED appliances.

Photo 82, 83, 84 and 85 - Villa Aosta district before (left) and after (right) retrofitting

7.14. BAIRRO DE LAS FUENTES
Zaragoza, Spain

Year of construction: 1957
Year of renovation: 2009-10
Location: Zaragoza
Client: Grupo Girón
Architectural design: M.A.R. Arquitectos

DATA BEFORE RETROFITTING:
Number of dwellings: 40
Number of floors: 5
Surface: 2264 m^2

DATA AFTER RETROFITTING:
Number of dwellings: 40
Number of floors: 5
Surface: 2556 m^2

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 170.3 kWh/m^{2}y
after: 78.4 kWh/m^{2}y

COSTS:
Total Cost: 1,768,180 €

FUNDS:
70% - Ministry of Housing and Zaragoza municipality
30% - Private investment

Built in two steps between 1954 and 1957, the district includes 790 dwellings, some shops and a church. The residential units, destined to low-income citizens, are distributed in five-storey buildings.
In 2004, Zaragoza Vivienda, the company which foster operations for the urban renovation of the city, launched a program of requalification of the Bairro de Las Fuentes, focusing on the renovation of one block of the district for a total of 40 apartments.

BUILDING ENVELOPE
The intervention on the building envelope focused mainly on the application of a 60 mm mineral wool thermal coating and in the realization of a ventilated façade made of ceramic cladding.
The old tiles of the roof have been substituted as well as the waterproofing membrane.
Existing windows have been substituted with new high performing ones.

Fig. 33 - Aerial view of the district

Photo 86 and 87 - The district before (left) and after (right) retrofitting

SYSTEMS

30 solar panel have been installed to cover 62% of hot water supply. In addiction, four highly efficient condensing boilers are used for heating. New elevators provided with indipendent structure have been installed outside the original perimeter of the block.

VEGETATION AND LANDSCAPING

The layout of the external spaces also underwent some changes and new trees have been planted.

BENEFITS PROVIDED

Through software simulations, the primary energy request has been calculated before and after retrofitting: respectively 198 kWh/m^{2}y and 14.1 kWh/m^{2}y, enabling to move from energy class E to B.

FUNDS

The total cost of intervention was of around 1.8M €. The investment was made for the 30% by private funds. The rest was supplied by the ERAP of Ancona and the Ancona municipality.

SUMMARY OF MAIN INTERVENTIONS:
- wool fibers thermal coating applied to external walls;
- Ventilated facades;
- New roof tiles and waterproofing membrane;
- New windows ;
- Solar panels;
- Condensing boilers for heating;
- New elevators;
- New vegetation;

Photo 88, 89, 90 and 91 - Views of the district before (left) and after (right) the retrofit intervention

Year of construction: 1954-72
Year of renovation: 2011
Location: Tudela
Client: Tudela municipality
Architectural design: LKS, M.A.R. Arquitectos, MYO Arquitectos

DATA:
Number of dwellings: 144
Number of floors: -
Surface: -

ENERGY PERFORMANCE:
Requested Primary Energy:
before: 92 kWh/m^2y
after: 48 kWh/m^2y

COSTS:
Total Cost: 3,065,300 €

FUNDS:
59% - Grants from Caja de Ahorros y Monte de Piedad de Navarra and European Investment Bank
41% - Tudela Municipality

7.15. BAIRRO DE LOURDES
Tudela, Spain

Bairro de Lourdes of the city of Tudela, was one of the district where demonstrations of the EU program ECO-City occurred. The program comprises a whole integrated community approach to energy efficiency and sustainable energy supply and constitute an extension of existing policies towards a more sustainable community development. In the field of this program, the CONCERTO project sets a reference for new standards to prevail in the community both in retrofitting, new buildings and energy supply and the initiatives will be anchored in the whole community through training and extensive dissemination.
The social house complex is composed by four different blocks: *Bloques anos 50* (blocks of the '50s), *Bloques anos 60-70 (*blocks of the '60s-'70s), *Los 100 pisos* (the 100 floors) and *Las Torres* (the towers). 42 apartments were chosen from the first blocks, 12 from the second and 90 (the entire building) from the third to undergo a process of renovation.

BUILDING ENVELOPE
The retrofit of the building envelopes consisted primarily in the thermal insulation of the walls, ceilings and roofs made according to different systems (rockwool, EPS etc). In some cases, a layer of thermoinsulating mortar has been also added.
In the blocks of the '50s, like in the other buildings, the original windows were mantained but new ones have been installed on the external side of the walls. New glazed balconies have been also created and provided of shading devices and ventilation systems.
In *Los 100 Pisos* the façades are characterised by the presence of a grid made of aluminum profiles with the aim to act as shading device, or to hide the air-conditioning units hung to the buildings.

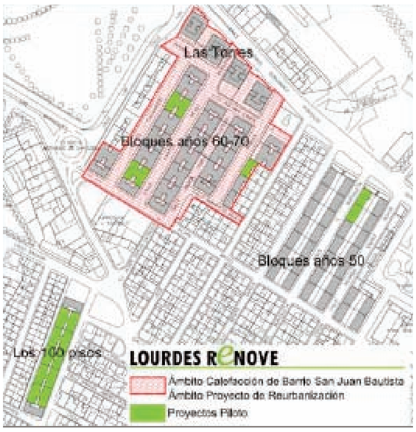


Fig. 6 - Layout of the district with in green the retrofitted blocks

Photo 92 - Aerial photo of the district during the '50s

SYSTEMS

In the Lourdes neighborhood the eco-buildings are supplied via a district-heating network, connected to two biomass boilers of 720 kW each. Additionally three photovoltaic plants with 2 x 12 kWp (each 79 m^2) and 24 kWp (157 m^2) have been installed.

BENEFITS PROVIDED

Globally, the annual energy consumption decreased by half, moving from 92 kWh/m^2y to 48 kWh/m^2y. In some cases it gets to 31,15 kWh/m^2y.

FUNDS

The total cost of intervention was of around 3M €. 59% of the investment was covered by grants received from Caja de Ahorros y Monte de Piedad de Navarra and European Investment Bank.

A new municipal ordinance published on September 2010 for the Lourdes district rehabilitation has been set up by Tudela City Council focused on social dwellings. The ordinance provides incentives for associations of co-owners using energy criteria in line with CONCERTO project requirements.

SUMMARY OF MAIN INTERVENTIONS:

- Thermal coating applied to external walls, ceilings and roofs;
- New glazed and shaded balconies;
- Metal grid to hide AC units;
- New low-e windows ;
- Photovoltaic panels;
- Biomass boilers

Photo 93, 94, 95, 96, 97 and 98 - Views of the district after retrofitting: *Los 100 Pisos* (left), *Bloques anos* 60-70 (centre) and *Bloques anos 50* (right)

Year of construction: 1994
Year of renovation: 2010
Location: Cordoba
Client: Vimcorsa (Viviendas Municipales de Cordoba)
Architectural design: Arch. Rafael Suárez

DATA:
Number of dwellings: 68
Number of floors: 5
Surface: 5600 m^2

ENERGY PERFORMANCE:
Requested Primary Energy: savings: 38.16%

COSTS:
Total Cost: -

7.16. SOCIAL HOUSING VIMCORSA
Cordoba, Spain

Built in 1994 by the municipal construction company Viviendas Municipales de Córdoba (Vimcorsa) and financed by the State Fund for Employment and Local Sustainability, this social housing building consists of 68 units for rent, with commercial premises and a garage. It is a symmetrical U-shaped five stories high block, with an interior courtyard. The retrofit project initiated in early 2010 by the architect Rafael Suárez, aiming at the energy rehabilitation and based on the promotion of energy saving and efficiency.

BUILDING ENVELOPE
Thermographic analysis shows thermal deficiency, revealing considerable energy dissipation in the building envelope through thermally weaker elements, with thermal bridges in framework edges, pillars, and window frames.
The retrofit of the building envelope focused on its thermal insulation, particularly on façades and external frameworks, and in the aluminum doors and windows with single glazing. Ventilated façade system were used, with a ceramic or metal finish, to reduce thermal bridges in beams and pillars and along the joints between bricks and load-bearing structure.The north- and east-facing façades of the building are barely in contact with the sun in the winter, but the southeast and southwest façades are exposed to it. For this reason windows have been protected by external movable shading devices which are activated during the cold seasons.
Airflow is encouraged, mainly through natural ventilation at night during the summer.

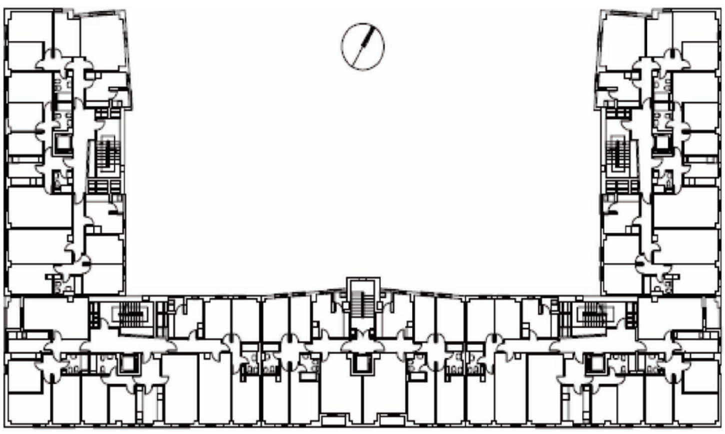


Fig. 7 - Layout of the building

BENEFITS PROVIDED

The retrofit proposal led to a significant reduction of the overall energy demand, calculated at 38.16%, and shows a more significant reduction of the demand for heating (45%) as opposed to the demand for cooling (30.2%).

There is an increase in the energy features of housing units through thermal stability and reductions of temperature oscillations. This is due to an increase in thermal mass, thanks to the incorporation of thermal insulation on the exterior, and the reduction of thermal exchanges through transmission due to the improvement of walls and windows. After retrofitting there is an increase in benefit from solar radiation in the winter. On the other hand, the effects of solar radiation are reduced in the summer, as a result of protection from the sun.

SUMMARY OF MAIN INTERVENTIONS:
- Thermal coating;
- Ventilated façades;
- Shading devices;
- New low-e windows;
- Photovoltaic panels;
- Encouraged natural ventilation.

TRANSMITTANCE VALUES (W/m²K):

	Before	After
Ext. walls	0.94	0.33
Bas. ceilings	2.25	0.54
Roof	0.47	0.47
Windows	5.70	3.30

Photo 99, 100, 101 and 102 - The building before (left) and after (right) retrofitting

PART III

CHAPTER 8
Proposal for the energy retrofit of a Social Housing complex in Palermo

The social housing complex Medaglie d'Oro of the city of Palermo was chosen as case study in order to assess to what extent vegetation, combined with other minor retrofit strategies, can affect the outdoor comfort of a micro urban area and, as a consequence, the users' comfort inside the buildings located in that area.

The research has been carried out according to the following steps:

- Stage 1 - Analysis of the current state of the area both at micro-urban and building scale, including the analysis of local weather data.
- Stage 2 - Meso-level simulation of an urban area of 470x740 m, enclosing the Medaglie d'Oro complex, in order to provide boundary conditions for the microclimate simulation within the residential area to be examined, in the absence of local measurements.
- Stage 3 - Simulation of an area of 110x375 m corresponding to the Medaglie d'Oro complex, starting from the microclimate data acquired through the simulation at stage 1, in order to evaluate the effects of vegetation on the near-buildings meteorology.
- Stage 4 - Simulation at the apartment scale in order to assess the indoor thermal comfort, starting from the microclimate data acquired through the simulation at stage 2, and proposal of some retrofit strategies at the building scale (low-e glazing, living walls, green roofs).

The urban simulations were performed with the software ENVI-met[1] while the energy analysis and thermal load simulation at the apartment scale were run with the program EnergyPlus.

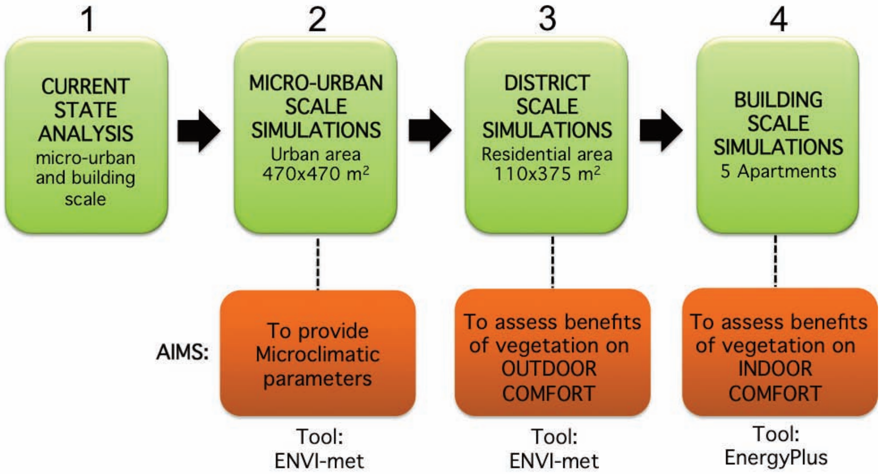


Fig. 1 - Scheme describing the used methodology

8.1. STAGE 1: Preliminary analyses

8.1.1. Current state of the area and buildings analysis

The Medaglie d'Oro complex is located in a south-west peripheral area of the city that went through a progressive urbanization process starting from the '70s. The residential complex, designed in 1972 by B. Colajanni, is constituted by two rows of three seven-storey apartment blocks, facing each other, and a three-storey building situated between them, occupying a total area of around 29,500 m[2] (Photo 1). Despite its dimension and configuration, the complex is lacking of open spaces for residents' leisure and social activities -conversely foreseen in the original layout- (Fig. 2), due to the almost exclusive utilization of the area for the vehicular access and park.

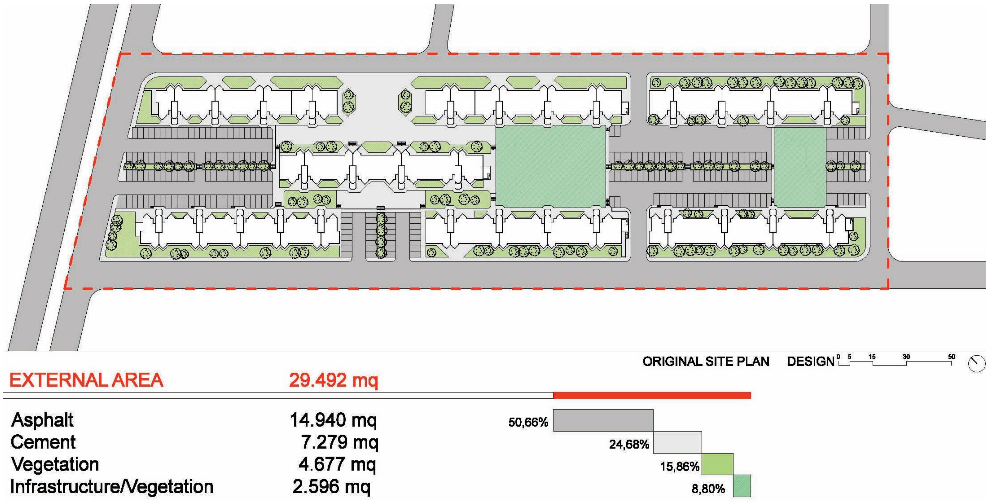


Fig. 2 - Layout of the residential complex with the identification of vegetation and soil typologies, according to the original design of 1972

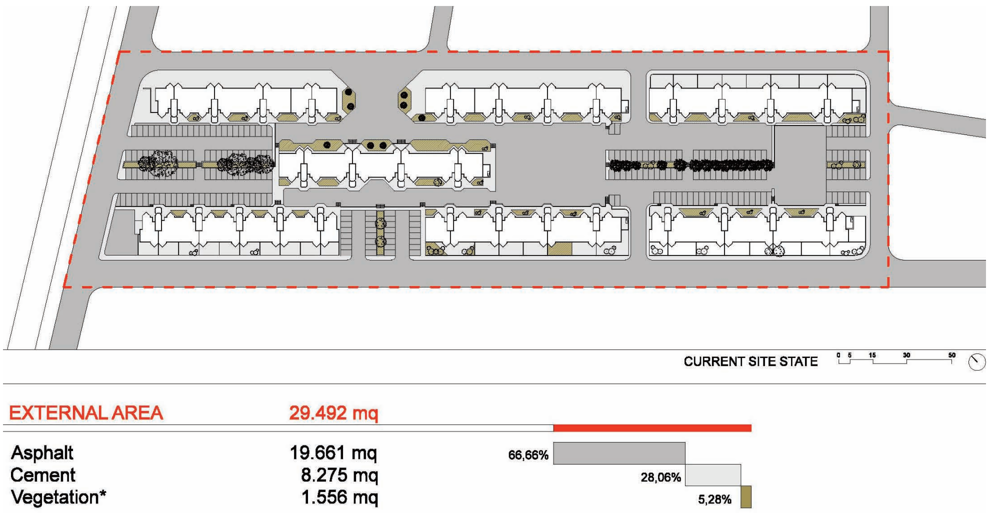


Fig. 3 - Layout of the residential complex with the identification of vegetation and soil typologies, according to the actual state

For this reason the site presents an extended use of asphalt (66.66%) and of concrete pavement (28.06%), while scarce spaces are assigned for vegetation (5.28%) (Fig. 3). The buildings are characterised by a reinforced concrete frame structure, visible from the outside, and external wall made by (from outside to inside) 13 cm pumice blocks separated from internal 8 cm perforate bricks by a 6 cm air cavity and finished with different thickness plaster layers on both sides.

The apartment blocks present considerable alterations of their original configuration as proved by the closure of many loggias and the addition of several air conditioning units hung to the buildings façades (Photo 3 and 4). These interventions demonstrate the inadequacy of the apartments to satisfy the contemporary users' needs related to the necessity of increased minimum living spaces and indoor comfort levels.

Photo 1 - Aerial photo of the Medaglie d'Oro complex

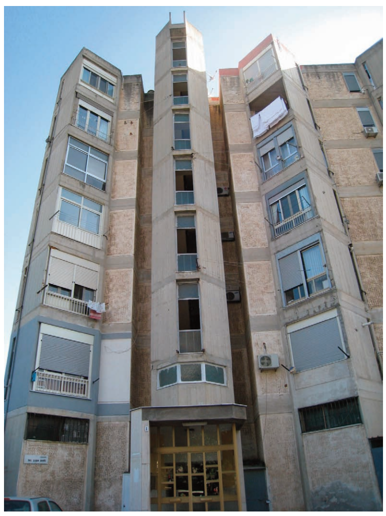


Photo 3 and 4 - Current state of the buildings

8.1.2. Definition of vegetation characteristics

A list of vegetation typologies was provided in order to identify the existing plants of the area and to identify the parameters to be entered into the software ENVI-met. In particular, the software requires the following information:

- CO_2 fixation plant typology;
- Leaf diameter and aerodynamic properties;
- Minimum stomata resistance of the plant;
- Short-wave albedo of the plant leaf;
- Height of the plant;
- Total depth of the root zone in positive values;
- Leaf Area Density (LAD) in m^2/m^3 for 10 data points;
- Root Area Density (RAD) in m^2/m^3 for 10 data points.

The ENVI-met plant database was hence improved with the information describing the vegetation existing in the area. As the Leaf Area Index (LAI) of plants was unknown, each plant was modelled by distributing it over the (normalized) height. The LAI value was divided in 10 parts that represent the LAD layers of the plant, as shown in Fig. 3.

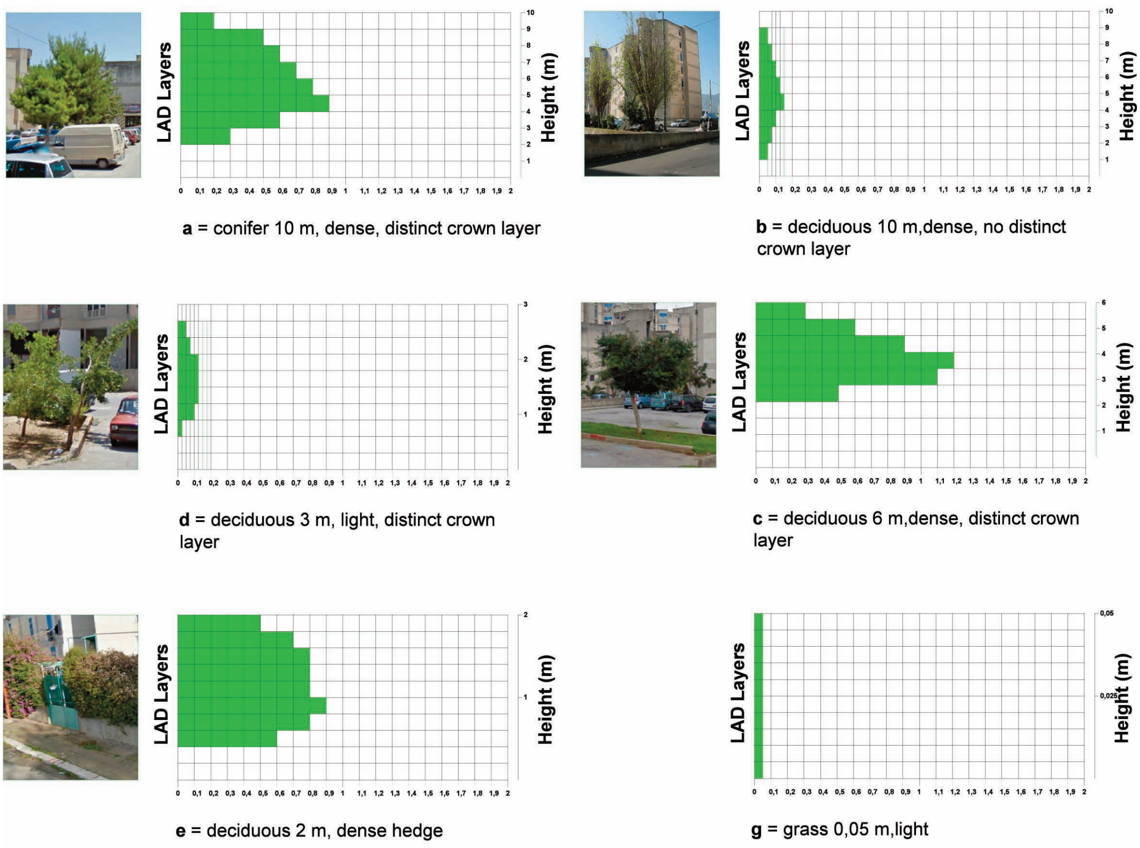


Fig. 3 - Evaluation of the Leaf Area Density of the existing vegetation

8.1.3. Weather data analysis

Palermo is one of the southern cities of Italy and one of the warmest in Europe. Its Mediterranean climate is characterized by mild winters and hot and dry summers with an average annual ambient air temperature of 18.5 °C, and approximately 2530 hours of sunshine per year. The city has several weather monitoring stations displaced in its territory. The University of Palermo (UniPa) has built up a weather monitoring system that works 24 hours per day and makes on-line data available in real-time. The data collected by the system have been used to implement a set of nonlinear black-box models aiming to obtain short-term forecasts of the air temperature and map them over the monitored area.

For running the simulation with ENVI-met program the data registered by UniPa weather station have been used considering their scientific reliability for the application in our case study, due also to the proximity of UniPa building -where the weather station is installed- to the area of investigation (ca.1200 m).

In particular, the measurements referring to the year 2012 have been considered, taking into account February and August, respectively the coldest and the warmest months of the year.

Photo 5 - Aerial map showing the location of the University of Palermo where the weather station is installed and the area of Medaglie d'Oro

Temperature

The weather data registered during February 2012 show an average monthly temperature of 9.81°C with a highest value of 14.23°C and a lowest value of 6.09°C (Graph. 1).

In summer, taking into account the data referring to the month of August, it can be observed a range of temperature from a minimum of 25.56°C to a maximum of 31.31°C and an average temperature of 27.7°C (Graph. 2).

Wind speed

Wind speed trends don't show great variations during both winter and summer seasons. In fact, in February the range comprises values from 0.89 to 4.80 m/s, with average wind speed of 2,19 m/s (Graph. 3).

In August this range is further reduced counting values comprised from 0.99 to 2.34 m/s and average wind speed of 1.48 m/s (Graph. 4).

According to Beaufort scale, the empirical measure that relates wind speed to observed conditions at sea or on land, it can be noticed that the range of wind speed during the month of February varies from "Light air" -when comprised between 0.3- 2 m/s- to "Gentle breeze" -when comprised between 3–5 m/s-, while in August the wind speed oscillates from "Light air" to "Light breeze".

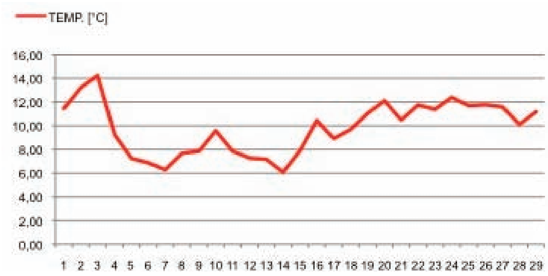
Despite the very limited monthly variation of wind speed throughout the two months, it's interesting to note that increasing temperatures in winter usually correspond to an increase of the wind speed and that, on the contrary, the highest temperatures registered in summer are related to a decrease of the wind speed.

Solar Radiation

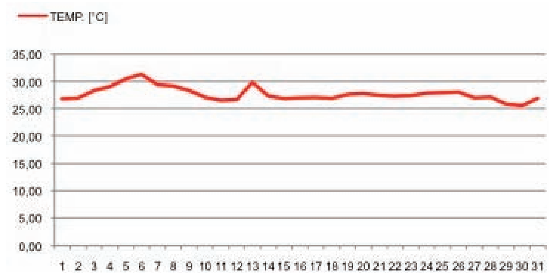
In February solar radiation data[2] move from 180.67 W/m^2 to 13.69 W/m^2 (Graph. 5). The latter value can be considered as an exceptional measurement since the average monthly solar radiation corresponds to 106.21 W/m^2 and the values registered during overcast and rainy days are never lower than 40 W/m^2.

In less than 50% of the days of the month pluviometric positive data were registered.

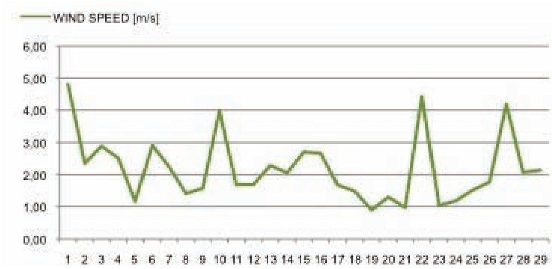
In August solar radiation data[3] oscillate between 209.46 and 282.81 W/m^2 with average values around 249.94 W/m^2 (Graph. 5). These data correspond to an entire month of clear and sunny days with no rainfall registered for the whole period.



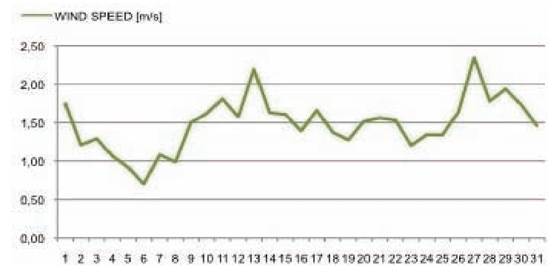
Graph. 1 - February Temperature Trend



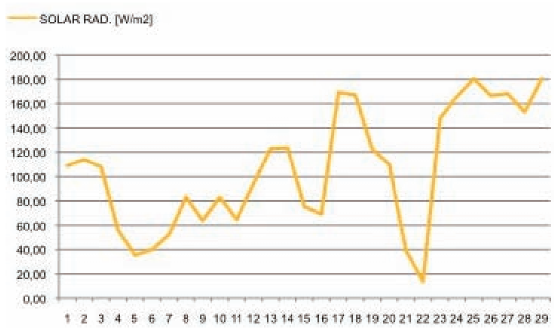
Graph. 2 - August Temperature Trend



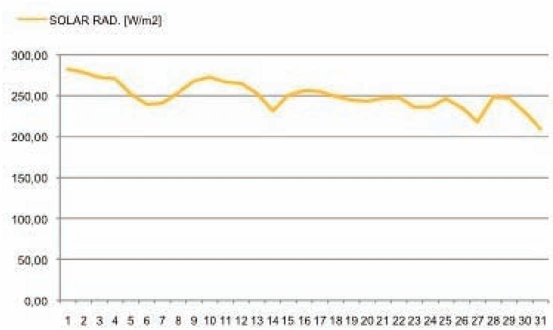
Graph. 3 - February Wind Speed Trend



Graph. 4 - August Wind Speed Trend



Graph. 5 - February Solar Radiation Trend



Graph. 6 - August Solar Radiation Trend

In light of the weather data previously analysed, two different “sample days” have been chosen for both months to be used for the next simulations.

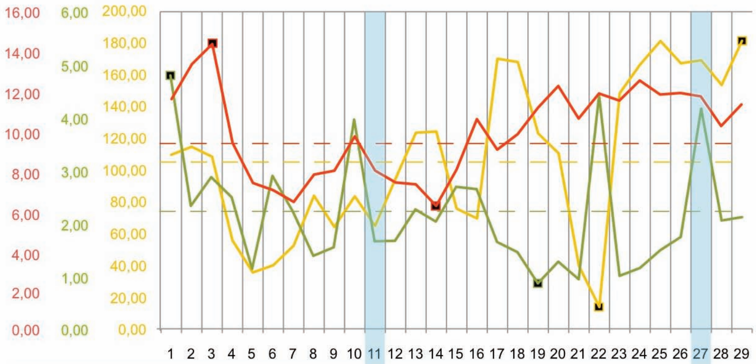
In particular, for the winter season, a day with average values of temperature, wind speed and solar radiation and a day with average temperature and higher wind speed and solar radiation have been picked out (Graph. 7).

The choice was made to evaluate the weather conditions in a typical day of winter (AAA - Average values for the three parameters) and the variation of local climate when wind speed and solar radiation are above the monthly average values.

For the month of August two dates were also chosen including a day with average temperature, wind speed and solar radiation and a day with low wind speed and higher temperature (Graph. 8).

	TEMP. [°C]	WIND SPEED [m/s]	SOLAR RAD. [W/m2]
1	11,46	4,80	109,19
2	13,22	2,35	114,19
3	14,23	2,89	107,98
4	9,25	2,51	55,48
5	7,24	1,16	35,33
6	6,88	2,91	39,83
7	6,29	2,24	52,10
8	7,67	1,41	83,44
9	7,86	1,57	63,90
10	9,59	3,97	83,08
11	7,86	1,68	64,60
12	7,27	1,69	94,15
13	7,17	2,28	123,02
14	6,09	2,05	123,79
15	7,91	2,71	75,38
16	10,45	2,66	69,23
17	8,92	1,67	169,44
18	9,69	1,48	167,40
19	11,03	0,89	122,56
20	12,12	1,30	110,10
21	10,48	0,97	39,38
22	11,74	4,42	13,69
23	11,39	1,03	147,81
24	12,40	1,18	165,79
25	11,69	1,51	180,54
26	11,77	1,76	166,60
27	11,60	4,18	168,46
28	10,11	2,07	152,98
29	11,19	2,14	180,67

February weather trend



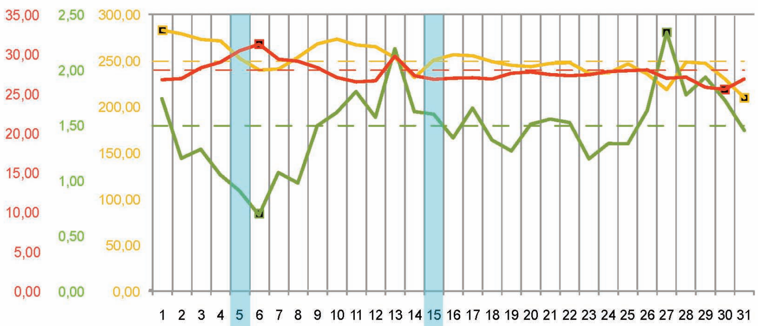
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Temperature	H	H	H	A	L	L	L	L	A	A	A	L	L	L	A	A	A	A	A	H	A	H	A	H	H	H	A	A	A
Wind Speed	H	A	A	A	L	A	A	L	L	H	A	A	A	A	A	A	A	L	L	L	L	H	L	L	L	A	H	A	A
Solar Radiation	A	A	A	L	L	L	L	A	A	A	A	A	A	A	A	A	H	H	A	A	L	L	H	H	H	H	H	H	H

Temperature [°C] — Aver. Monthly Temperature [°C] — H= High/Above Average
Wind Speed [m/s] — Aver. Monthly Wind Speed [m/s] — A= Average
Solar Radiation [W/m2] — Aver. Monthly Solar Radiation [W/m2] — L= Low/Below Average

Graph. 7 - Selection of winter days according to February weather trend

	TEMP. [°C]	WIND SPEED [m/s]	SOLAR RAD. [W/m2]
1	26,80	1,75	282,81
2	26,95	1,21	278,79
3	28,32	1,29	272,77
4	29,03	1,06	271,19
5	30,49	0,92	251,94
6	31,31	0,70	239,52
7	29,40	1,08	240,83
8	29,15	0,99	253,65
9	28,34	1,50	268,04
10	27,09	1,62	273,13
11	26,53	1,81	266,79
12	26,66	1,58	264,83
13	29,81	2,19	252,77
14	27,31	1,63	231,58
15	26,85	1,61	250,63
16	26,99	1,39	256,17
17	27,05	1,66	255,08
18	26,89	1,38	248,71
19	27,62	1,28	244,71
20	27,78	1,52	243,31
21	27,46	1,56	246,75
22	27,31	1,53	247,56
23	27,43	1,21	236,10
24	27,84	1,34	236,46
25	27,95	1,34	246,25
26	28,05	1,64	235,15
27	26,98	2,34	218,31
28	27,13	1,78	248,29
29	25,85	1,94	246,85
30	25,56	1,73	229,88
31	26,88	1,46	209,46

August weather trend



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Temperature	A	A	A	A	H	H	A	A	A	A	L	L	H	A	A	A	A	A	A	A	A	A	A	A	A	A	A	L	L	L	A
Wind Speed	A	A	A	L	L	L	L	L	A	A	A	A	H	A	A	A	A	A	A	A	A	A	A	A	A	A	H	A	H	A	A
Solar Radiation	H	H	H	H	A	A	A	A	H	H	H	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	L	A	A	L	L

Temperature [°C] — Aver. Monthly Temperature [°C] — H= High/Above Average
Wind Speed [m/s] — Aver. Monthly Wind Speed [m/s] — A= Average
Solar Radiation [W/m2] — Aver. Monthly Solar Radiation [W/m2] — L= Low/Below Average

Graph. 8 - Selection of summer days according to August weather trend

8.2. STAGE 2: Simulations for input data assessment

Although the meteorological station of the University of Palermo is situated not very far from the case study area (ca. 1200 m), in the absence of local measurements in the area, a more detailed analysis on the trend of weather conditions in the proximity of the residential lot was needed in order to evaluate the boundary conditions depending on the surrounding built environment and open spaces. For this purpose an area of 470x740 m, including part of the Parco Urbano d'Orleans on to the north, green and open spaces in the south and south west sides and a denser urban area on the east side, was first considered for simulation (Fig. 4).

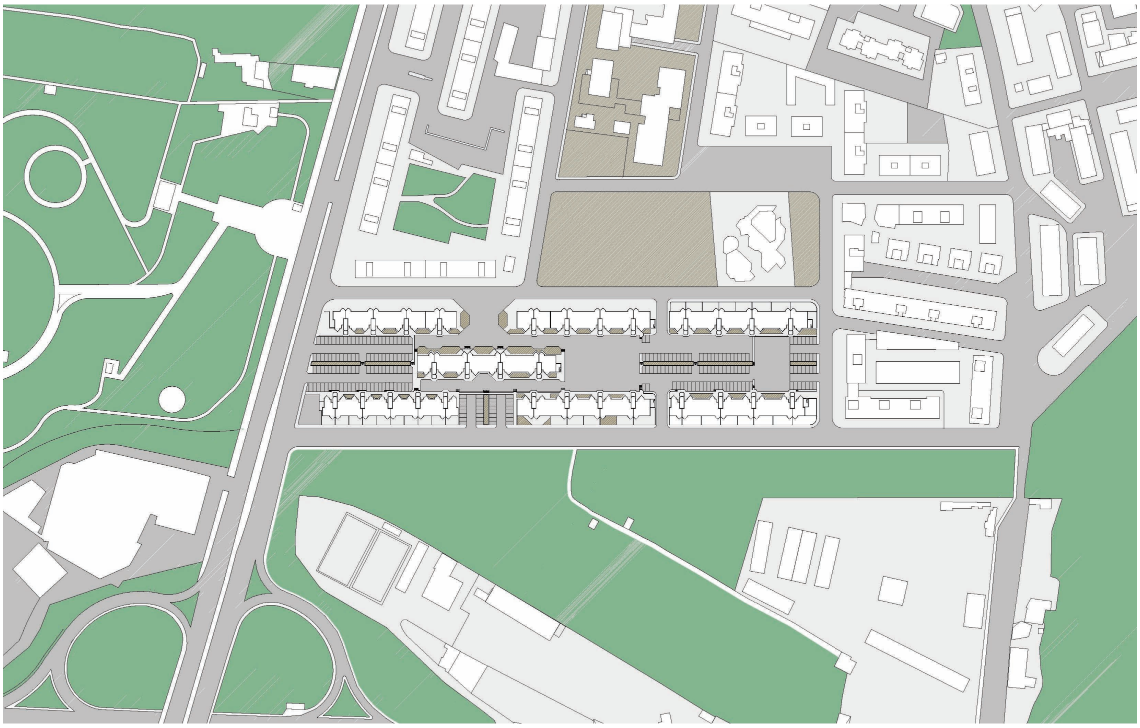


Fig. 4 - The urban area considered for the simulations at Stage 2

To facilitate the simulation process the area was discretized according to a 3D-nesting grid of 74 x 47 x 6, with x,y and z grid size of 10 m and four receptors, called A, B, C and D, have been set into the ENVI-met model at the boundary of the area of Medaglie d'Oro (Fig. 5).

The four days (two in winter and two in summer) previously considered were used for running the ENVI-met simulations. The data entered into the configuration editor of the program are shown in the Table 1 and the meteorological data refers to the measurements taken at UniPa.

As recommended by the software developer, Micheal Bruse, 48 hours simulations were used to pass the initial transient time in order to obtain results that are more reliable[4].

Fig. 5 - The ENVIi-met model of the area including the surrounding of Medaglie d'Oro

By comparing the results obtained from the four simulations to the weather data registered at the University of Palermo, correspondence of values emerges in relation to temperature and direct solar radiation, while significant differences can be noticed for the wind speed values in correspondence to the four receptors.

As shown in the graphs below, quite uniform trends of receptors temperature values can be observed and some predictable incongruities stand out comparing to the data registered at UniPa.

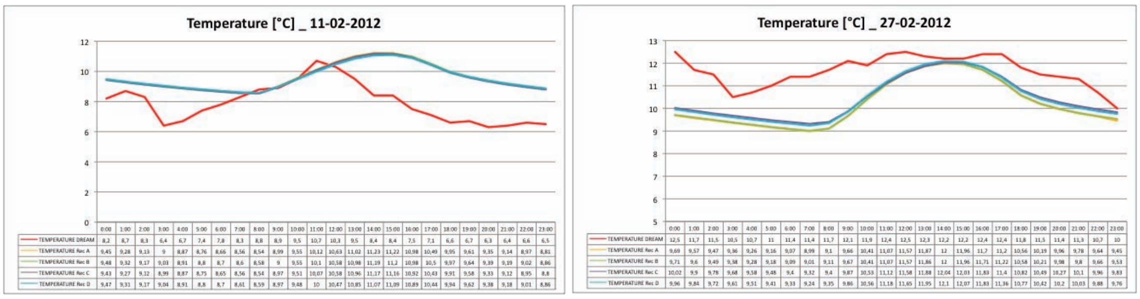
In particular, during the winter days temperature registered at UniPa varies of about 4°C for the first date chosen and of 2.5 °C for the second date, while the values simulated for the four receptors varies respectively of 2.7°C and 2.9°C (Graph. 9). For February 11th, the trend of temperature registered at Unipa moves differently compared to the others, starting from 11 AM onwards. This is due to the fact that the software could not simulate the presence of clouds which, indeed, caused a diminished solar radiation during those hours.

Also in summer the results obtained after the simulations can be assimilated to the input data: the temperature registered at UniPa varies of about 3.6°C during the first date and of 7°C during the second date while the values simulated for the four receptors varies respectively of about 4°C and of 5.5°C (Graph. 10).

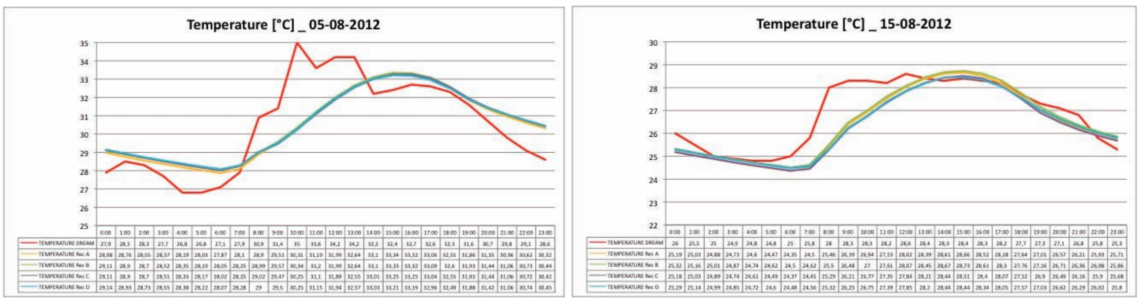
However, in all four cases, the value given as main input for the simulations, that is the air temperature at 7:00 AM, stays nearly unvaried for the first date of winter and the second of summer, while differences of 1.4°C and of 1.6°C occur respectively during the second day of winter and the first of summer.

	Winter		Summer	
MAIN-DATA Block				
Start simulation at day	10.02.2012	26.02.2012	04.08.2012	14.08.2012
Start simulation at time	07:00 am	07:00 am	07:00 am	07:00 am
Total simulation time	48h	48h	48h	48h
Save Model State each	240 min	240 min	240 min	240 min
Wind Speed (z=10m)	2.7 [m/s]	5.4 [m/s]	0.91 [m/s]	1.64 [m/s]
Wind Direction	SW: 225	NNW: 357.5	SW: 212.5	SSW: 225
Roughness Length z0	0.1	0.1	0.1	0.1
Initial Temp. Atm.	8.3°C (281.45°K)	11.4°C (284.55°K)	27.9°C (301.05°K)	27.9°C (298.95°K)
Specific Hum. in 2500	4.49 [g water/kg air]	4.2 [g water/kg air]	14.5 [g water/kg air]	5.99 [g water/kg air]
Relative Hum. in 2m	66%	50%	66%	25%
BUILDING PROPERTIES				
Inside Temperature	18°C (291.15°K)	21.10°C (294.25°K)	23°C (296.15°K)	25°C (298.15°K)
Heat Transm. Walls	0.827 [W/m2K]	0.827 [W/m2K]	0.827 [W/m2K]	0.827 [W/m2K]
Heat Transm. Roofs	2.27 [W/m2K]	2.27 [W/m2K]	2.27 [W/m2K]	2.27 [W/m2K]
Albedo Walls	0.22	0.22	0.22	0.22
Albedo Roofs	0.22	0.22	0.22	0.22
SOLAR ADJUST				
Shortwave Adj. Factor	0.75	0.75	0.82	0.85

Table 1 - Data input for the preliminary simulations



Graph. 9 - Comparison between temperature registered at UniPa and those generated by ENVI-met (winter)



Graph. 10 - Comparison between temperature registered at UniPa and those generated by ENVI-met (summer)

Higher values incongruities emerged in regards to wind speed values and trends: as show in Fig. 6, wind speed progressively decreases in correspondence of buildings, although differences are of the order of around 1m/s. Both in winter and in summer, wind speed UniPa data include a range of values that can vary up to 5.8 m/s during winter days and up to 3.2 m/s during summer days. The receptors results instead show very linear wind speed trends during both days of winter and the second date of summer: in winter values oscillate from 0.12 to 0.98 m/s in case of S-W wind, and from 2.32 to 4.2 m/s in case of predominant N-NW wind (Graph. 11); in summer they go from 0.04 to 0.58 m/s in case of S-W wind while they show a significant variation (closer to the UniPa data) in case of S-SW wind, oscillating from 0.24 to 4.87 m/s (Graph. 12).

Regarding direct solar radiation, differences of around 26% (Graph. 13) and of 18% in summer in winter emerged from the first simulations (Graph. 14). This is due to over or underestimation of the solar energy fluxes that, depending on locations, sometimes occurs using ENVI-met. For this reason, the program is supplied with a feature for the solar adjustment which allows to adjust the shortwave solar radiation to the given situation. Therefore, for the next simulations a factor of shortwave adjustment of 0.82 and of 0.85 was applied in summer (respectively for the 5th and the 15th of August) and of 0.75 in winter.

Moreover, for the first winter day, data lower values can be noticed. This is due to the fact that, in real condition, the values were registered during a partially covered sky day while, normally, ENVI-met is run for cloud-free sky conditions[5].

Despite the results obtained from the simulations are supposed to take into account the boundary conditions of the case study area, some adjustment are anyway needed to achieve better correlation with these ones and the measured values and to avoid the risk of undervaluation of the data.

For the next input data simulations, average values have been worked out considering average results related to the four receptors weighed up with measured UniPa data.

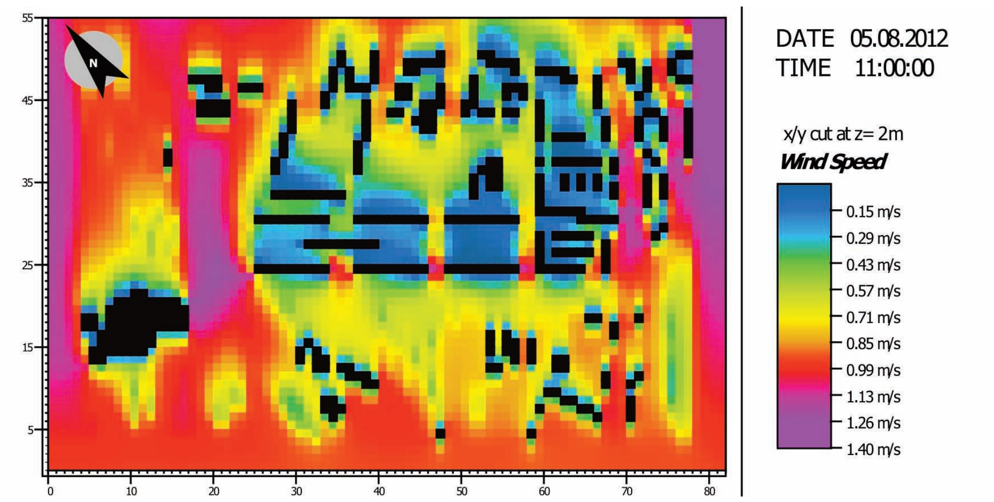
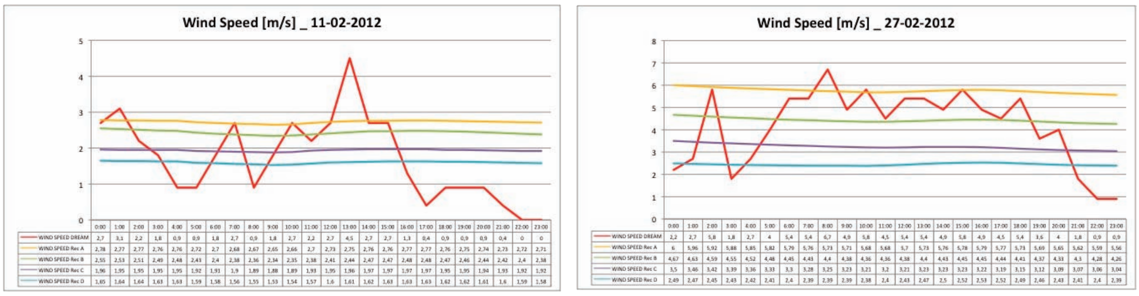
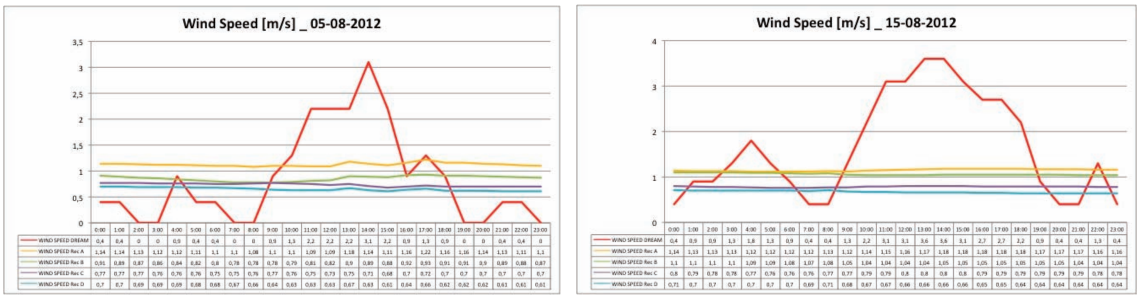


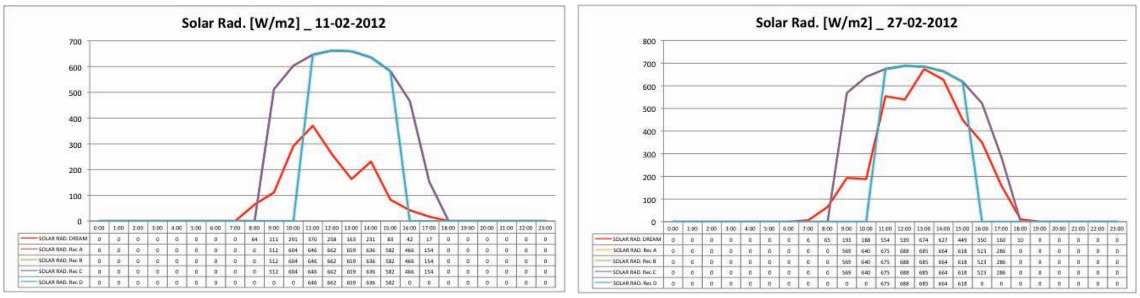
Fig. 6 - Wind speed values performed by ENVI-met for August 5th at 11 AM



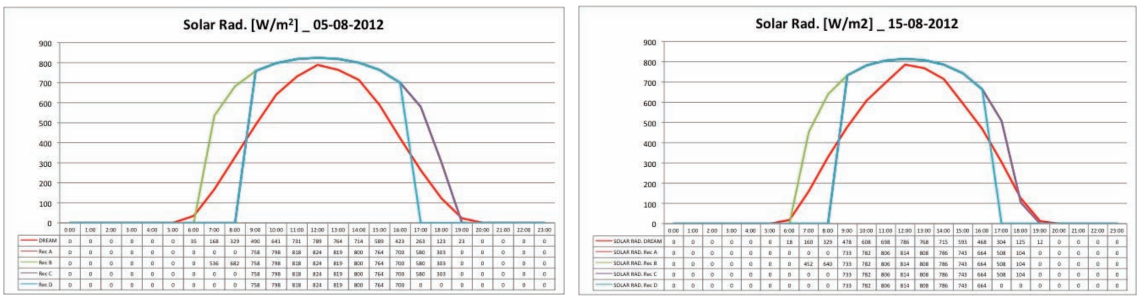
Graph. 11 - Comparison between wind speed registered at UniPa and those generated by ENVI-met (winter)



Graph. 12 - Comparison between wind speed registered at UniPa and those generated by ENVI-met (summer)



Graph. 13 - Comparison between solar radiation registered at UniPa and those generated by ENVI-met (winter)



Graph. 14 - Comparison between solar radiation registered at UniPa and those generated by ENVI-met (summer)

8.3. STAGE 3: Simulations for outdoor temperature assessment

For this stage of the research results obtained from the previous simulations were taken into account to identify the new input data. In particular, average values were calculated by weighing up the results registered by the four receptors and the values registered at the weather station of the University of Palermo.

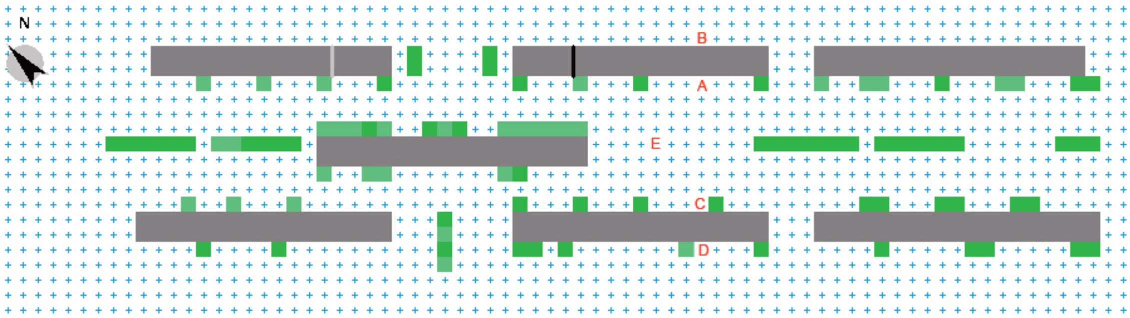
Furthermore new input data were entered such as walls and roofs thermal transmittance.

	Winter		Summer	
MAIN-DATA Block				
Start simulation at day	10.02.2012	26.02.2012	04.08.2012	14.08.2012
Start simulation at time	07:00 am	07:00 am	07:00 am	07:00 am
Total simulation time	48h	48h	48h	48h
Save Model State each	240 min	240 min	240 min	240 min
Wind Speed (z=10m)	2.7 [m/s]	5.4 [m/s]	0.88 [m/s]	1.51 [m/s]
Wind Direction	SW: 225	NNW: 357.5	SW: 212.5	SSW: 225
Roughness Length z0	0.1	0.1	0.1	0.1
Initial Temp. Atm.	8.4°C (281.55°K)	10.3°C (284.45°K)	29.88°C (303.03°K)	26.86°C (300.01°K)
Specific Hum. in 2500	5.3 [g water/kg air]	5.4 [g water/kg air]	12.6 [g water/kg air]	18.5 [g water/kg air]
Relative Hum. in 2m	78%	76%	50.43%	68.41%
BUILDING PROPERTIES				
Inside Temperature	18°C (291.15°K)	21.10°C (294.25°K)	23°C (296.15°K)	25°C (298.15°K)
Heat Transm. Walls	0.827 [W/m2K]	0.827 [W/m2K]	0.827 [W/m2K]	0.827 [W/m2K]
Heat Transm. Roofs	2.27 [W/m2K]	2.27 [W/m2K]	2.27 [W/m2K]	2.27 [W/m2K]
Albedo Walls	0.22	0.22	0.22	0.22
Albedo Roofs	0.22	0.22	0.22	0.22
SOLAR ADJUST				
Shortwave Adj. Factor	0.75	0.75	0.82	0.85

Table. 2 - Data input for the simulations at stage 3

The new ENVI-met model was built according to a 3D-nesting grid of 117x21x10 (x,y,z grid size = 5 m). Five receptors (A, B, C, D, E) were taken into account for these simulations in order to extract exact values of temperature, wind speed and solar radiation: four receptors in correspondence of two apartments situated in two different buildings (two receptors for each apartment positioned on the two façades of the building) and one placed in the open space between the two buildings (Fig. 7).

ENVI-met is capable to generate climate data at different heights. In this case, for receptors A, B, C and D) generated data refer to 7.5 m a.g.l. (above ground level) representing the hight of a typical apartment while for receptor E a height of 1.5 m was considered, corresponding to the pedestrian zone.



Height from the ground level:
A = 7.5 m B = 7.5 m C = 7.5 m D = 7.5 m E = 1.5 m

Fig. 7 - Individuation of the receptors in the ENVI-met model at stage 3

In addition to the current situation, four different "greening scenarios" were simulated, considering progressive addiction of vegetation with different LAI - Leaf Area Index values.

In particular the following retrofit scenarios were considered:

- Scenario 1 - Additional vegetation: dense grass and 2m high hedges around the buildings;
- Scenario 2 - Additional vegetation: dense grass, 2m high hedges around five buildings, few 10m high trees (medium dense crowns) in the central area and 15m high trees (medium dense crowns) around two buildings;
- Scenario 3 - Additional vegetation: dense grass, 2m high hedges around five buildings, some 15m high trees in the central area (very dense crowns) and 15m high trees (medium dense crowns) around two buildings;
- Scenario 4 - Additional vegetation: dense grass, 15m high trees (medium dense crowns) around all buildings and two compact stands of 15m high trees (very dense crowns) in the central areas.

In the following paragraphs for each scenario the layout of the area is reported as well as the related ENVI-met models with the identified vegetation. On the side, 2D map data generated by the software Leonardo are included to show Temperature, Wind Speed and Solar Radiation in each condition. The case of August 5th was considered as exemplification.

8.3.1. Current state

Fig. 8 - Layout of the Current State

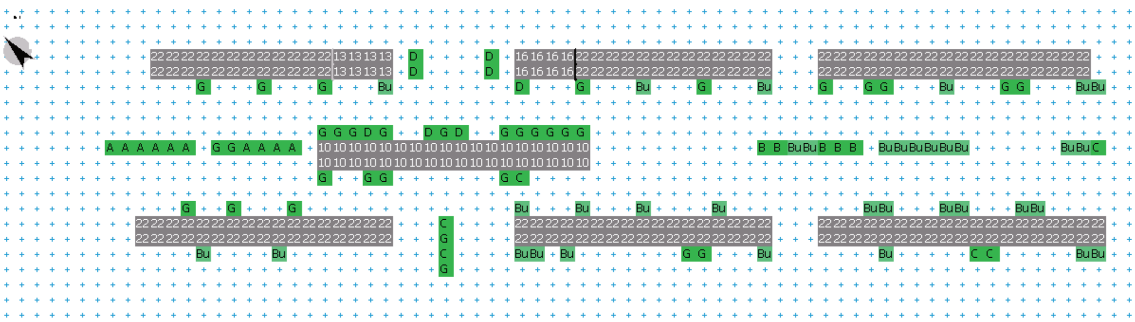


Fig. 9 - ENVI-met model of the Current State

ID	Vegetation Typology	H (m)	LAI (m2/m2)
A	Tree	10	4.6
B	Tree	10	1.175
C	Tree	6	4.6
D	Tree	3	1.75
Bu	Hedge	2	5.9
G	Grass	0.05	0.5

Table 3 - List of vegetation typologies of the Current State

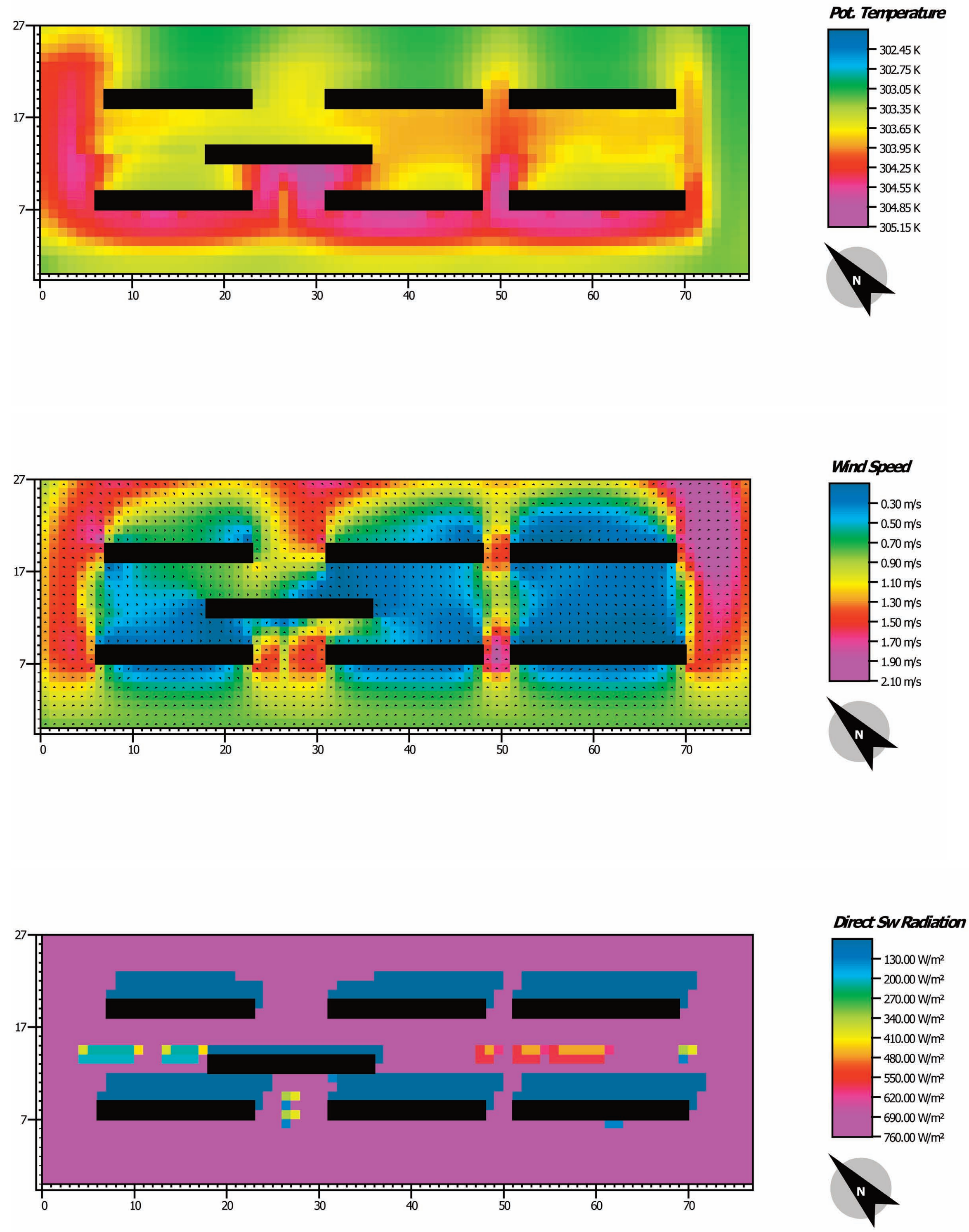


Fig. 10 - 2D data map generated by Leonardo for the Current State

8.3.2. Scenario 1

Fig. 11 - Layout of the Scenario 1

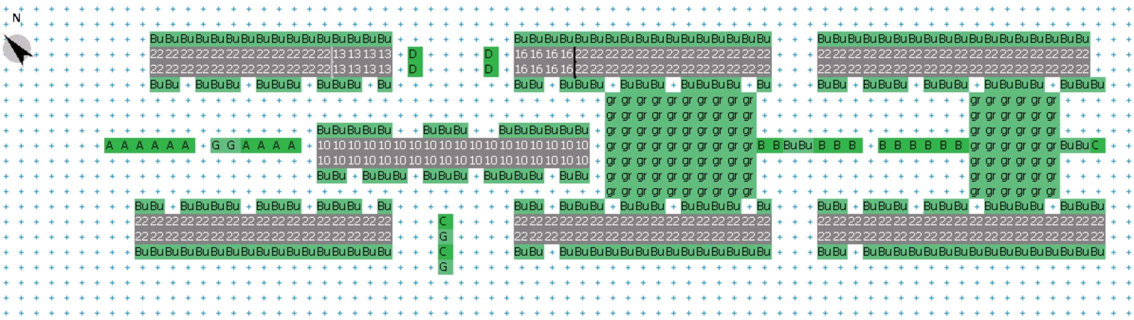


Fig. 12 - ENVI-met model of the Scenario 1

ID	Vegetation Typology	H (m)	LAI (m2/m2)
A	Tree	10	4.6
B	Tree	10	1.175
C	Tree	6	4.6
D	Tree	3	1.75
Bu	Hedge	2	5.9
G	Grass	0.05	0.5
Gr	Grass	0.10	3

Table 4 - List of vegetation typologies for the Scenario 1

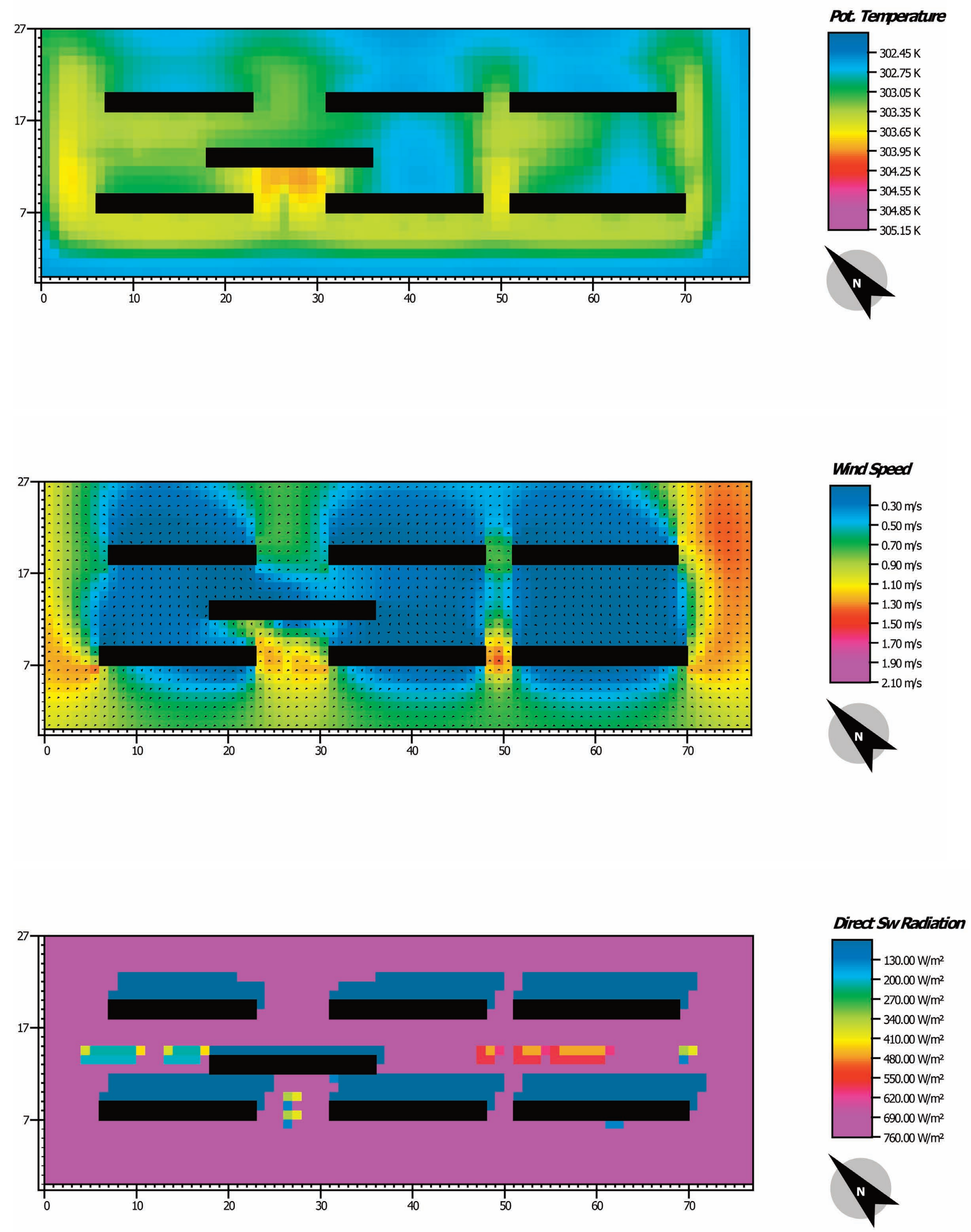


Fig. 13 - 2D data map generated by Leonardo for the Scenario 1

8.3.3. Scenario 2

Fig. 14 - Layout of the Scenario 2

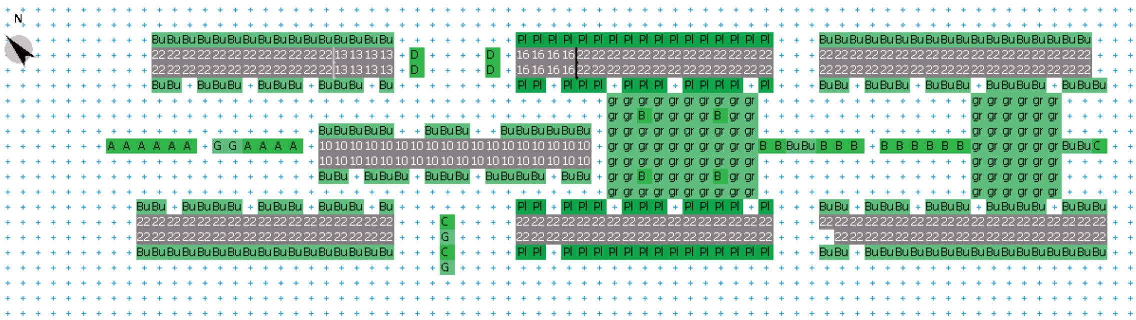


Fig. 15 - ENVI-met model of the Scenario 2

ID	Vegetation Typology	H (m)	LAI (m2/m2)
A	Tree	10	4.6
B	Tree	10	1.175
C	Tree	6	4.6
D	Tree	3	1.75
Pl	Tree	15	2.6
Bu	Hedge	2	5.9
G	Grass	0.05	0.5
Gr	Grass	0.10	3

Table 5 - List of vegetation typologies for the Scenario 2

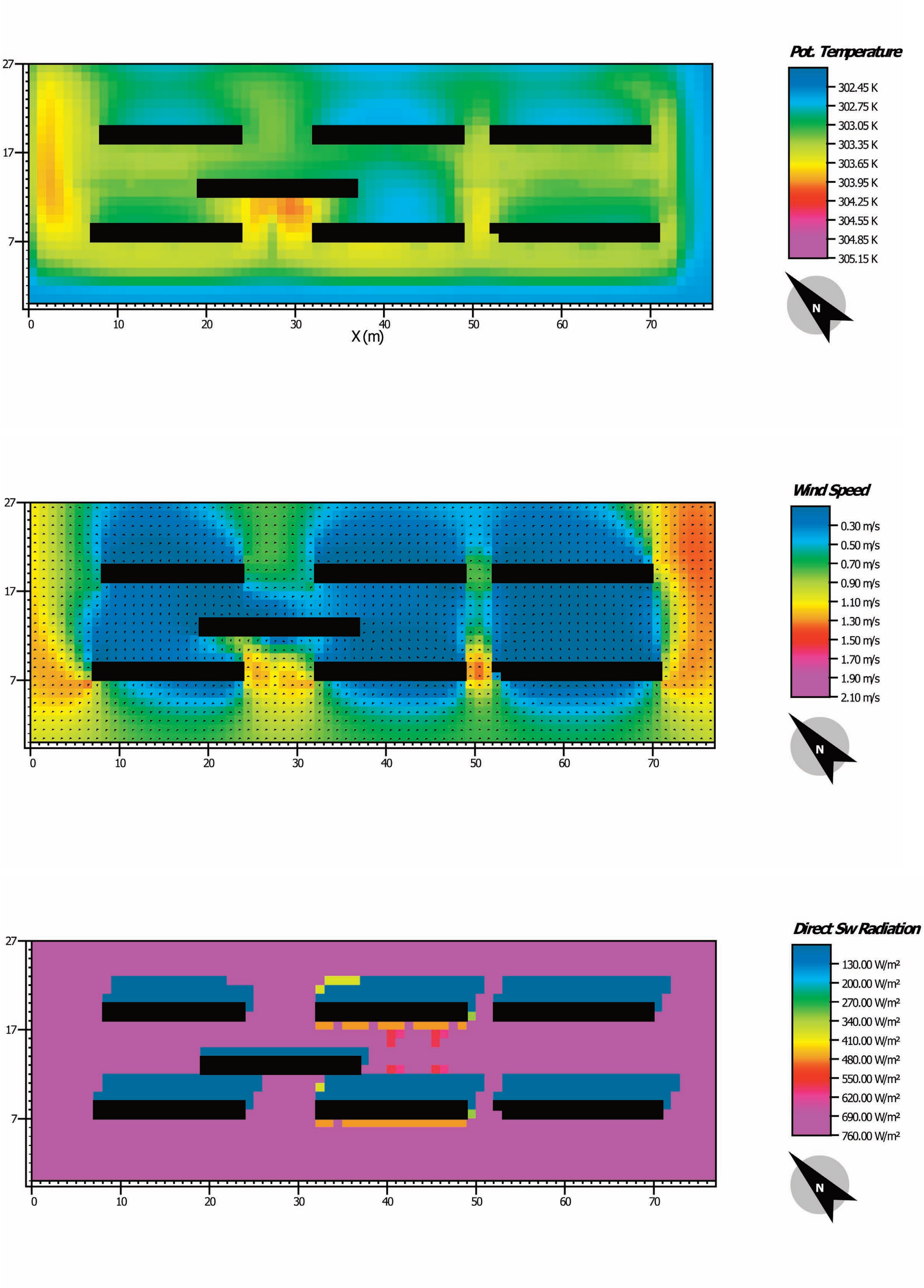


Fig. 16 - 2D data map generated by Leonardo for the Scenario 2

8.3.4. Scenario 3

Fig. 17 - Layout of the Scenario 3

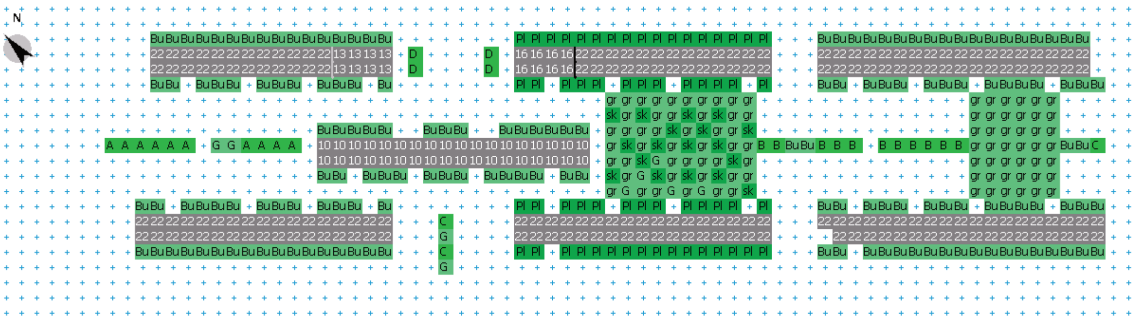


Fig. 18 - ENVI-met model of the Scenario 3

ID	Vegetation Typology	H (m)	LAI (m2/m2)
A	Tree	10	4.6
B	Tree	10	1.175
C	Tree	6	4.6
D	Tree	3	1.75
Sk	Tree	15	6.5
Pl	Tree	15	2.6
Bu	Hedge	2	5.9
G	Grass	0.05	0.5
Gr	Grass	0.10	3

Table 6 - List of vegetation typologies for the Scenario 3

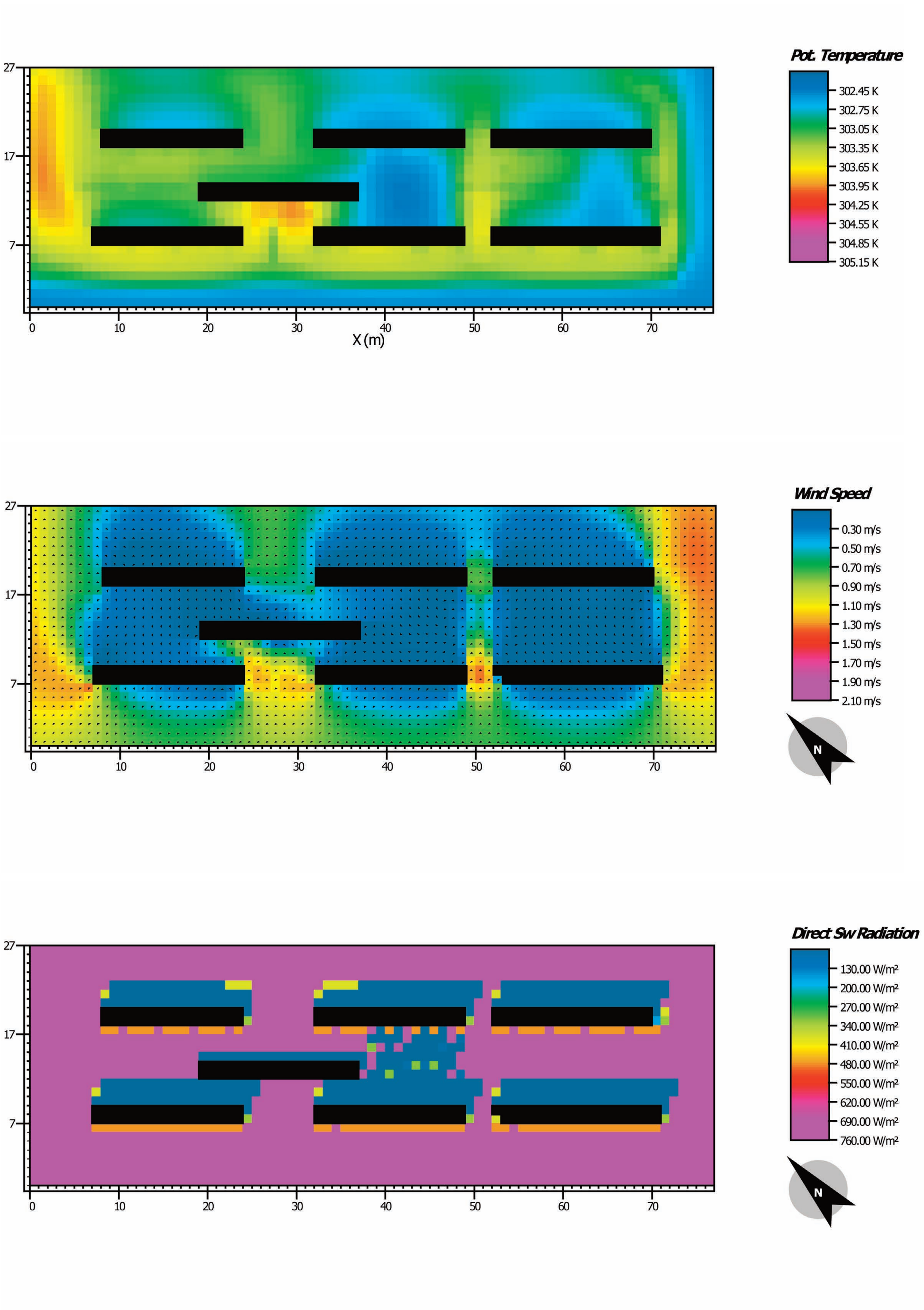


Fig. 19 - 2D data map generated by Leonardo for the Scenario 3

8.3.5. Scenario 4

Fig. 20 - Layout of the Scenario 4

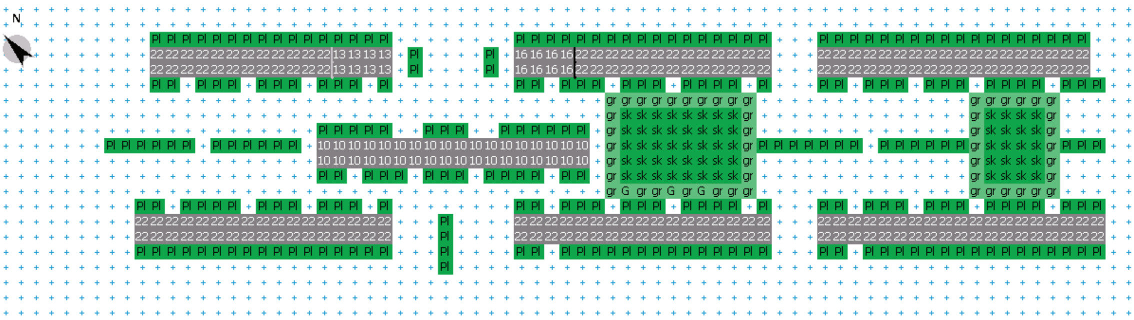


Fig. 21 - ENVI-met model of the Scenario 4

ID	Vegetation Typology	H (m)	LAI (m2/m2)
Sk	Tree	15	6.5
Pl	Tree	15	2.6
Gr	Grass	0.10	3

Table 7 - List of vegetation typologies for the Scenario 4

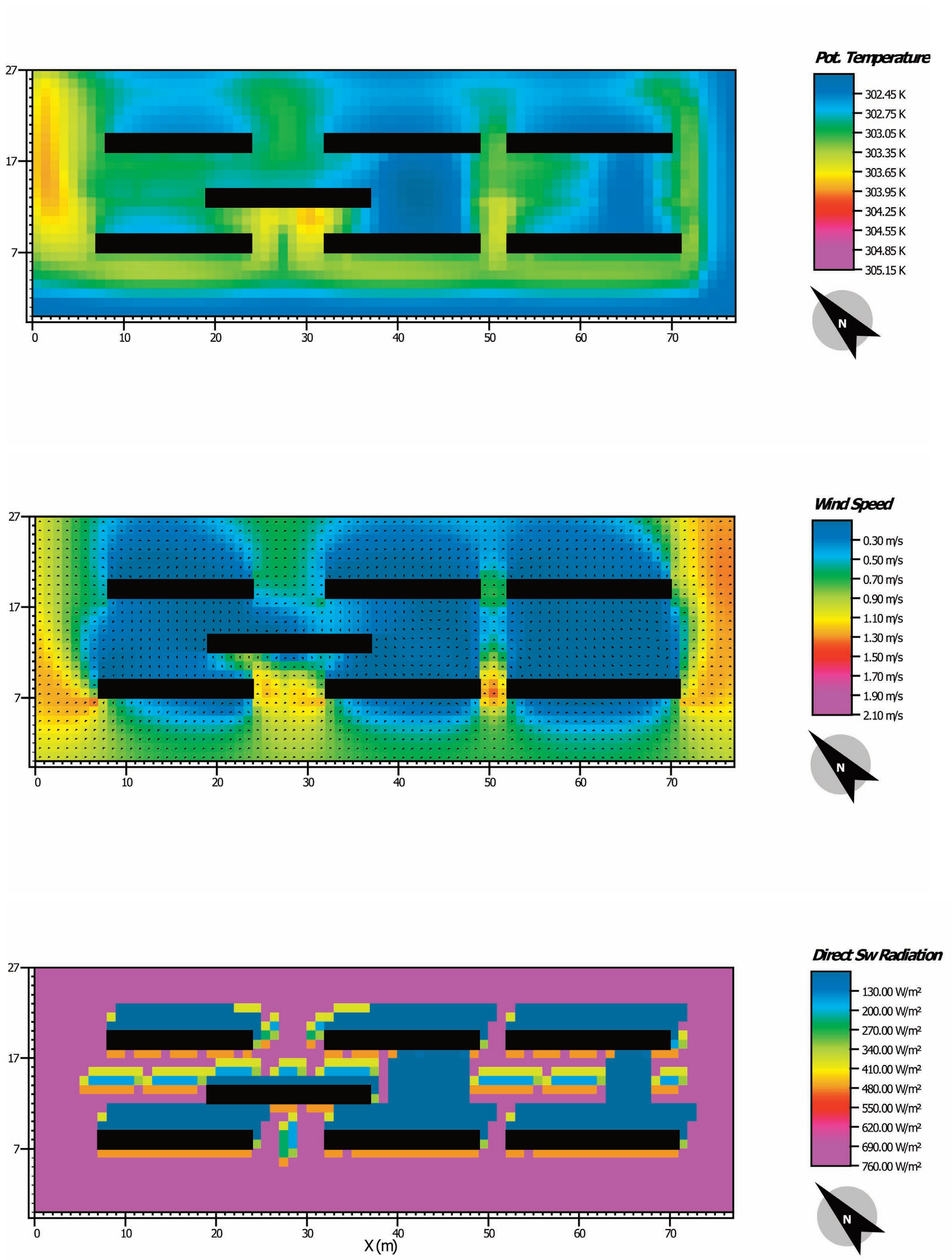


Fig. 22 - 2D data map generated by Leonardo for the Scenario 4

August 5th TEMPERATURE		Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR A	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C
	Current - Sc3	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C	ΔT ≈ 1° C
	Current - Sc4	ΔT ≈ 1° C	ΔT ≈ 1° C	ΔT ≈ 1.5° C

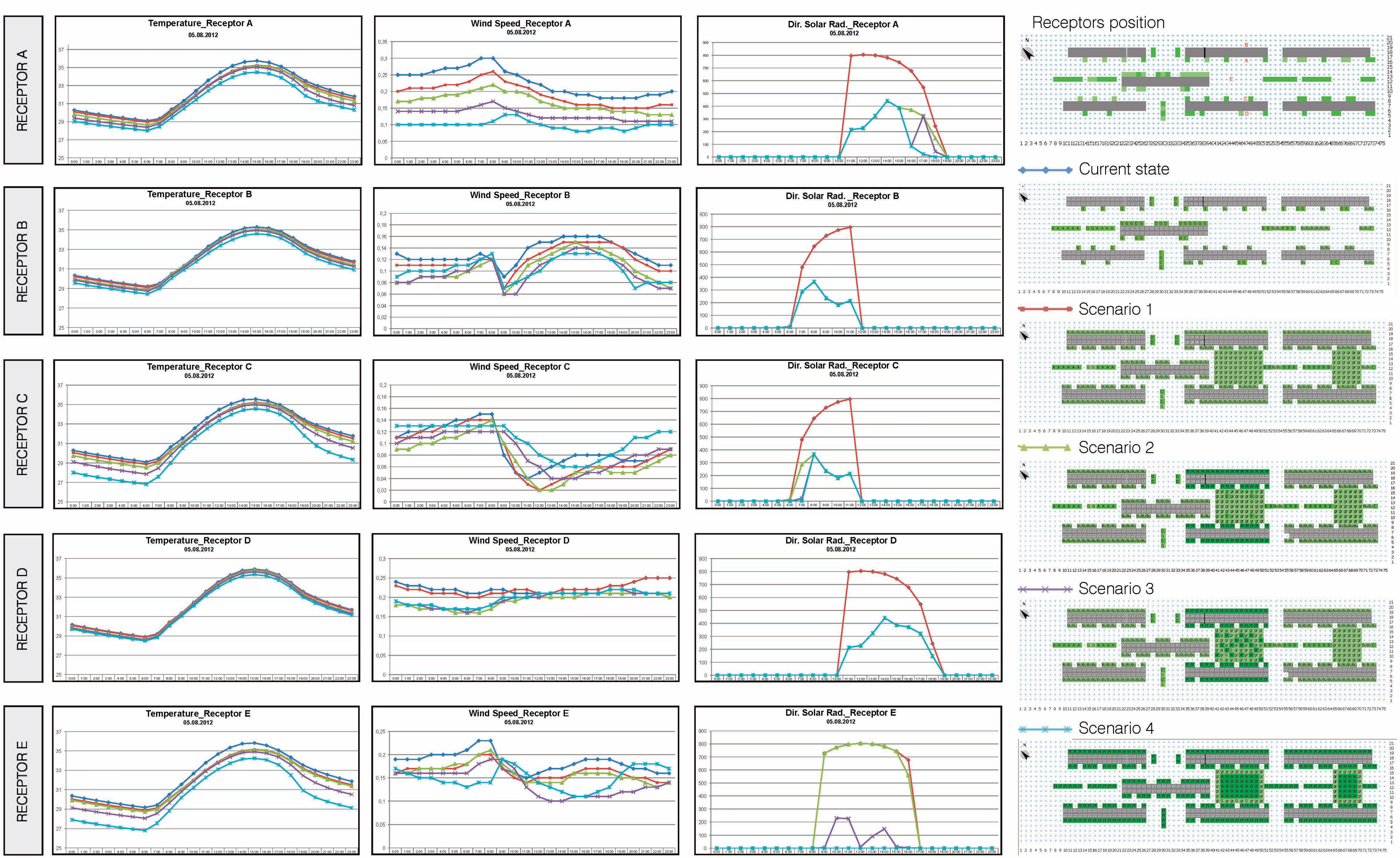
August 5th TEMPERATURE		Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR B	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc3	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0.5° C
	Current - Sc4	ΔT ≈ 0.5° C	ΔT ≈ 1° C	ΔT ≈ 1° C

August 5th TEMPERATURE		Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR C	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C
	Current - Sc3	ΔT ≈ 1° C	ΔT ≈ 0.5° C	ΔT ≈ 1° C
	Current - Sc4	ΔT ≈ 1.5° C	ΔT ≈ 1° C	ΔT ≈ 2.5° C

August 5th TEMPERATURE		Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR D	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc3	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0.5° C
	Current - Sc4	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C

August 5th TEMPERATURE		Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR E	Current - Sc1	ΔT ≈ 0.5° C	ΔT ≈ 1° C	ΔT ≈ 0.5° C
	Current - Sc2	ΔT ≈ 0.5° C	ΔT ≈ 1° C	ΔT ≈ 0.5° C
	Current - Sc3	ΔT ≈ 1° C	ΔT ≈ 1° C	ΔT ≈ 1.5° C
	Current - Sc4	ΔT ≈ 1.5° C	ΔT ≈ 1° C	ΔT ≈ 3° C

Table 8 - Summary of the decrease of temperature on August 5th comparing the current state with the four scenarios



Graph. 15 - Temperature [°C], wind speed [m/s]and direct radiation [W/m²] generated at stage 2 for August 5th: comparison between the current state and the four scenarios

	August 15th TEMPERATURE	Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR A	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C
	Current - Sc3	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C
	Current - Sc4	ΔT ≈ 0.5° C	ΔT ≈ 1° C	ΔT ≈ 1° C

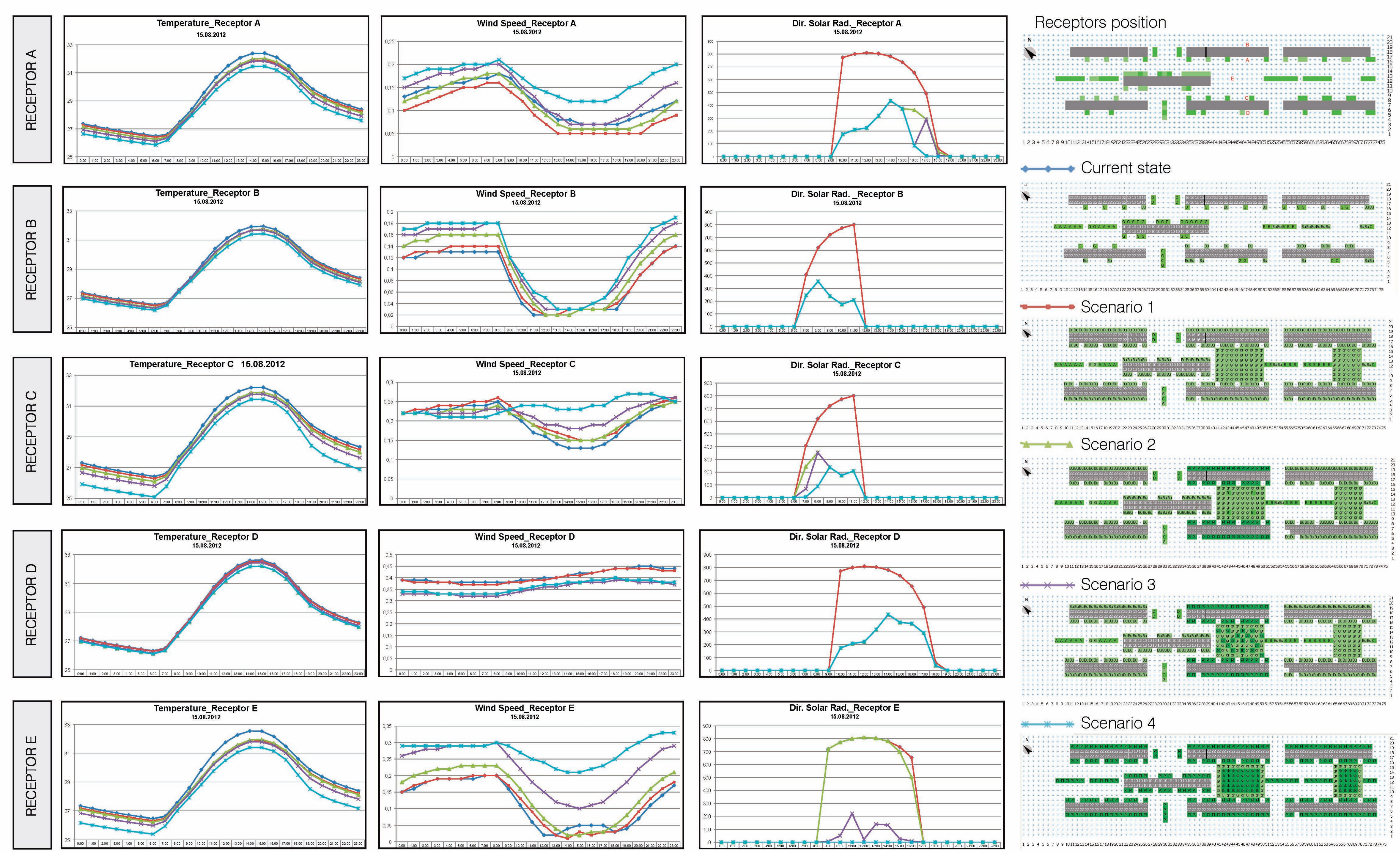
	August 15th TEMPERATURE	Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR B	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc3	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc4	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C

	August 15th TEMPERATURE	Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR C	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C
	Current - Sc3	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C	ΔT ≈ 1° C
	Current - Sc4	ΔT ≈ 1° C	ΔT ≈ 1° C	ΔT ≈ 1.5° C

	August 15th TEMPERATURE	Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR D	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc3	ΔT ≈ 0° C	ΔT ≈ 0° C	ΔT ≈ 0° C
	Current - Sc4	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C

	August 15th TEMPERATURE	Early Morning (7-10 AM)	Morning-Afternoon (10 AM-7 PM)	Evening-Night (7 PM-7 AM)
RECEPTOR E	Current - Sc1	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0° C
	Current - Sc2	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 0.5° C
	Current - Sc3	ΔT ≈ 0° C	ΔT ≈ 0.5° C	ΔT ≈ 1° C
	Current - Sc4	ΔT ≈ 0.5° C	ΔT ≈ 1° C	ΔT ≈ 1.5° C

Table 9 - Summary of the decrease of temperature on August 15th comparing the current state with the four scenarios



Graph. 16 - Temperature [°C], wind speed [m/s]and direct radiation [W/m²] generated at stage 2 for August 15th: comparison between the current state and the four scenar-

By comparing the data generated during the winter days, irrelevant differences are recorded as for wind speed and ambient temperature while in scenarios 2, 3 and 4, a considerable reduction of direct radiation is registered due to the shade provided by the trees.

Regarding the summer days, data generated show analogous results for the two days.

For all four receptors, wind speed does not present significant variation comparing the current situation with the proposed scenarios.

Benefits derived from the presence of hedges and lawn of scenario 1 are almost imperceptible for receptors B and D. The same situation occurs for scenarios 2 unless for the shading effect of the trees foliage on the building façades. Also in scenarios 3 and 4, in which dense crown trees are used as shading elements, solar radiation is obviously very reduced in respect to the original layout. Relevant results are obtained in correspondence of receptors A and C, positioned near the buildings walls overlooking the internal area of the complex, and for receptor E, positioned in the open area.

In general what emerges is that, comparing the scenarios, highest variations of temperature imputable to the presence of vegetation occur during the warmest hours of the day (1-3 P.M.) and during the night (11 P.M.- 4 A.M.). In particular, in scenario 4 the following situation occurs:

- receptor A (south-west exposed) registered a decrease up to 1°C in the early morning and in the afternoon and up to 1.5 °C during the night;
- receptor C (north-east exposed) registered a decrease up to 1.5°C in the early morning, up to 1°C in the morning/afternoon and up to 2.5 °C during the night;
- receptor E registered a decrease up to 1.5°C in the early morning, up to 1°C in the morning/afternoon and up to 3°C during the night.

This is attributable to the fact that the greater trees densification of the complex common area has a higher influence on the microclimate.

Data generated in this first stage of the research by means of the software ENVI-met demonstrate how effective the adoption of vegetation can be for the control of the outdoor comfort levels during the design and the renovation process of micro urban areas. In fact

the results of the measurements gave important information about the microclimatic differences among the five scenarios analysed related to the social housing complex Medaglie d'Oro and prove that the cooling effect of the area is higher in correspondence of the internal common area of the complex where vegetation is denser. Hence, this part of the research draws attention to the importance of deeper approaches for high accuracy investigations on real urban and building scale thermal comfort levels.

8.4. STAGE 4: Simulations for indoor temperature and comfort assessment

Starting from generated meteorology at stage 2, further analyses were held at the building and apartment scale to assess the effect of shading, radiant interactions and evapotranspiration on indoor thermal comfort levels and to evaluate how these strategies can be combined with other retrofit interventions to further reduce the buildings energy consumptions.

For this stage of simulation five different apartments situated in the building (north-east positioned), whose weather parameters refer to receptors A and B of the previous simulations, were considered. The apartments chosen are those shown in blue in Fig. 23 and consist in: a typical left and a typical right apartment, a typical left end and right end apartment, and a left end top floor apartment. These last three were studied because they are subject to particular thermal conditions due to their higher surface exposed to the outdoor environment. The apartments have all the same geometry and dimension but they present loggias with different exposition that can differently influence the thermal gain of the adjacent rooms.

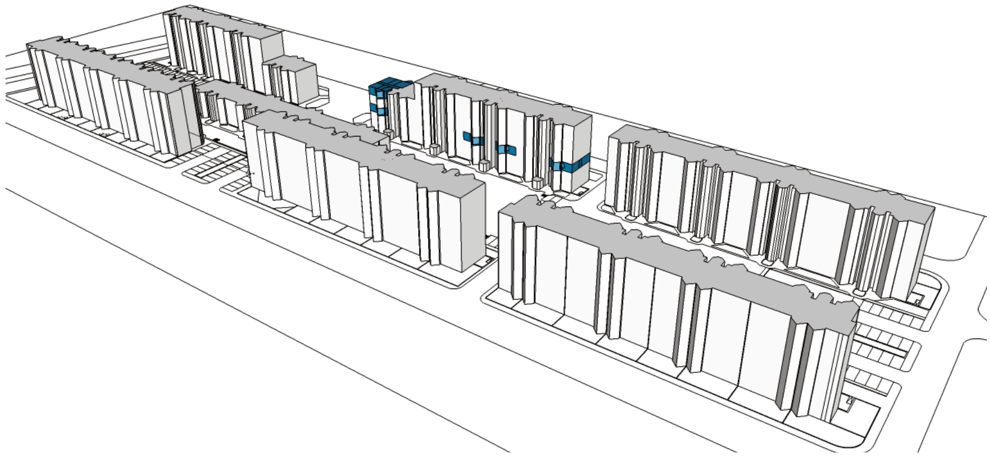


Fig. 23 - Individuation of the apartments (in blue) chosen for simulation at stage 3

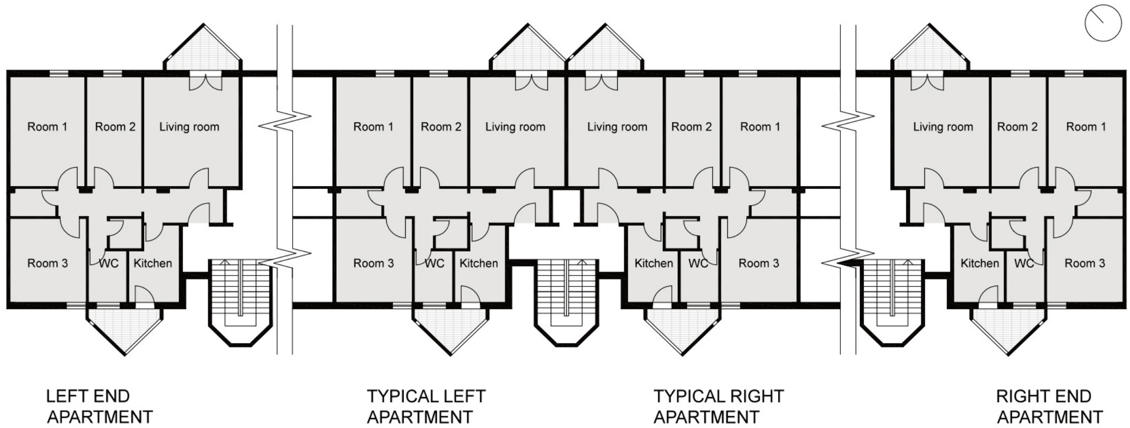


Fig. 24 - Layout of the apartments chosen for simulation at stage 3

Every apartment consists of a kitchen, a living room, one bathroom and three bedrooms. The living room and two bedrooms are north-east exposed while the kitchen, the bathroom and one bedroom are south-west exposed.

Simulations at this stage were performed with the software EnergyPlus jointly with the Legacy OpenStudio Plug-in for SketchUp to create and edit the building geometry in the EnergyPlus input files. Each room of the apartments were considered as a single EnergyPlus "thermal zone" in order to identify the temperature inside every residential space.

For each apartment five different simulations were run (six for the top floor apartments) to assess to what extent the progressive use of vegetation -from the renovation of the outdoor environment to the application of living walls and green roof- combined with the substitution of the current windows and glazed doors, influences the indoor temperatures and tenants' comfort. Hence, the following scenarios were considered:

1. Current state;
2. Outside vegetation (as resulted from the previous stage);
3. Outside vegetation + Substitution of windows (low-e glazing);
4. Outside vegetation + Substitution of windows (silver low-e glazing);
5. Outside vegetation + Silver low-e glazing + Living walls;
6. Outside vegetation + Silver low-e glazing + Living walls + Green roof (only for the top floor apartment).

The simulations were performed for the four days considered at stage 3 (two days in winter and two days in summer).

Regarding the outside vegetation, among the scenarios evaluated at the stage 3, only the one which provided the greatest benefits (scenario 4), in terms of temperature reduction in summer, was considered but the apartments corresponding to the receptors that gave the lowest reductions were analysed (receptors A and B, positioned on the outside façades of the building considered at this stage).

The tree typologies taken into account were evergreen. This choice depended on the fact that LAD values of deciduous trees for winter months were not available for these simulations although the use of deciduous trees could be hypothetised as more congenial considering that the presence of foliage could deeply influence passive thermal gain of the apartments during the coldest days.

Furthermore for each apartment and for the retrofit scenarios considered at this stage, three different ventilation conditions were simulated:

- CDCW - Closed Doors and Closed Windows[6]
- CDOW - Closed Doors and Open Windows
- ODOW - Open Doors and Open Windows

These different ventilation conditions were considered for the summer days, while only the condition CDCW was taken into account in winter.

For each configuration a proper "Design Day" configuration file was provided entering the weather data summarized in Table 10.

For the conditions CDCW and CDOW, simulation with different input data were run depending on the thermal zone exposition (and then their relation with the receptors used for the ENVI-met simulations). In particular, for the north-east rooms the input data related to receptor B were taken into account while for the south-west rooms the input data related to receptor A were considered.

For the condition ODOW, only the input data related to the receptor positioned in the direction of the prevailing wind (receptor B) were entered.

Values related to the solar radiation used are those registered at the UniPa weather station. For the configurations that foresee outside vegetation, to simulate the presence of the trees in the EnergyPlus model, shading object were created in correspondence of the two building façades.

In the next paragraphs the simulations related to the different configurations are described. Graphics and thermal maps summarizing the obtained results are included in the appendix.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Weather data</th><th rowspan="2">Room orientation</th><th colspan="2">Data input origin</th></tr>
<tr><th>Current state</th><th>Outside vegetation</th></tr>
<tr><td rowspan="6">CDCW</td><td rowspan="2">Temperature and Humidity</td><td>N-E</td><td>REC. B (Curr. state)</td><td>REC. B (Sc.4)</td></tr>
<tr><td>S-W</td><td>REC. A (Curr. state)</td><td>REC. A (Sc.4)</td></tr>
<tr><td rowspan="2">Wind Speed</td><td>N-E</td><td>REC. B (Curr. state)</td><td>REC. B (Sc.4)</td></tr>
<tr><td>S-W</td><td>REC. A (Curr. state)</td><td>REC. A (Sc.4)</td></tr>
<tr><td rowspan="2">Solar Radiation</td><td>N-E</td><td rowspan="2">UniPa</td><td rowspan="2">UniPa</td></tr>
<tr><td>S-W</td></tr>
<tr><td rowspan="6">CDOW</td><td rowspan="2">Temperature and Humidity</td><td>N-E</td><td>REC. B (Curr. state)</td><td>REC. B (Sc.4)</td></tr>
<tr><td>S-W</td><td>REC. A (Curr. state)</td><td>REC. A (Sc.4)</td></tr>
<tr><td rowspan="2">Wind Speed</td><td>N-E</td><td>REC. B (Curr. state)</td><td>REC. B (Sc.4)</td></tr>
<tr><td>S-W</td><td>REC. A (Curr. state)</td><td>REC. A (Sc.4)</td></tr>
<tr><td rowspan="2">Solar Radiation</td><td>N-E</td><td rowspan="2">UniPa</td><td rowspan="2">UniPa</td></tr>
<tr><td>S-W</td></tr>
<tr><td rowspan="6">ODOW</td><td rowspan="2">Temperature and Humidity</td><td>N-E</td><td rowspan="2">REC. B (Curr. state)</td><td rowspan="2">REC. B (Sc.4)</td></tr>
<tr><td>S-W</td></tr>
<tr><td rowspan="2">Wind Speed</td><td>N-E</td><td rowspan="2">REC. B (Curr. state)</td><td rowspan="2">REC. B (Sc.4)</td></tr>
<tr><td>S-W</td></tr>
<tr><td rowspan="2">Solar Radiation</td><td>N-E</td><td rowspan="2">UniPa</td><td rowspan="2">UniPa</td></tr>
<tr><td>S-W</td></tr>
</table>

Table 10 - Origin of the input weather data for the EnergyPlus simulations

8.4.1. Current state

8.4.1.1. Data input setting

The first EnergyPlus simulations aimed at the evaluation of the indoor temperature considering the current state of the building envelopes and of the external area. In the program input editor, the building materials properties were entered according to the following parameters:

- t - Thickness
- λ - Conductivity [W/mK]
- ρ - Density [kg/m^2]
- c - Specific Heat [J/kgK]
- r - Thermal Resistance [m^{2}K/W]

As for windows and glazed doors, the parameters specified were:

- U - Thermal transmittance [W/m^{2}K]
- SHGC - Solar Heat Gain Coefficient
- VT - Visible Transmittance

	Material	t [m]	λ [W/mK]	ρ [kg/m^2]	c [J/kgK]
External walls	Plaster	0.03	1	1800	900
	Pumice block	0.13	0.2	929	840
	Air cavity	0.06	r= 0.15		
	Perforated brick	0.08	0.39	1000	840
	Plaster	0.02	0.7	1400	840
Int. walls	Plaster	0.02	0.7	1400	840
	Gipsum block	0.06	0.35	900	840
	Plaster	0.02	0.7	1400	840
Ceiling	Tiles	0.015	1	2300	840
	Mortar	0.02	0.7	1400	840
	Concrete	0.04	1,28	2200	880
	Perforated brick	0.16	0.39	1000	840
	Plaster	0.03	1	1800	900
Roof	Bituminous coating	0.003	0.17	1200	920
	Concrete+pumice conglomerate	0.08	0.39	1100	920
	Concrete	0.04	1.28	2200	880
	Perforated brick	0.16	0.39	1000	840
	Plaster	0.03	1	1800	900
			U [W/m^{2}K]	SHCG	VT
Windows and Glazed Doors			6	0.9	0.9

Table 11 - Building materials properties

8.4.1.2.Results

The simulations corresponding to the three different ventilation conditions (CDCW-CDOW-ODOP) demonstrate, as predictable, that the condition CDCW entails a linear temperature trend while in CDOW and ODOW, temperatures describe higher curves with difference of temperature along the day up to about 5°C. As predictable, the highest temperatures were registered in the south-west oriented rooms and in particular in the kitchen. This demonstrates the role of the closed loggias that act as a sunspace and heat gainers for the apartments in winter, adversely affecting the users' indoor comfort in summer. The left end and the right end apartment present worse conditions, if compared with the other typical apartments, in correspondence of the rooms situated at the extremities of the building and then mainly exposed to the outdoor environment. Finally, the top floor apartment is the one which present the worst conditions in summer.

Summer

Temperature registered in summer oscillates from around 30° to 35°C on August 5th and from around 27° to 32°C on August 15th. The typical left and right apartments registered similar temperature trends. The left end and right end apartments registered quite elevated temperatures in correspondence of the bedrooms whose walls are mainly exposed to the solar direct radiation, with peak of 31°C on August 15th and of 33.62°C on August 5th.

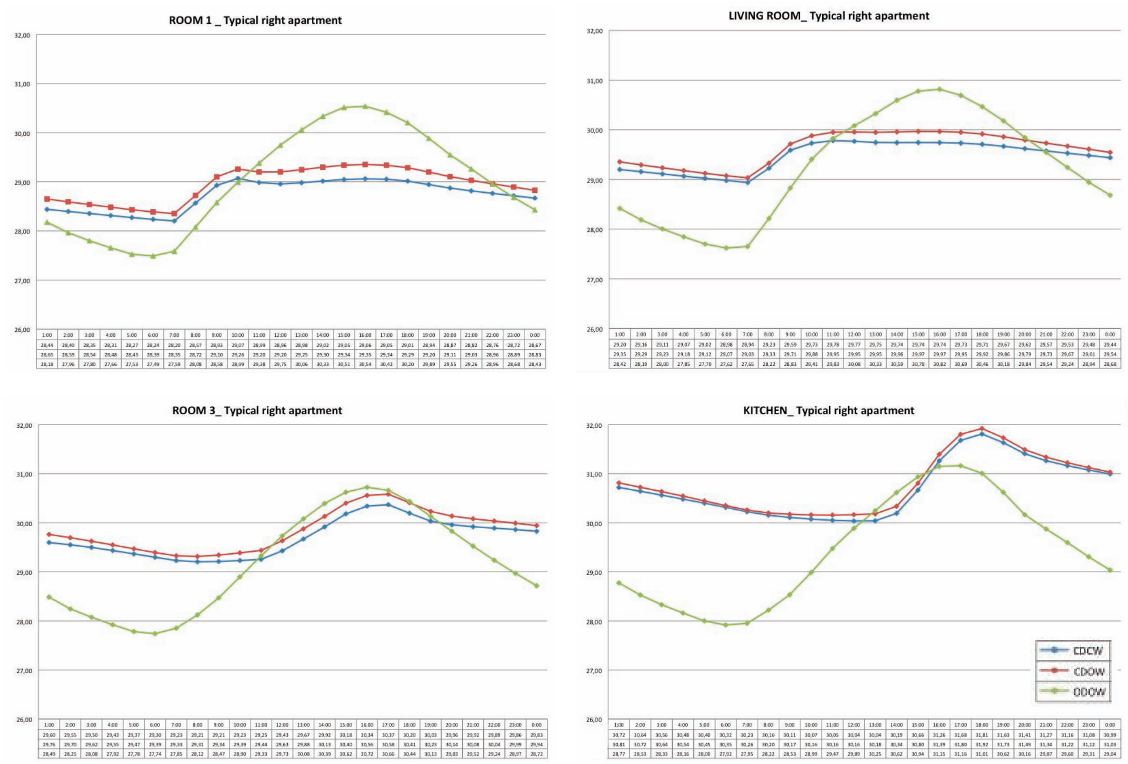
The top floor apartment is the one which present the worst conditions, with peak up to 35.64°C.

The ODOW configuration is the one that offers high levels of comfort during the night and in the morning and, on the contrary, worse conditions during the afternoon.

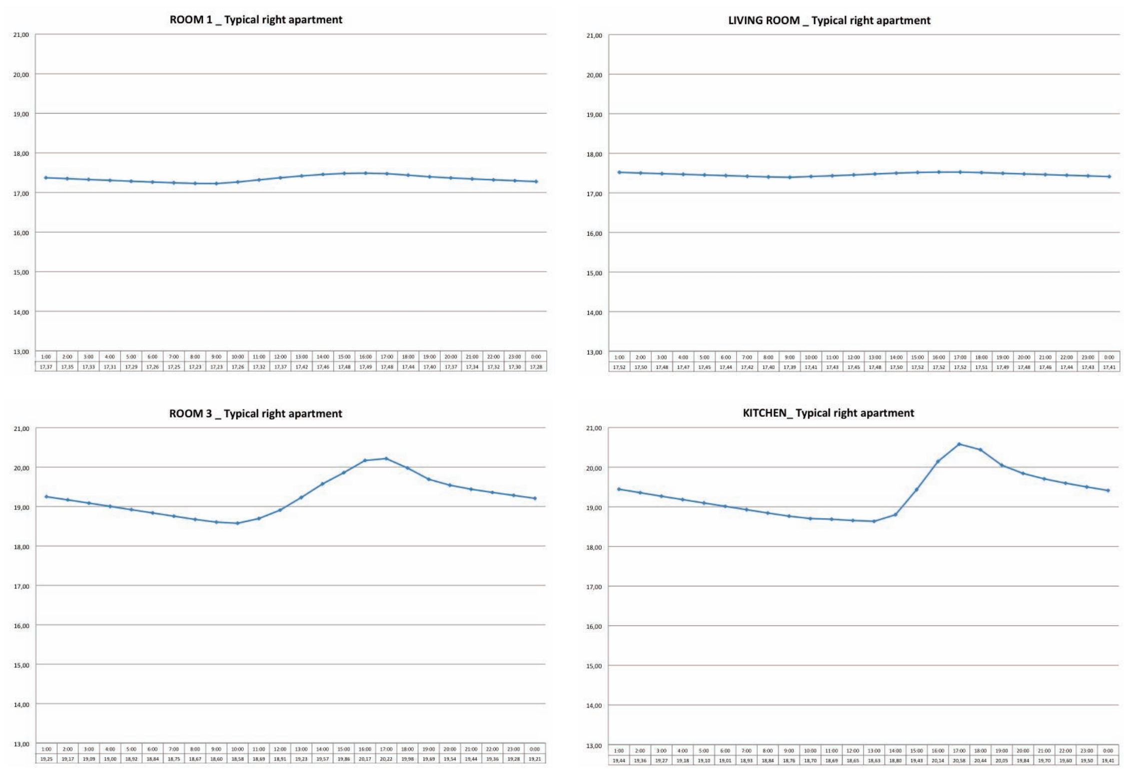
Winter

Temperatures registered in winter follow a quite stable curve. Values on February 11th are comprised between 17-18°C in the north-west exposed rooms and temperature between 18.58 and 20.58° C in the south-east rooms. Only in the left end apartment, Room1 registered values under 17°C. Temperature on February 27th moves from 15 to 16°C for the north-west exposed rooms and from 16 to 19°C for the south-east rooms.

Fig. 25 - Thermal map of the typical right and left apartments on August 15th at 6AM (left) and at 4PM (right) for the current state



Graph. 17 - Examples of temperature trends on August 15th for the current state



Graph. 18 - Examples of temperature trends on February 11th for the current state

8.4.2. Outside vegetation

These simulations started from the microclimate parameters resulted at stage 3 that considered the retrofit of the outside spaces through the integration with plants, specifically 15m high trees with dense crown. Considering the significant reduction of the outdoor temperature obtained through the ENVI-met simulations, a substantial increase of the indoor thermal comfort was also expected.

8.4.2.1. Assessment of direct radiation on vertical walls

As previously mentioned, the presence of trees was simulated through the use of shadings elements positioned in correspondence of the two façades.

Energy plus, indeed, allows assigning a shading device level of transmittance that can be tuned according to necessity. In this case, the challenge was to identify the values which could enable the shading objects to get as closest as possible to the trees effect. For this reason firstly the values of direct solar radiation on the building façades in the Scenario 4 simulated at stage 3 were calculated in order to identify, through several attempts, the values of transmittance to be entered for the shading devices in EnergyPlus.

Since ENVI-met only allows to assess, for each receptors, the direct shortwave radiation given at the maximum possible value, namely the one calculated on the plane perpendicular to the solar beam direction, the following formula was applied to calculated the radiation on the vertical walls:

$$I = I_n * \cos\beta \quad (\cos\beta > 0)$$

where

$$\cos\beta = \cos\alpha_S + \cos(\gamma_S - \gamma_f)\sin\phi_f + \sin\alpha_S \cos\phi_f$$

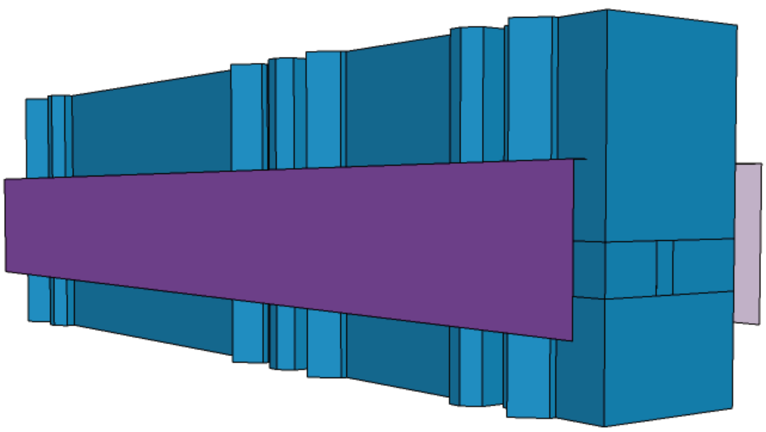


Fig. 26 - Shading devices simulating the presence of trees

and

I_n is intensity of radiation normal to the solar beam (W/m^2)
β is the angle between the solar beam and a line normal to the surface (°)
α_S is the solar altitude angle (°)
γ_S is the solar azimuth angle (south 0°, east -90°, west 90°) (°)
γ_f is the wall azimuth angle (south 0°, east -90°, west 90°) (°)
ϕ_f is the angle of the sloping surface (vertical 90°, horizontal 0°) (°)

8.4.2.2. Data input setting

Once the values of direct radiation on all the building vertical surfaces were obtained, the transmittance schedules referring to the EnergyPlus shading devices were individuated. Different values to determine the transmittance of the shading devices were calculated according to the hour of the day and in relation to the orientation of the tree rows, as shown in Table 12.

Field	Units	Obj1	Obj2
Name		Tree_RecA	Tree_RecB
Schedule Type Limits Name		Fraction	Fraction
Field 1	varies	Through: 12/31	Through: 12/31
Field 2	varies	For: AllDays	For: AllDays
Field 3	varies	Until: 10:00	Until: 05:00
Field 4	varies	1	1
Field 5	varies	Until: 11:00	Until: 09:00
Field 6	varies	0.3	0.7
Field 7	varies	Until: 12:00	Until: 11:00
Field 8	varies	0.5	0.6
Field 9	varies	Until: 15:00	Until: 24:00
Field 10	varies	0.5	1
Field 11	varies	Until: 19:00	
Field 12	varies	0.3	
Field 13	varies	Until: 24:00	
Field 14	varies	1	

Table 12 - Transmittance schedule set in EnergyPlus to simulate the presence of trees

8.5.2.2. Results

The simulations demonstrate that the presence of vegetation situated in the close surrounding of a residential complex offers a great contribute for the thermal mitigation inside the building. The south-east side of the apartments resulted more affected than the north-west one.

Summer

For the days chosen in summer, simulations generally show that, in the N-E side of the apartments, significant differences of temperature between the current state and the scenario where the outside vegetation is foreseen are registered, especially in the bedrooms (Room1 and Room2) at the early morning in the ventilation condition CDOW. On the S-W side of the apartments, greatest improvements in terms of temperature reduction are registered in the kitchen, in the late afternoon, for the ventilation condition CDCW.

Greatest benefits are registered in the apartments situated at the two extremities of the building. This is what occurs in particular on August 5th:

- Typical Right Apartment: In the N-E side the temperatures are subject to reductions of around 1°C, with Δt up to 1.74°C in Room 2 registered in the early morning in the condition CDOW. In the S-W side the average difference of temperature goes around 2°C and raises up to 2.99°C in the kitchen, in the late afternoon, in the condition CDCW.
- Typical Left Apartment: In the N-E side the temperatures are subject to reductions comprised between 0.5 and 1°C, with Δt up to 1.77°C in Room 2 registered in the early morning in the condition CDOW. In the S-W side the differences of temperature oscillate around 1°C with Δt up to 1.60°C in the kitchen in the late afternoon. In Room 3, in the early morning, in the condition CDOW, the temperature decrease of 2.52°C.
- Right End Apartment: In the N-E side the temperatures are subject to reductions comprised between 0.5 and 1°C, with Δt up to 2.02°C in Room 1 registered in the early morning in the condition CDOW. In the S-W side the differences of temperature oscillate around 2°C with going up to 2.74°C in the kitchen and up to 2.99°C in Room 3, in the early morning, in the condition CDOW.
- Left End Apartment: In the N-E side the temperatures are subject to reductions of around 0.5-1°C but decrease up to 1.99°C in Room 1 registered in the early morning in the condition CDOW. In the S-W side the differences of temperature oscillate around 1°C with Δt up to 1.38°C in the kitchen in the CDCW condition. In Room 3, Δt grows up to 3.08°C in the early morning, in the condition CDOW.
- Top Left End Apartment: In the N-E side the temperatures are subject to reductions lower than 1°C. In the S-W side the differences of temperature oscillate around 1°C with Δt up to 1.24°C in Room 3, in the early morning, in the condition CDOW.

This is what occurs in particular on August 15th:

- Typical Right Apartment: In the N-E side the temperatures are subject to reductions comprised between 0.5 and 1°C, with Δt up to 1.95°C in Room 2 registered in the early morning in the condition CDOW. In the S-W side the average difference of temperature goes around 2°C and grows up to 3.35°C in the kitchen, in the late afternoon, in the condition CDCW.
- Typical Left Apartment: In the N-E side the temperatures are subject to reductions comprised between 0.5 and 1°C, with Δt up to 1.78°C in Room 2 registered in the early morning in the condition CDOW. In the S-W side the differences of temperature oscillate be-

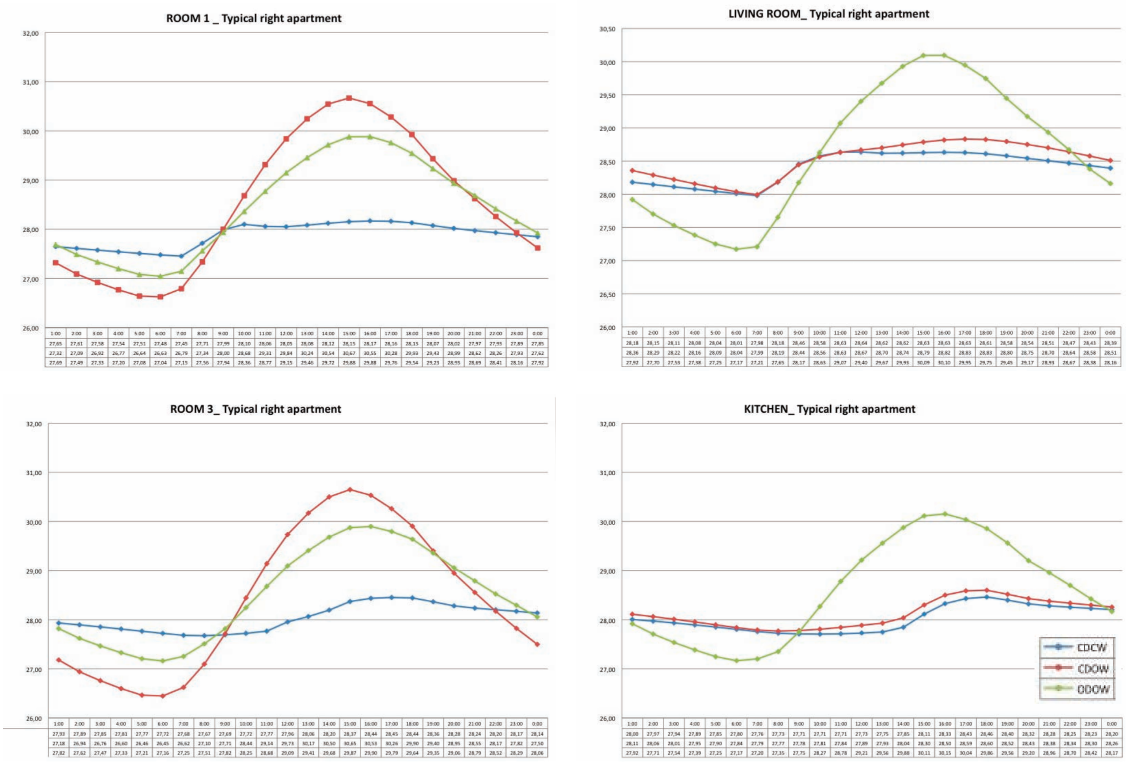
tween 1.5 - 2°C with higher values up to 2.94°C in Room 3, in the early morning, in the condition CDOW.

- Right End Apartment: In the N-E side the temperatures are subject to reductions comprised between 0.5 and 1°C, with Δt up to 2.04° in Room 1 registered in the early morning in the condition CDOW. In the S-W side the differences of temperature oscillate around 2°C with going up to 3.43°C in Room 3, in the early morning, in the condition CDOW.
- Left End Apartment: In the N-E side the temperatures are subject to reductions of around 0.5°C but could rise up to 1.91°C in Room 1 registered in the early morning in the condition CDCW. In the S-W side the differences of temperature oscillate around 1.5°C with Δt up to 1.70°C in the kitchen in the CDCW condition. In Room 3, Δt grows up to 3.30°C in the early morning, in the condition CDOW.
- Top Left End Apartment: Very low differences are registered in the N-E side. Although the outdoor temperatures are lower than in the current state, higher temperature are registered in the S-W exposed rooms, with the exception of the ventilation condition CDOW where little improvements take place[7].

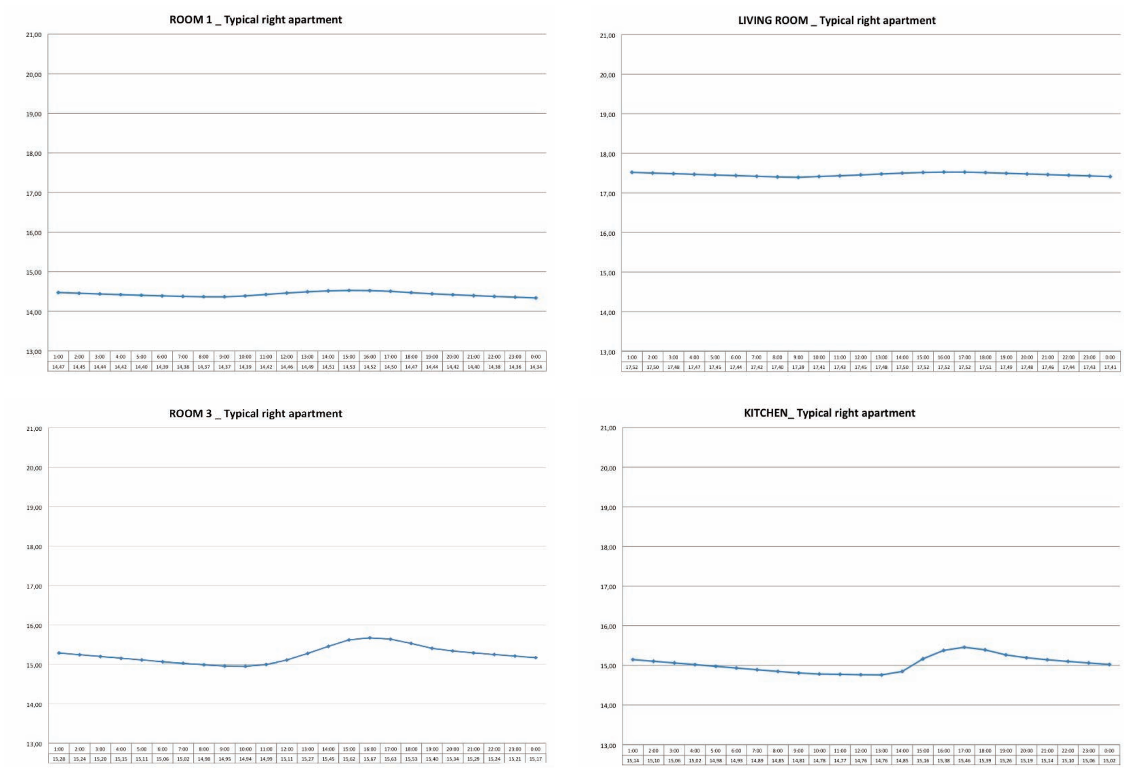
Winter

For the day in summer, simulations were run only in the ventilation condition CDCW. The results show significant decrease of the temperatures. In particular, on February 11th the temperature decrease of around 2.80°C on the N-E rooms and of 4°C on the S-W rooms, while on February 27th the temperature decrease respectively of around 1°C and 2°C. Such results demonstrate that the use of deciduous trees would be more advisable although this condition is not studied in the present work.

Fig. 27 - Thermal map of the typical right and left apartments on August 15th at 6AM (left) and at 4PM (right) for the scenario with outside vegetation



Graph. 19 - Examples of temperature trends on August 15th when outside vegetation in considered



Graph. 20 - Examples of temperature trends on February 11th when outside vegetation in considered

8.4.3. Substitution of windows and glazed doors

The aim of this stage was to evaluate, after the results obtained from the application of vegetation on the external spaces, the possible benefits provided by the substitution of the current windows and glazed doors, which present a visible state of obsolescence being constituted by a metal frame and a single glass.

8.4.3.1. Windows characteristics

For the purpose of this stage two different type of windows were tested:

- Windows with low-e glazing
- Windows with silver low-e glazing

Window glass is by nature highly thermal emissive. To improve thermal efficiency thin film coatings are applied to the raw glass. Low-e metal based coating are able to lower the glass emissivity to values comprised between 0.8 to 0.1. The thermal losses in the window cavity are significantly reduced, hence improving the thermal insulation. The characteristics of these glasses are the high level of visible transmittance and thermal gains. There are two primary methods in use to obtain low-e glass: Pyrolytic CVD and Magnetron Sputtering. The first involves deposition of fluorinated tin oxide at high temperatures.

The second involves depositing one or more thin silver layers with antireflection layers. Silver based films are environmentally unstable and must be enclosed in an Insulated glazing or Insulated Glass Unit (IGU) to maintain their properties over time. These coatings reflect radiant infrared energy, thus tending to keep radiant heat on the same side of the glass from which it originated, while letting visible light pass. This results in more efficient windows, especially for temperate climate areas, because radiant heat originating from indoors in winter is reflected back inside, while infrared heat radiation from the sun during summer is reflected away, keeping it cooler inside. Nevertheless, it is necessary to verify the real efficiency of this kind of glazing, not only in relation to the thermo-physical parameters, but also to the specific building and climate conditions.

The values of Thermal transmittance [W/m^{2}K], Solar Heat Gain Coefficient and Visible Transmittance entered in the EnergyPlus input file are shown in Table 13.

For these simulations only the condition CDCW was taken into account.

	U [W/m^{2}K]	SHCG	VT
Low-e glazing windows	1.8	0.75	0.8
Silver low-e glazing windows	1.8	0.4	0.7

Table 13 - Windows properties entered for simulations

8.4.3.2. Results

The simulations show different performance of the two type of windows selected.

In particular, low-e windows demonstrated to have mostly a very feeble or a negative effect on the indoor comfort, both in summer and in winter, with the exception of decrease of temperature, not exceeding 0.37°C, registered in the S-W side of the top floor apartment during both days of August, and a light increase of average temperature (0.30°C), in the same side of the building, during winter. On the other hand, silver low-e glazing windows, offered generally better performance, especially in summer.

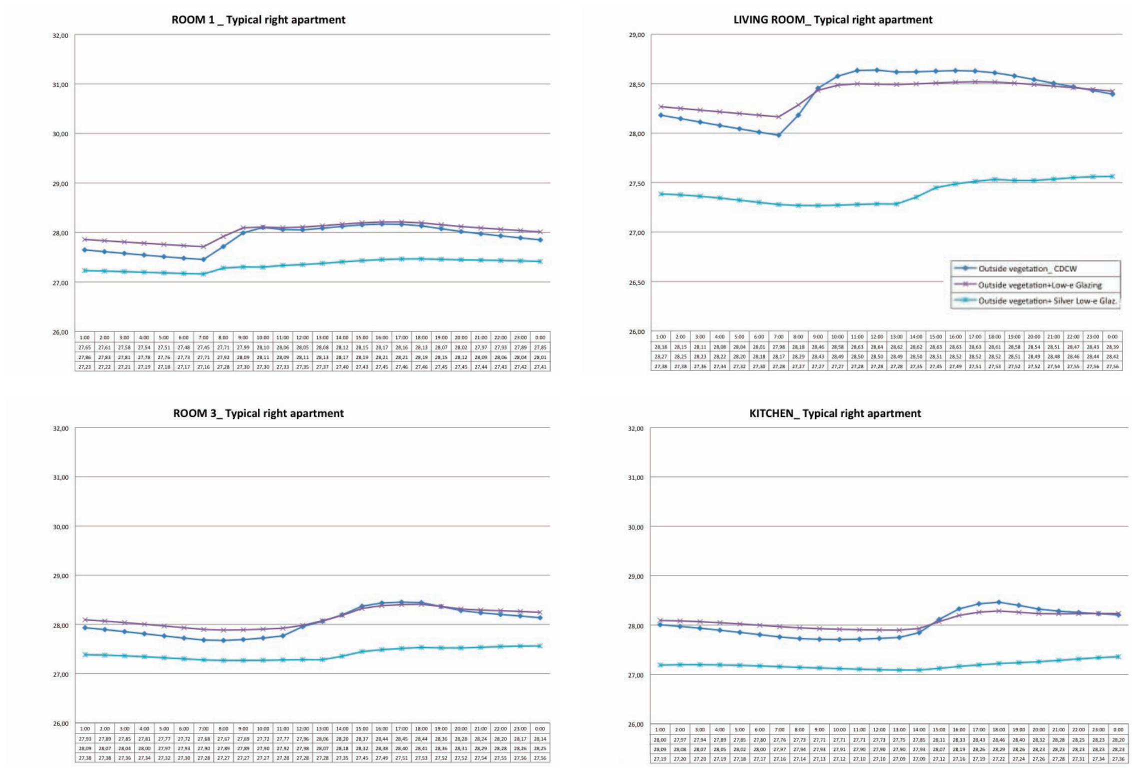
Summer

On August 5th and 15th the differences of temperature reach average values that go from 0.6 to 1°C in all the apartments except the top floor apartment where the average Δt is of 1.79°C with values up to 2.75°C.

Winter

In winter, unsubstantial changes could be observed in respect to the previous condition, unless for the lowering of the temperature of about 0.5°C in correspondence of the S-W oriented rooms and of about 1.30°C in the kitchen of the top floor apartment.

For the next simulation the configuration with the silver low-e glazing windows and glazed doors will be considered.



Graph. 21 - Examples of temperature trends on August 15th with the substitution of current windows

8.4.4. Living walls

The simulations conducted to evaluate the thermal performance of the apartments at the current state highlighted that the apartments positioned at the extremities of the building (left end, right end and top floor apartment) present the worse conditions, if compared with the other typical apartments, due to the higher exposition to the outdoor environment. For this reason, at this stage, new simulations were run to assess the possible benefits deriving from the application of a living walls on the two blind walls of the building situated in correspondence to the left end and right end apartments and on one of the oblique walls that constitute the loggias, specifically, the one with the narrowest window[8].

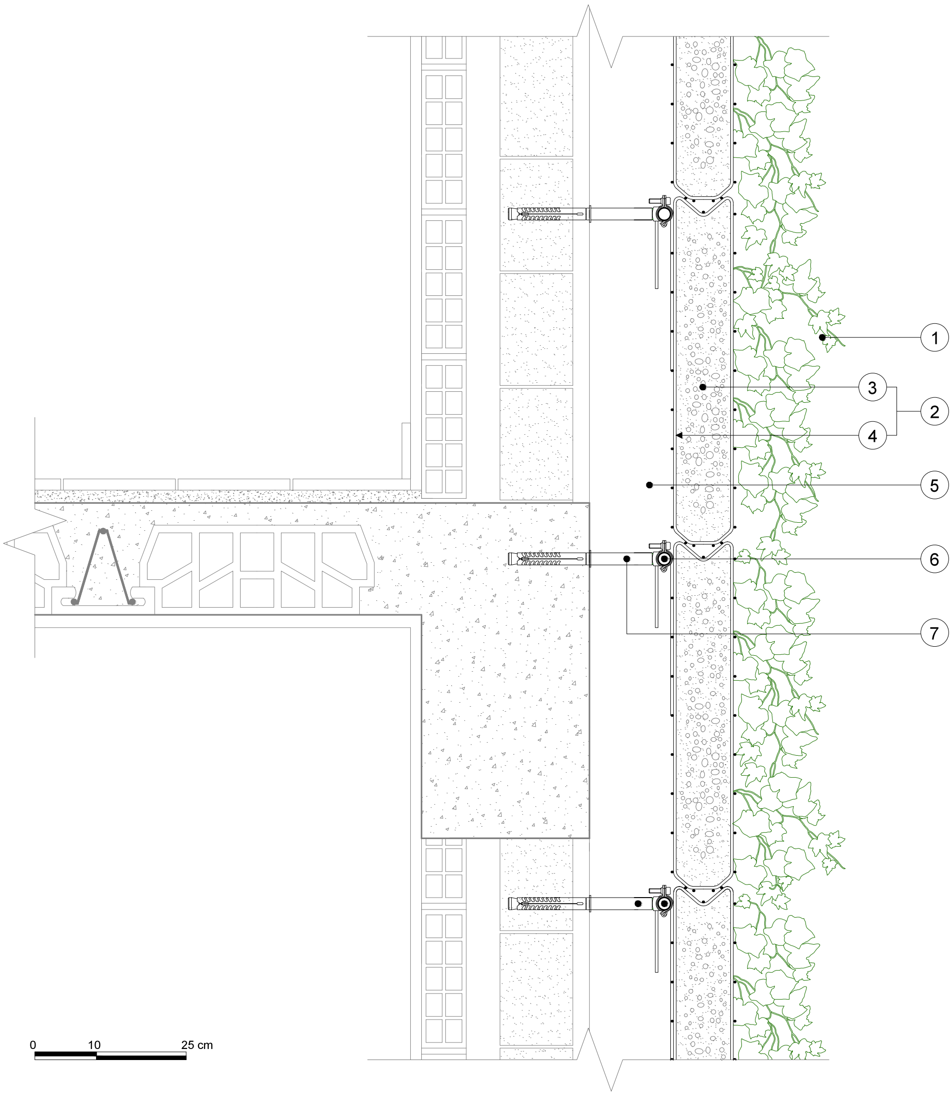
8.4.4.1. Living wall characteristics

The living wall typology considered for these simulations consists of modular panels that can be either pre-cultivated or with plants planted in place. The panels have a rectangular shape consisting of a number of individual cells. Each cell is independently designed to contain enough space to add growing medium and to sustain water supply to the roots, maintaining a healthy and growing plant. The living wall panels are picked up and hung directly on the appropriate support structure and fastened to the existing wall. The vegetal species hypothesised is the Hedera helix (common ivy) which is a species of flowering plant in the family Araliaceae, and very diffuse in all the Mediterranean Basin. This plant does not need onerous maintenance, thus not weighing excessively on the building management.

Living wall characteristics were entered in the software EnergyPlus by using the item “Material:RoofVegetation”, where it is possible to enter the main properties of the layers that compose the vegetal layer of horizontal and vertical surfaces (Table 14).

Field	Units	Obj1
Name		Living wall
Height of Plants	m	0,05
Leaf Area Index	dimensionless	3
Leaf Reflectivity	dimensionless	0,22
Leaf Emissivity		0,95
Minimum Stomatal Resistance	s/m	180
Soil Layer Name		Green Roof Soil
Roughness		MediumRough
Thickness	m	0,08
Conductivity of Dry Soil	W/m-K	0,35
Density of Dry Soil	kg/m3	900
Specific Heat of Dry Soil	J/kg-K	1100
Thermal Absorptance		0,95
Solar Absorptance		0,8
Visible Absorptance		0,7
Saturation Volumetric Moisture Content of the Soil Layer		0,4
Residual Volumetric Moisture Content of the Soil Layer		0,01
Initial Volumetric Moisture Content of the Soil Layer		0,2
Moisture Diffusion Calculation Method		Advanced

Table 14 - Parameters of the living wall considered for simulations



LEGEND

1. Finishing layer: Vegetal essence of the type hedera helix (150 mm)
   P.P.V. - Strato di finitura: Essenza vegetale tipo hedera helix (150 mm)
2. Support element: Pre-cultivated module
   P.P.V. - Elemento di supporto: Modulo precoltivato
3. Growing media: Peat-moss and perlite (85 mm)
   P.P.V. - Substrato di coltivazione: Torba e perlite (85 mm)
4. Support element: Galvanized steel cage (600x600x95 mm)
   P.P.V. - Elemento di supporto: Gabbia di acciaio zincato (600x600x95 mm)
5. Insulation/Ventilation layer: ventilated air cavity (60mm)
   P.P.V. - Strato di isolamento/ventilazione: Intercapedine ventilata (60 mm)
6. Support structure: Stainless steel tubes ((ø 25 mm)
   P.P.V. - Struttura di supporto: Tubi di acciaio inox (ø 25 mm)
7. Anchoring element: Stainless steel brace
   P.P.V. - Elemento di ancoraggio/collegamento: Collare in acciaio inox

Fig. 28 - Living wall layers added to the existing wall

8.4.4.2. Results

Living walls positioned on the building extremities as well as those on the loggias walls led to further reductions of temperatures in summer and a noteworthy increase in winter, especially in the rooms adjacent to them.

Summer

As predictable, compared to the previous scenario, Room1, Room3, the living room and the kitchen are the rooms that registered the greatest reduction of temperature, the first ones in the condition CDCW and the second ones in the condition CDOW.

The typical right and left apartments, in the condition CDCW, registered average Δt that never exceed 0.20°C. In the condition CDOW Δt oscillates from about 0.20 to 0.50°C except for the kitchens and the living rooms where the temperatures lower down of around 1°C. On August 5th a decrease up to 1.22°C was also registered in Room1 during the afternoon.

As for the right end and left end apartments, the N-E rooms situated close to the living walls, Rooms1 and living rooms, registered the highest reduction in the condition CDCW, calculated between 0.70-0.80°C along the day in the first case and of 0.5°C in the second case. The same situation occurred on the S-W side, with average reduction comprised between 0.68 and 0.80°C in Rooms3 and between 0.5 and 0.73°C in the kitchens.

The top floor apartment registered conditions similar to the right end and left end ones, with average Δt in Room1 and Room3 of about 0.5-0.6°C and of around 0.5°C and of 1°C respectively in the living room and in the kitchen. Here the temperature lower down up to 2°C in the afternoon.

Winter

For the typical right and left apartment increase of temperature of around 0.2°C occurs. In the left end apartment, the increase of temperature is of around 0.5°C while in the right end apartment the temperature decrease slightly (0.1°C).

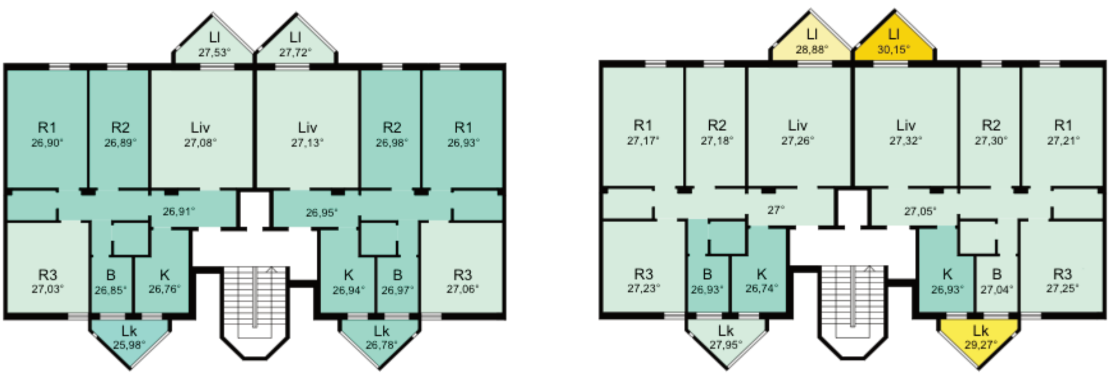
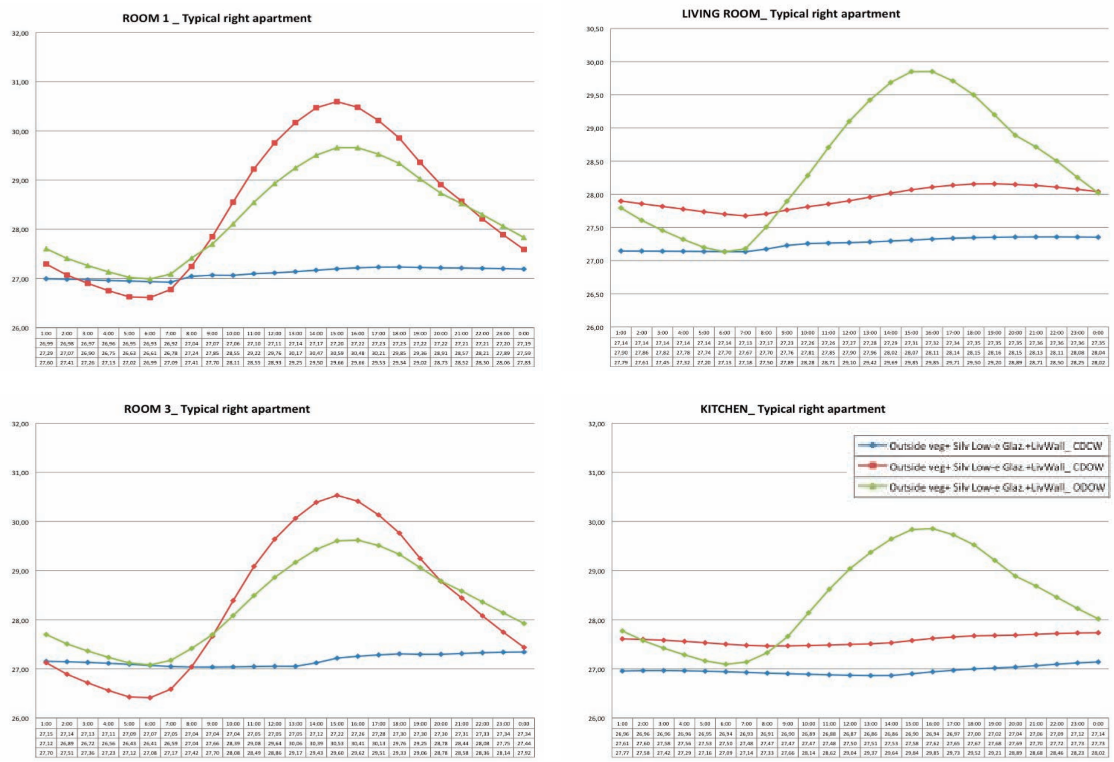
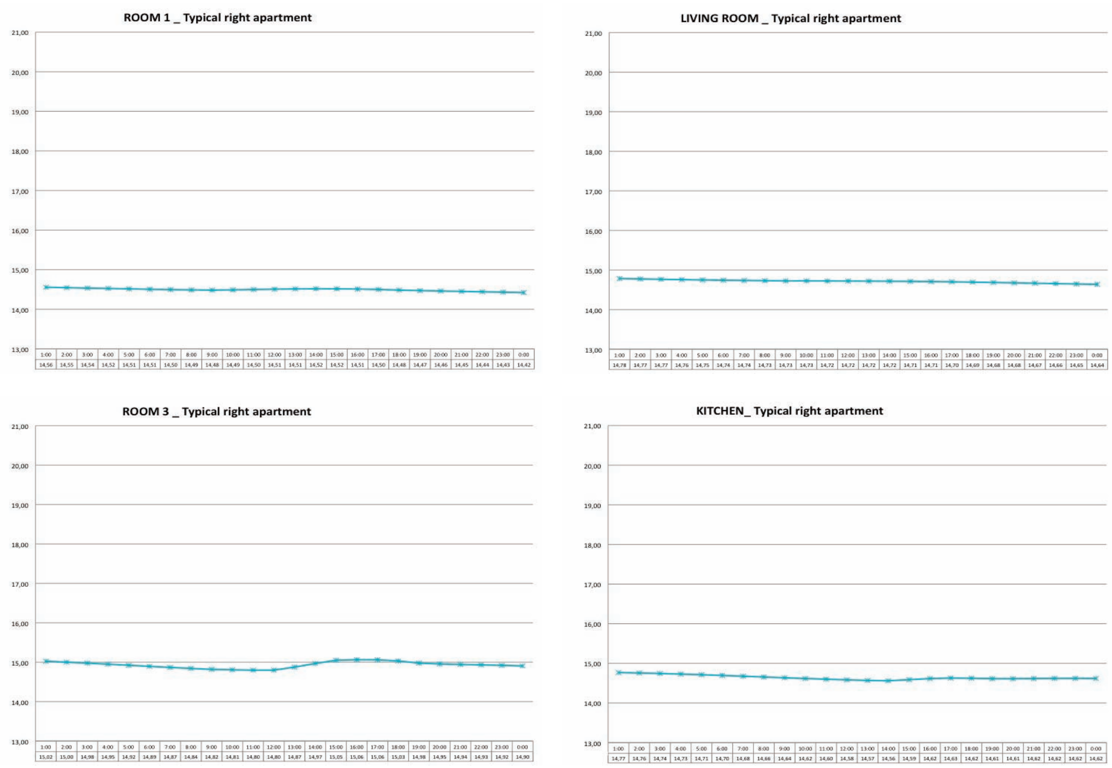


Fig. 29 - Thermal map of the typical right and left apartments on August 15th at 6AM (on the left) and at 4PM (on the right) for the scenario with silver low-e glazing windows and living walls



Graph. 22 - Examples of temperature trends on August 15th with the application of living walls



Graph. 20 - Examples of temperature trends on February 11th with the application of living walls

8.4.5. Green roof

The last retrofit strategy tested on the Medaglie d'Oro building is a green roof applied in correspondence of the top floor apartment. In fact, as shown in the previous paragraphs, this apartment is the one that presents the highest temperature, affecting, hence, the indoor comfort of the tenants. The application of a green roof was, therefore, supposed as a possible solution for its thermal improvement.

The design of the roof was done according to the Italian law UNI 11235: 2007[9], which gives indication about the design and the management of intensive and extensive green roofs.

8.4.5.1. Green roof characteristics

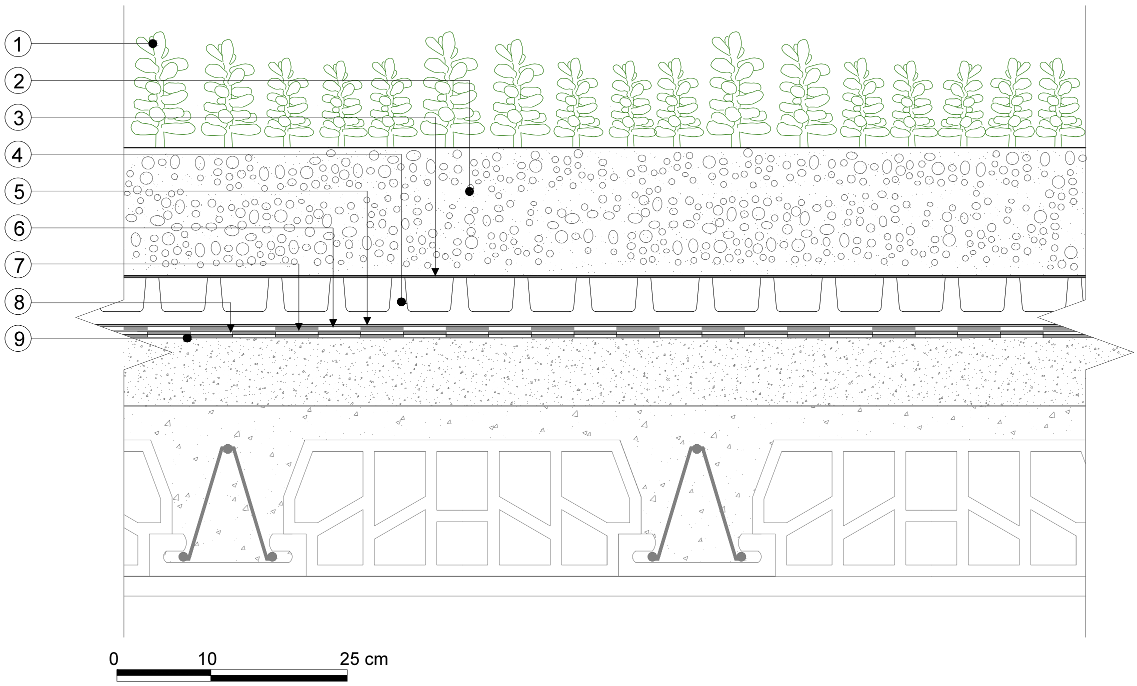
The green roof considered for the purpose of the research was of the type *extensive*, which would imply the improvement of the thermal mass and thermal insulation of the roof with an intervention of reasonable cost and low management. In fact, this system after the first year of realization required a reduced maintenance (one or two interventions per year) since it is structured so that the water and nutritive elements supply occurs mostly through natural processes.

A perennial vegetal species was considered with a 15 cm substrate, chosen according to the UNI 11235:2007 which establishes, for each plant, the minimum thickness of the substratum.

As in the case of living wall, the representation of the vegetal layers of the green roof occurred by using the item "Material:RoofVegetation", where data shown in Table 15 were entered.

Field	Units	Obj1
Name		Green Roof
Height of Plants	m	0.3
Leaf Area Index	dimensionless	1
Leaf Reflectivity	dimensionless	0.22
Leaf Emissivity		0.95
Minimum Stomatal Resistance	s/m	180
Soil Layer Name		Green Roof Soil
Roughness		MediumRough
Thickness	m	0.15
Conductivity of Dry Soil	W/m-K	0.35
Density of Dry Soil	kg/m3	900
Specific Heat of Dry Soil	J/kg-K	1100
Thermal Absorptance		0.95
Solar Absorptance		0.8
Visible Absorptance		0.7
Saturation Volumetric Moisture Content of the Soil Layer		0.4
Residual Volumetric Moisture Content of the Soil Layer		0.01
Initial Volumetric Moisture Content of the Soil Layer		0.2
Moisture Diffusion Calculation Method		Advanced

Table 15 - Parameters of the green roof considered for simulations



LEGEND

1. Vegetal layer: Sedum/Perennial plants (300 mm)
   COPERTURA - Strato vegetale: Sedum/erbacee perenni (300 mm)
2. Growing media: Vegetal soil (150 mm)
   COPERTURA - Substrato di coltivazione: Terreno vegetale (150 mm)
3. Filter layer: Filter fabric (2 mm)
   COPERTURA - Strato filtrante: Tessuto non tessuto (2 mm)
4. Drainage layer: Styrofoam panels (55 mm)
   COPERTURA - Strato drenante e di accumulo idrico: Elementi in polistirolo (55 mm)
5. Protection layer: Felt (2 mm)
   COPERTURA - Strato di protezione e accumulo: Feltro (2 mm)
6. Waterproofing layer: Anti-roots waterproofing membrane (4 mm)
   COPERTURA - Strato impermeabilizzante: Membrana sintetica antiradice (4 mm)
7. Separation layer: Geotextile fabric (2mm)
   COPERTURA - Strato di separazione: Tessuto geotessile (2 mm)
8. Vapour barrier: Elastomeric membrane (3 mm)
   COPERTURA - Barriera al vapore: membrana elastomerica (3 mm)
9. Waterproofing layer: Bituminous sheath (4 mm)
   COPERTURA - Strato impermeabilizzante: Guaina bituminosa (4 mm)

Fig. 30 - Green roof layers added to the existing roof

8.4.5.2. Results

The simulations that considered the application of a vegetal layer in the roof offered very different effects in relation to the different ventilation condition.

Summer

In summer negligible differences compared to the previous retrofit configuration were registered in the condition CDOW, while in the conditions CDCW and ODOW two opposite phenomena occur. In the first case, indeed, an average raise of temperature of around 1°C is registered while when a cross ventilation conditions is created inside the apartment, the temperatures lower down on average of 1.50°C on August 15 and of 2.50°C on August 5th with Δt up to 4.17°C.

Winter

In winter average increases of temperature comprised between 1.79 and 2°C are observed.

8.4.6. Summary of simulations results

Benefits derived from the different retrofit interventions during summer, in terms of temperature reduction in the five apartments typology and for the three ventilation conditions CDCW-CDOW-ODOW, are summarised in Table 16, 17, 18, 19 and 20.

For each room of each apartment typology the number of hours of thermal comfort and discomfort were calculated according to the Adaptive Comfort Model[10].

The Outdoor Running mean temperatures calculated for the two days in summer are:

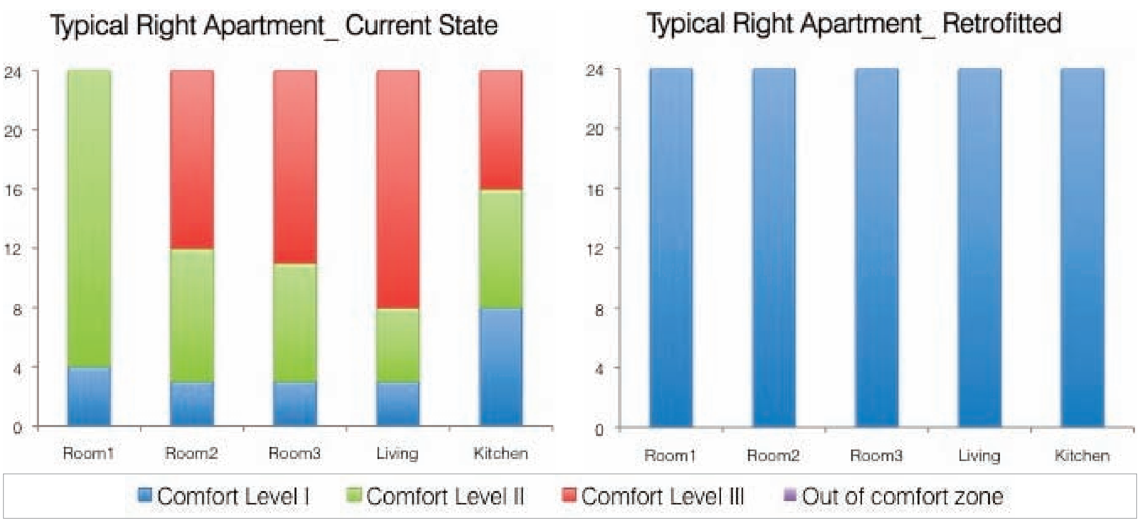
- for August 5th: T_{rm} = 29.01 °C
- for August 15th: T_{rm} = 27.30 °C

Graphs. 21, 22, 23, 24 and 25 show the amount of hours of comfort related to the comfort levels individuated by the Adaptive model (Comfort Level I, II or III), before and after retrofitting. This assessment was carried out for all the rooms of each apartment typology and the best thermal conditions among the simulations CDCW-CDOW-ODOW were considered.

To exemplify the results, graphs reported are those referring only to August 5th, although the reduction of temperature after retrofitting is also visible for August 15th in

As it can be observed, before the retrofit interventions, all the rooms of all the apartments register few or no hours inside the first bracket of comfort, especially in the case of the left end, right end and top floor apartment. After retrofitting, instead, all the rooms show, almost in all cases, the best comfort condition during the whole day.

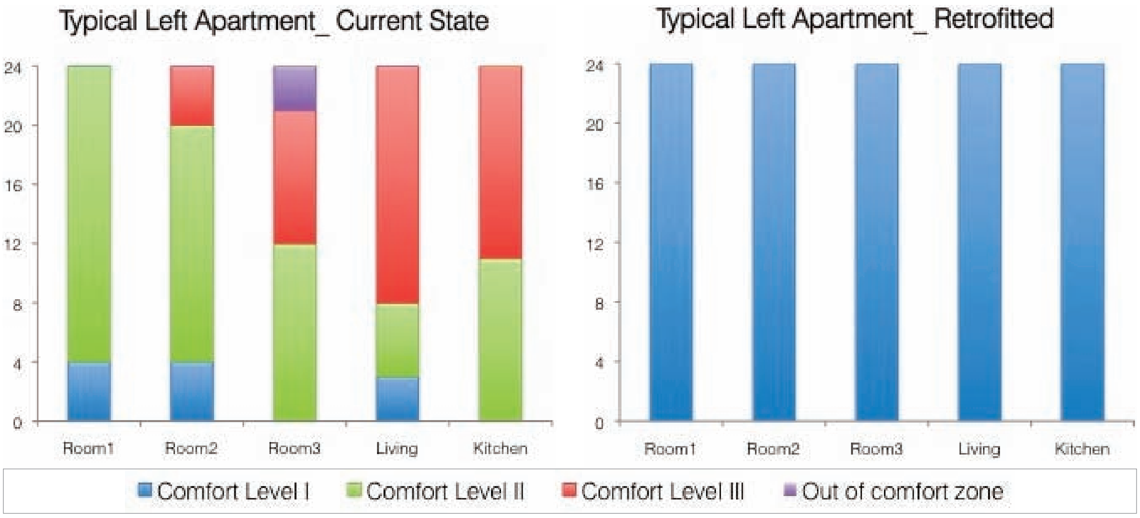
Regarding the winter period, the simulations show that the presence of trees in the external spaces lead to the reduction of temperature inside the apartment, mainly due to the presence of foliage interfering with passive solar gain. For this reason, it is supposable that the use of deciduous trees would significantly alter this condition, although further simulation in this sense should be carried out. On the other hand, the other retrofit measures demonstrate to be very effective for the energy improvement of the building and the increase of the indoor temperature.



Graph. 21 - Hours of comfort, according to the Adaptive Comfort Model, of typical right apartmens before and after retrofitting

Right End Apartment	Date		Δt										
			Outside vegetation_ CDCW	Outside vegetation_ CDOW	Outside vegetation_ ODOW	Outside vegetation+Low-e Glazing	Outside vegetation+ Silver Low-e Glaz.	Outside veg+ Silv Low-e Glaz.+LivWall _CDCW	Outside veg+ Silv Low-e Glaz.+LivWall _CDOW	Outside veg+ Silv Low-e Glaz.+LivWall _ODOW	ΣΔt CDCW	ΣΔt CDOW	ΣΔt ODOW
Room1 N-E	Aug 5th	6:00 m.	-0,17	-1,94	-0,73	0,23	-0,40	-0,67	-0,04	-0,03	-1,25	-1,98	-0,76
		11:00 m.	-0,24	0,50	-0,70	-0,09	-1,01	-0,44	-0,11	-0,21	-1,70	0,39	-0,91
		4:00 p.	-0,23	1,66	-0,65	-0,04	-0,93	-0,66	-0,13	-0,36	-1,82	1,54	-1,01
		9:00 p.	-0,20	-0,47	-0,82	0,05	-0,70	-0,92	-0,15	-0,19	-1,83	-0,63	-1,01
		1:00 m.	-0,18	-1,60	-0,77	0,17	-0,55	-0,89	-0,09	-0,12	-1,63	-1,70	-0,88
	Aug 15th	6:00 m.	-0,29	-1,97	-0,35	0,27	-0,32	-0,77	-0,04	-0,11	-1,38	-2,01	-0,46
		11:00 m.	-0,34	0,12	-0,47	0,00	-0,83	-0,53	-0,10	-0,22	-1,71	0,01	-0,69
		4:00 p.	-0,34	1,05	-0,57	0,03	-0,79	-0,74	-0,13	-0,29	-1,86	0,93	-0,86
		9:00 p.	-0,33	-0,75	-0,43	0,11	-0,58	-0,97	-0,16	-0,37	-1,88	-0,91	-0,79
		1:00 m.	-0,31	-1,72	-0,38	0,21	-0,44	-0,99	-0,10	-0,23	-1,74	-1,81	-0,61
Room2 N-E	Aug 5th	6:00 m.	-0,39	-1,82	-0,40	0,24	-0,43	-0,40	-0,02	-0,36	-1,22	-1,83	-0,77
		11:00 m.	-0,57	0,35	-0,99	-0,07	-1,02	-0,37	-0,13	0,01	-1,96	0,22	-0,98
		4:00 p.	-0,49	1,75	-0,93	-0,04	-0,97	-0,35	-0,09	-0,08	-1,81	1,65	-1,02
		9:00 p.	-0,45	-0,19	-0,55	0,05	-0,74	-0,38	-0,08	-0,39	-1,57	-0,26	-0,94
		1:00 m.	-0,41	-1,30	-0,38	0,17	-0,58	-0,40	-0,04	-0,46	-1,39	-1,34	-0,84
	Aug 15th	6:00 m.	-0,49	-1,86	-0,38	0,27	-0,34	-0,51	-0,03	-0,08	-1,33	-1,88	-0,47
		11:00 m.	-0,62	-0,04	-0,52	-0,52	-0,87	-0,47	-0,13	-0,24	-1,95	-0,16	-0,75
		4:00 p.	-0,58	1,11	-0,58	-0,29	-0,83	-0,44	-0,10	-0,26	-1,85	1,02	-0,84
		9:00 p.	-0,55	-0,48	-0,50	-0,04	-0,61	-0,46	-0,08	-0,22	-1,62	-0,55	-0,71
		1:00 m.	-0,51	-1,43	-0,42	0,17	-0,47	-0,51	-0,04	-0,14	-1,49	-1,48	-0,56
Room3 S-W	Aug 5th	6:00 m.	-1,08	-2,88	-1,49	0,18	-0,51	-0,65	-0,12	0,52	-2,24	-3,00	-0,97
		11:00 m.	-1,05	0,49	0,00	0,14	-0,55	-0,44	-0,16	-0,91	-2,04	0,34	-0,91
		4:00 p.	-1,40	1,00	-0,10	-0,04	-0,94	-0,63	-0,33	-1,09	-2,98	0,67	-1,19
		9:00 p.	-1,13	-1,16	-1,20	0,02	-0,79	-0,88	-0,25	-0,04	-2,79	-1,40	-1,24
		1:00 m.	-1,14	-2,53	-1,55	0,13	-0,64	-0,85	-0,17	0,40	-2,64	-2,70	-1,15
	Aug 15th	6:00 m.	-1,38	-3,33	-0,54	0,22	-0,43	-0,73	-0,06	-0,16	-2,54	-3,39	-0,70
		11:00 m.	-1,29	-0,50	-0,55	0,17	-0,49	-0,51	-0,05	-0,16	-2,29	-0,55	-0,71
		4:00 p.	-1,71	-0,30	-0,75	-0,03	-0,89	-0,69	-0,16	-0,33	-3,29	-0,46	-1,08
		9:00 p.	-1,47	-1,99	-0,65	0,06	-0,70	-0,90	-0,21	-0,40	-3,06	-2,20	-1,04
		1:00 m.	-1,45	-3,10	-0,59	0,16	-0,56	-0,92	-0,12	-0,29	-2,93	-3,22	-0,89
Living Room N-E	Aug 5th	6:00 m.	-0,60	-0,66	-0,64	0,19	-0,44	-0,27	-0,18	-0,11	-1,31	-0,84	-0,75
		11:00 m.	-0,65	-0,74	-0,75	0,10	-0,59	-0,27	-0,36	-0,15	-1,51	-1,10	-0,90
		4:00 p.	-0,63	-0,56	-0,89	0,00	-0,72	-0,27	-0,46	-0,10	-1,62	-1,03	-0,99
		9:00 p.	-0,62	-0,51	-0,67	0,04	-0,64	-0,28	-0,39	-0,33	-1,54	-0,89	-1,00
		1:00 m.	-0,61	-0,53	-0,66	0,13	-0,56	-0,26	-0,27	-0,15	-1,43	-0,80	-0,82
	Aug 15th	6:00 m.	-0,71	-0,74	-0,43	0,24	-0,36	-0,38	-0,25	-0,04	-1,45	-0,99	-0,47
		11:00 m.	-0,75	-0,82	-0,52	0,14	-0,50	-0,37	-0,40	-0,16	-1,62	-1,21	-0,68
		4:00 p.	-0,75	-0,68	-0,61	0,06	-0,61	-0,36	-0,48	-0,22	-1,72	-1,16	-0,83
		9:00 p.	-0,74	-0,62	-0,55	0,10	-0,54	-0,36	-0,40	-0,23	-1,63	-1,02	-0,78
		1:00 m.	-0,72	-0,64	-0,47	0,18	-0,46	-0,38	-0,33	-0,11	-1,55	-0,97	-0,58
Kitchen S-W	Aug 5th	6:00 m.	-2,00	0,26	-1,37	0,14	-0,73	-0,27	-0,52	0,32	-3,00	-0,26	-1,05
		11:00 m.	-1,79	0,46	-0,12	0,12	-0,74	-0,27	-0,57	-0,83	-2,81	-0,10	-0,95
		4:00 p.	-2,33	-0,04	-0,26	-0,20	-1,27	-0,27	-1,06	-1,06	-3,87	-1,10	-1,32
		9:00 p.	-2,46	-0,19	-1,10	-0,14	-1,13	-0,27	-0,87	-0,29	-3,86	-1,06	-1,38
		1:00 m.	-2,22	0,08	-1,44	0,02	-0,93	-0,26	-0,70	0,23	-3,41	-0,62	-1,21
	Aug 15th	6:00 m.	-2,27	-2,38	-0,68	0,21	-0,58	-0,38	-0,35	-0,10	-3,23	-2,73	-0,78
		11:00 m.	-2,10	-2,18	-0,60	0,21	-0,55	-0,37	-0,37	-0,15	-3,03	-2,56	-0,74
		4:00 p.	-2,70	-2,76	-0,93	-0,12	-1,11	-0,36	-0,89	-0,31	-4,17	-3,65	-1,24
		9:00 p.	-2,75	-2,82	-0,87	-0,04	-0,94	-0,36	-0,68	-0,33	-4,05	-3,51	-1,20
		1:00 m.	-2,48	-2,57	-0,79	0,11	-0,76	-0,38	-0,52	-0,19	-3,62	-3,08	-0,98

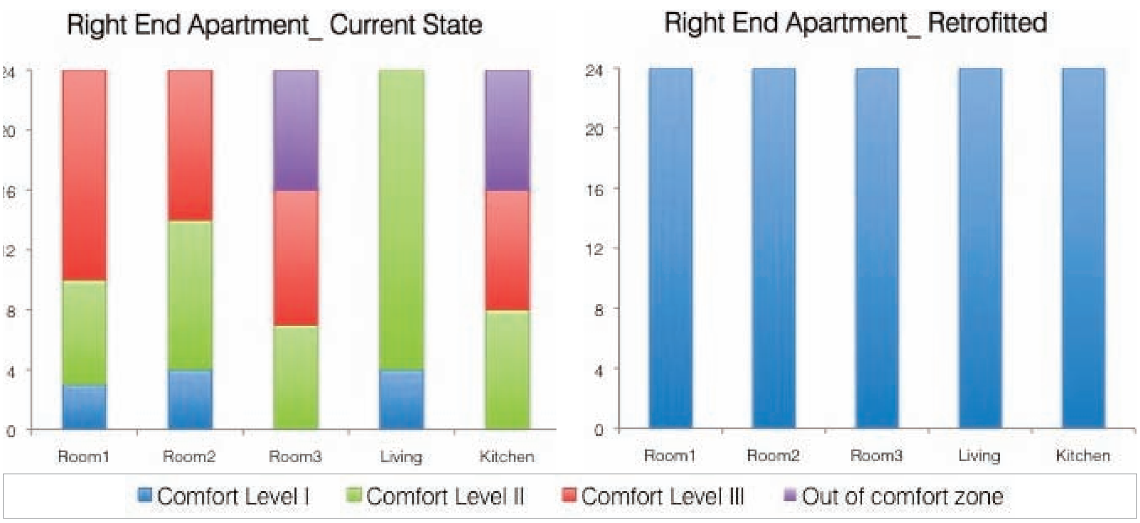
Table 16 - Temperature reduction in a typical right apartment considering the single retrofit scenarios and the whole intervention



Graph. 22 - Hours of comfort, according to the Adaptive Comfort Model, of typical left apartmens before and after retrofitting

Typical Left Apartment	Date		Δt										
			Outside vegetation_ CDCW	Outside vegetation_ CDOW	Outside vegetation_ ODOW	Outside vegetation+Low-e Glazing	Outside vegetation+ Silver Low-e Glaz.	Outside veg+ Silv Low-e Glaz.+LivWall _ CDCW	Outside veg+ Silv Low-e Glaz.+LivWall _ CDOW	Outside veg+ Silv Low-e Glaz.+LivWall _ ODOW	ΣΔt CDCW	ΣΔt CDOW	ΣΔt ODOW
Room1 N-E	Aug 5th	6:00 m.	-0,63	-1,61	-1,02	0,24	-0,33	-0,12	0,00	0,22	-1,07	-1,61	-0,79
		11:00 m.	-0,82	0,67	0,12	0,03	-0,77	-0,13	-0,08	-1,11	-1,72	0,59	-1,00
		4:00 p.	-0,80	1,95	0,08	0,01	-0,76	-0,14	-0,06	-1,09	-1,70	1,88	-1,01
		9:00 p.	-0,74	-0,01	-0,64	0,09	-0,56	-0,14	-0,05	-0,32	-1,44	-0,05	-0,96
		1:00 m.	-0,68	-1,09	-0,90	0,19	-0,44	-0,11	-0,01	0,07	-1,24	-1,10	-0,83
	Aug 15th	6:00 m.	-0,72	-1,65	-0,46	0,27	-0,32	-0,16	-0,01	-0,05	-1,19	-1,66	-0,51
		11:00 m.	-0,87	0,27	-0,57	0,10	-0,69	-0,16	-0,08	-0,20	-1,72	0,19	-0,77
		4:00 p.	-0,88	1,31	-0,64	0,07	-0,69	-0,16	-0,07	-0,21	-1,74	1,25	-0,85
		9:00 p.	-0,82	-0,30	-0,58	0,14	-0,52	-0,15	-0,04	-0,16	-1,50	-0,34	-0,74
		1:00 m.	-0,76	-1,22	-0,49	0,23	-0,41	-0,16	-0,02	-0,08	-1,34	-1,24	-0,57
Room2 N-E	Aug 5th	6:00 m.	-0,68	-1,73	-0,79	0,22	-0,47	-0,11	-0,01	-0,01	-1,26	-1,75	-0,79
		11:00 m.	-0,85	0,57	-0,74	0,02	-0,90	-0,12	-0,09	-0,27	-1,87	0,47	-1,01
		4:00 p.	-0,85	1,79	-0,79	-0,03	-0,94	-0,13	-0,08	-0,24	-1,91	1,71	-1,03
		9:00 p.	-0,79	-0,15	-0,88	0,05	-0,74	-0,13	-0,07	-0,06	-1,67	-0,21	-0,94
		1:00 m.	-0,73	-1,22	-0,83	0,16	-0,61	-0,10	-0,03	0,00	-1,44	-1,25	-0,83
	Aug 15th	6:00 m.	-0,74	-1,75	-0,45	0,27	-0,43	-0,16	-0,02	-0,05	-1,33	-1,77	-0,50
		11:00 m.	-0,85	0,21	-0,56	0,10	-0,80	-0,16	-0,09	-0,20	-1,81	0,12	-0,77
		4:00 p.	-0,89	1,20	-0,65	0,05	-0,85	-0,16	-0,08	-0,23	-1,89	1,12	-0,88
		9:00 p.	-0,84	-0,40	-0,57	0,12	-0,67	-0,15	-0,06	-0,14	-1,66	-0,46	-0,71
		1:00 m.	-0,78	-1,32	-0,49	0,22	-0,55	-0,16	-0,03	-0,08	-1,49	-1,36	-0,56
Room3 S-W	Aug 5th	6:00 m.	-1,28	-2,45	-0,70	0,18	-0,45	-0,12	-0,06	-0,23	-1,85	-2,50	-0,93
		11:00 m.	-1,10	0,79	-0,92	0,11	-0,55	-0,13	-0,12	-0,06	-1,79	0,68	-0,98
		4:00 p.	-1,60	1,22	-1,12	-0,08	-0,99	-0,14	-0,23	-0,11	-2,73	1,00	-1,23
		9:00 p.	-1,59	-0,87	-0,95	0,01	-0,76	-0,14	-0,13	-0,30	-2,50	-1,00	-1,24
		1:00 m.	-1,45	-2,03	-0,76	0,13	-0,58	-0,11	-0,08	-0,30	-2,14	-2,11	-1,06
	Aug 15th	6:00 m.	-1,57	-2,87	-0,64	0,22	-0,36	-0,23	-0,03	-0,08	-2,16	-2,90	-0,72
		11:00 m.	-1,45	-0,18	-0,62	0,17	-0,42	-0,23	-0,05	-0,16	-2,09	-0,23	-0,78
		4:00 p.	-1,98	0,02	-0,84	-0,01	-0,84	-0,23	-0,12	-0,28	-3,05	-0,10	-1,12
		9:00 p.	-1,91	-1,66	-0,85	0,07	-0,63	-0,22	-0,10	-0,20	-2,76	-1,76	-1,04
		1:00 m.	-1,75	-2,57	-0,73	0,18	-0,48	-0,23	-0,05	-0,11	-2,46	-2,62	-0,85
Living Room N-E	Aug 5th	6:00 m.	-0,82	-0,85	-0,84	0,13	-0,73	-0,09	-0,28	0,05	-1,64	-1,13	-0,79
		11:00 m.	-0,91	-1,03	-1,09	-0,17	-1,23	-0,10	-0,74	-0,02	-2,24	-1,77	-1,11
		4:00 p.	-0,92	-0,86	-1,02	-0,15	-1,17	-0,11	-0,69	-0,01	-2,19	-1,56	-1,03
		9:00 p.	-0,90	-0,78	-0,94	-0,07	-1,02	-0,11	-0,56	-0,11	-2,03	-1,33	-1,05
		1:00 m.	-0,86	-0,76	-0,92	0,04	-0,89	-0,08	-0,40	0,04	-1,84	-1,16	-0,89
	Aug 15th	6:00 m.	-0,87	-0,89	-0,45	0,20	-0,66	-0,15	-0,32	-0,03	-1,68	-1,20	-0,48
		11:00 m.	-0,90	-1,01	-0,57	-0,07	-1,09	-0,15	-0,69	-0,28	-2,14	-1,71	-0,85
		4:00 p.	-0,94	-0,91	-0,65	-0,06	-1,06	-0,14	-0,66	-0,23	-2,13	-1,57	-0,88
		9:00 p.	-0,93	-0,83	-0,59	0,01	-0,92	-0,13	-0,53	-0,21	-1,99	-1,36	-0,79
		1:00 m.	-0,90	-0,82	-0,49	0,12	-0,81	-0,15	-0,43	-0,11	-1,86	-1,25	-0,60
Kitchen S-W	Aug 5th	6:00 m.	-1,56	0,92	-0,56	0,17	-0,61	-0,14	-0,35	-0,41	-2,31	0,57	-0,97
		11:00 m.	-1,52	0,97	-1,05	0,15	-0,63	-0,14	-0,41	0,06	-2,29	0,56	-0,99
		4:00 p.	-1,63	0,84	-1,20	-0,09	-0,96	-0,15	-0,68	0,03	-2,74	0,15	-1,16
		9:00 p.	-1,63	0,87	-0,86	-0,01	-0,84	-0,15	-0,55	-0,35	-2,62	0,32	-1,21
		1:00 m.	-1,60	0,91	-0,64	0,09	-0,75	-0,13	-0,47	-0,40	-2,47	0,44	-1,05
	Aug 15th	6:00 m.	-1,84	-1,86	-0,64	0,21	-0,54	-0,24	-0,24	-0,06	-2,62	-2,10	-0,71
		11:00 m.	-1,79	-1,78	-0,61	0,20	-0,55	-0,23	-0,29	-0,15	-2,57	-2,08	-0,77
		4:00 p.	-1,96	-1,99	-0,80	-0,07	-0,93	-0,23	-0,61	-0,27	-3,12	-2,60	-1,07
		9:00 p.	-1,92	-1,92	-0,80	0,03	-0,77	-0,22	-0,45	-0,23	-2,92	-2,37	-1,04
		1:00 m.	-1,88	-1,88	-0,72	0,13	-0,68	-0,24	-0,36	-0,12	-2,79	-2,24	-0,84

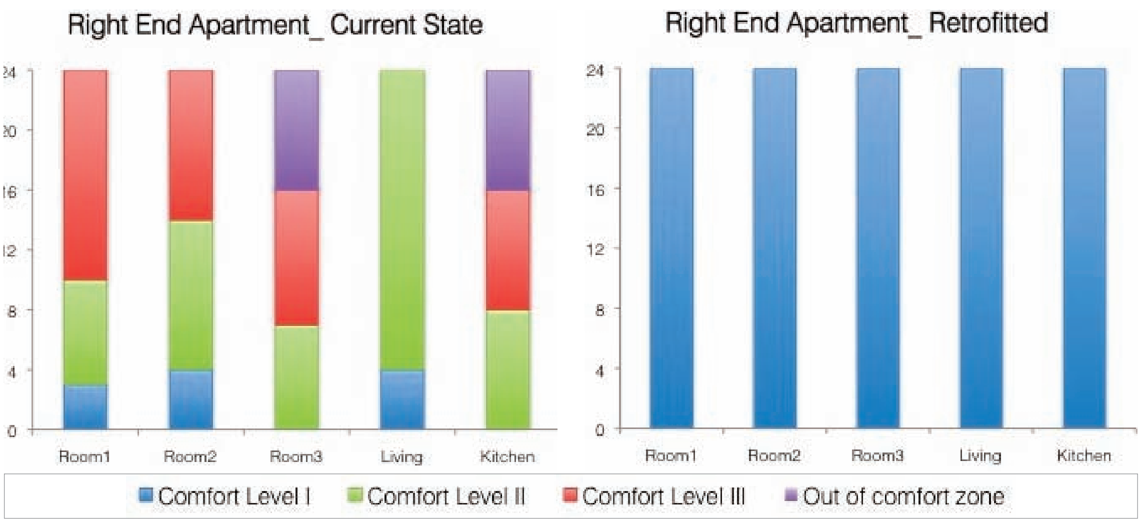
Table 17 - Temperature reduction in a typical left apartment considering the single retrofit scenarios and the whole intervention



Graph. 23 - Hours of comfort, according to the Adaptive Comfort Model, of typical right end apartmens before and after retrofitting

Right End Apartment	Date		Δt										
			Outside vegetation_ CDCW	Outside vegetation_ CDOW	Outside vegetation_ ODOW	Outside vegetation+Low-e Glazing	Outside vegetation+ Silver Low-e Glaz.	Outside veg+ Silv Low-e Glaz.+LivWall _CDCW	Outside veg+ Silv Low-e Glaz.+LivWall _CDOW	Outside veg+ Silv Low-e Glaz.+LivWall _ODOW	ΣΔt CDCW	ΣΔt CDOW	ΣΔt ODOW
Room1 N-E	Aug 5th	6:00 m.	-0,17	-1,94	-0,73	0,23	-0,40	-0,67	-0,04	-0,03	-1,25	-1,98	-0,76
		11:00 m.	-0,24	0,50	-0,70	-0,09	-1,01	-0,44	-0,11	-0,21	-1,70	0,39	-0,91
		4:00 p.	-0,23	1,66	-0,65	-0,04	-0,93	-0,66	-0,13	-0,36	-1,82	1,54	-1,01
		9:00 p.	-0,20	-0,47	-0,82	0,05	-0,70	-0,92	-0,15	-0,19	-1,83	-0,63	-1,01
		1:00 m.	-0,18	-1,60	-0,77	0,17	-0,55	-0,89	-0,09	-0,12	-1,63	-1,70	-0,88
	Aug 15th	6:00 m.	-0,29	-1,97	-0,35	0,27	-0,32	-0,77	-0,04	-0,11	-1,38	-2,01	-0,46
		11:00 m.	-0,34	0,12	-0,47	0,00	-0,83	-0,53	-0,10	-0,22	-1,71	0,01	-0,69
		4:00 p.	-0,34	1,05	-0,57	0,03	-0,79	-0,74	-0,13	-0,29	-1,86	0,93	-0,86
		9:00 p.	-0,33	-0,75	-0,43	0,11	-0,58	-0,97	-0,16	-0,37	-1,88	-0,91	-0,79
		1:00 m.	-0,31	-1,72	-0,38	0,21	-0,44	-0,99	-0,10	-0,23	-1,74	-1,81	-0,61
Room2 N-E	Aug 5th	6:00 m.	-0,39	-1,82	-0,40	0,24	-0,43	-0,40	-0,02	-0,36	-1,22	-1,83	-0,77
		11:00 m.	-0,57	0,35	-0,99	-0,07	-1,02	-0,37	-0,13	0,01	-1,96	0,22	-0,98
		4:00 p.	-0,49	1,75	-0,93	-0,04	-0,97	-0,35	-0,09	-0,08	-1,81	1,65	-1,02
		9:00 p.	-0,45	-0,19	-0,55	0,05	-0,74	-0,38	-0,08	-0,39	-1,57	-0,26	-0,94
		1:00 m.	-0,41	-1,30	-0,38	0,17	-0,58	-0,40	-0,04	-0,46	-1,39	-1,34	-0,84
	Aug 15th	6:00 m.	-0,49	-1,86	-0,38	0,27	-0,34	-0,51	-0,03	-0,08	-1,33	-1,88	-0,47
		11:00 m.	-0,62	-0,04	-0,52	-0,52	-0,87	-0,47	-0,13	-0,24	-1,95	-0,16	-0,75
		4:00 p.	-0,58	1,11	-0,58	-0,29	-0,83	-0,44	-0,10	-0,26	-1,85	1,02	-0,84
		9:00 p.	-0,55	-0,48	-0,50	-0,04	-0,61	-0,46	-0,08	-0,22	-1,62	-0,55	-0,71
		1:00 m.	-0,51	-1,43	-0,42	0,17	-0,47	-0,51	-0,04	-0,14	-1,49	-1,48	-0,56
Room3 S-W	Aug 5th	6:00 m.	-1,08	-2,88	-1,49	0,18	-0,51	-0,65	-0,12	0,52	-2,24	-3,00	-0,97
		11:00 m.	-1,05	0,49	0,00	0,14	-0,55	-0,44	-0,16	-0,91	-2,04	0,34	-0,91
		4:00 p.	-1,40	1,00	-0,10	-0,04	-0,94	-0,63	-0,33	-1,09	-2,98	0,67	-1,19
		9:00 p.	-1,13	-1,16	-1,20	0,02	-0,79	-0,88	-0,25	-0,04	-2,79	-1,40	-1,24
		1:00 m.	-1,14	-2,53	-1,55	0,13	-0,64	-0,85	-0,17	0,40	-2,64	-2,70	-1,15
	Aug 15th	6:00 m.	-1,38	-3,33	-0,54	0,22	-0,43	-0,73	-0,06	-0,16	-2,54	-3,39	-0,70
		11:00 m.	-1,29	-0,50	-0,55	0,17	-0,49	-0,51	-0,05	-0,16	-2,29	-0,55	-0,71
		4:00 p.	-1,71	-0,30	-0,75	-0,03	-0,89	-0,69	-0,16	-0,33	-3,29	-0,46	-1,08
		9:00 p.	-1,47	-1,99	-0,65	0,06	-0,70	-0,90	-0,21	-0,40	-3,06	-2,20	-1,04
		1:00 m.	-1,45	-3,10	-0,59	0,16	-0,56	-0,92	-0,12	-0,29	-2,93	-3,22	-0,89
Living Room N-E	Aug 5th	6:00 m.	-0,60	-0,66	-0,64	0,19	-0,44	-0,27	-0,18	-0,11	-1,31	-0,84	-0,75
		11:00 m.	-0,65	-0,74	-0,75	0,10	-0,59	-0,27	-0,36	-0,15	-1,51	-1,10	-0,90
		4:00 p.	-0,63	-0,56	-0,89	0,00	-0,72	-0,27	-0,46	-0,10	-1,62	-1,03	-0,99
		9:00 p.	-0,62	-0,51	-0,67	0,04	-0,64	-0,28	-0,39	-0,33	-1,54	-0,89	-1,00
		1:00 m.	-0,61	-0,53	-0,66	0,13	-0,56	-0,26	-0,27	-0,15	-1,43	-0,80	-0,82
	Aug 15th	6:00 m.	-0,71	-0,74	-0,43	0,24	-0,36	-0,38	-0,25	-0,04	-1,45	-0,99	-0,47
		11:00 m.	-0,75	-0,82	-0,52	0,14	-0,50	-0,37	-0,40	-0,16	-1,62	-1,21	-0,68
		4:00 p.	-0,75	-0,68	-0,61	0,06	-0,61	-0,36	-0,48	-0,22	-1,72	-1,16	-0,83
		9:00 p.	-0,74	-0,62	-0,55	0,10	-0,54	-0,36	-0,40	-0,23	-1,63	-1,02	-0,78
		1:00 m.	-0,72	-0,64	-0,47	0,18	-0,46	-0,38	-0,33	-0,11	-1,55	-0,97	-0,58
Kitchen S-W	Aug 5th	6:00 m.	-2,00	0,26	-1,37	0,14	-0,73	-0,27	-0,52	0,32	-3,00	-0,26	-1,05
		11:00 m.	-1,79	0,46	-0,12	0,12	-0,74	-0,27	-0,57	-0,83	-2,81	-0,10	-0,95
		4:00 p.	-2,33	-0,04	-0,26	-0,20	-1,27	-0,27	-1,06	-1,06	-3,87	-1,10	-1,32
		9:00 p.	-2,46	-0,19	-1,10	-0,14	-1,13	-0,27	-0,87	-0,29	-3,86	-1,06	-1,38
		1:00 m.	-2,22	0,08	-1,44	0,02	-0,93	-0,26	-0,70	0,23	-3,41	-0,62	-1,21
	Aug 15th	6:00 m.	-2,27	-2,38	-0,68	0,21	-0,58	-0,38	-0,35	-0,10	-3,23	-2,73	-0,78
		11:00 m.	-2,10	-2,18	-0,60	0,21	-0,55	-0,37	-0,37	-0,15	-3,03	-2,56	-0,74
		4:00 p.	-2,70	-2,76	-0,93	-0,12	-1,11	-0,36	-0,89	-0,31	-4,17	-3,65	-1,24
		9:00 p.	-2,75	-2,82	-0,87	-0,04	-0,94	-0,36	-0,68	-0,33	-4,05	-3,51	-1,20
		1:00 m.	-2,48	-2,57	-0,79	0,11	-0,76	-0,38	-0,52	-0,19	-3,62	-3,08	-0,98

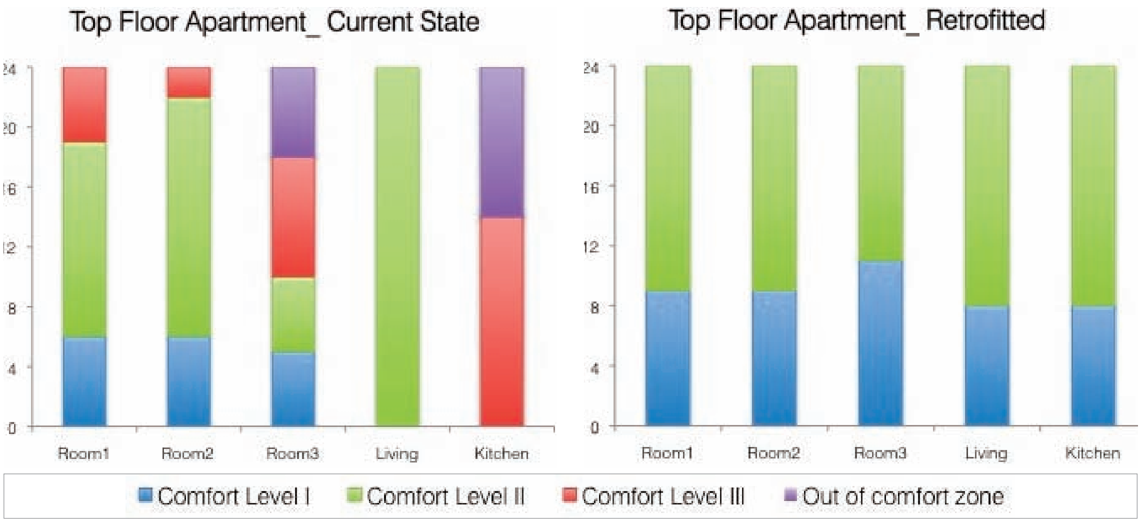
Table 18 - Temperature reduction in a typical right end apartment considering the single retrofit scenarios and the whole intervention



Graph. 24 - Hours of comfort, according to the Adaptive Comfort Model, of typical left end apartmens before and after retrofitting

Left End Apartment	Date		Δt										
			Outside vegetation_ CDCW	Outside vegetation_ CDOW	Outside vegetation_ ODOW	Outside vegetation+Low-e Glazing	Outside vegetation+ Silver Low-e Glaz.	Outside veg+ Silv Low-e Glaz.+LivWall _CDCW	Outside veg+ Silv Low-e Glaz.+LivWall _CDOW	Outside veg+ Silv Low-e Glaz.+LivWall _ODOW	ΣΔt CDCW	ΣΔt CDOW	ΣΔt ODOW
Room1 N-E	Aug 5th	6:00 m.	-0,38	-1,99	-0,67	0,26	-0,35	-0,76	-0,06	-0,16	-1,48	-2,05	-0,83
		11:00 m.	-0,56	0,47	-0,70	0,06	-0,78	-0,53	-0,09	-0,22	-1,87	0,38	-0,93
		4:00 p.	-0,57	1,82	-0,72	0,03	-0,78	-0,41	-0,06	-0,22	-1,76	1,76	-0,94
		9:00 p.	-0,51	-0,21	-0,69	0,11	-0,60	-0,57	-0,09	-0,25	-1,68	-0,30	-0,94
		1:00 m.	-0,44	-1,53	-0,68	0,21	-0,47	-0,83	-0,10	-0,23	-1,75	-1,63	-0,91
	Aug 15th	6:00 m.	-0,46	-1,85	-0,38	0,29	-0,26	-0,73	-0,05	-0,12	-1,46	-1,90	-0,50
		11:00 m.	-0,62	0,23	-0,50	0,12	-0,63	-0,52	-0,08	-0,19	-1,76	0,14	-0,68
		4:00 p.	-0,63	1,35	-0,56	0,09	-0,65	-0,41	-0,06	-0,20	-1,69	1,29	-0,76
		9:00 p.	-0,58	-0,36	-0,49	0,16	-0,49	-0,56	-0,08	-0,21	-1,62	-0,44	-0,70
		1:00 m.	-0,52	-1,48	-0,42	0,25	-0,38	-0,81	-0,09	-0,19	-1,71	-1,57	-0,61
Room2 N-E	Aug 5th	6:00 m.	-0,46	-1,74	-0,69	0,29	-0,38	-0,35	-0,02	-0,08	-1,20	-1,76	-0,77
		11:00 m.	-0,67	0,48	-0,73	0,08	-0,85	-0,35	-0,10	-0,23	-1,87	0,38	-0,95
		4:00 p.	-0,65	1,72	-0,74	0,02	-0,91	-0,32	-0,09	-0,24	-1,89	1,63	-0,99
		9:00 p.	-0,59	-0,17	-0,71	0,10	-0,71	-0,31	-0,07	-0,20	-1,60	-0,25	-0,91
		1:00 m.	-0,52	-1,25	-0,70	0,21	-0,55	-0,31	-0,03	-0,12	-1,38	-1,28	-0,82
	Aug 15th	6:00 m.	-0,53	-1,69	-0,39	0,32	-0,29	-0,41	-0,02	-0,06	-1,24	-1,71	-0,46
		11:00 m.	-0,68	0,20	-0,51	0,14	-0,70	-0,40	-0,10	-0,20	-1,78	0,10	-0,71
		4:00 p.	-0,70	1,20	-0,60	0,09	-0,77	-0,37	-0,09	-0,23	-1,84	1,11	-0,83
		9:00 p.	-0,64	-0,36	-0,51	0,16	-0,58	-0,35	-0,07	-0,16	-1,57	-0,43	-0,67
		1:00 m.	-0,58	-1,27	-0,44	0,26	-0,44	-0,39	-0,04	-0,10	-1,40	-1,31	-0,54
Room3 S-W	Aug 5th	6:00 m.	-0,84	-2,97	-0,72	0,18	-0,55	-0,71	-0,13	-0,19	-2,10	-3,11	-0,91
		11:00 m.	-0,71	0,47	-0,69	0,12	-0,63	-0,50	-0,18	-0,19	-1,85	0,28	-0,89
		4:00 p.	-1,28	0,96	-0,87	-0,07	-1,07	-0,38	-0,28	-0,29	-2,73	0,68	-1,15
		9:00 p.	-1,12	-1,21	-0,80	-0,02	-0,95	-0,53	-0,21	-0,34	-2,60	-1,42	-1,14
		1:00 m.	-0,96	-2,58	-0,76	0,10	-0,73	-0,75	-0,18	-0,29	-2,43	-2,76	-1,05
	Aug 15th	6:00 m.	-1,16	-3,21	-0,48	0,22	-0,45	-0,67	-0,07	-0,15	-2,28	-3,28	-0,63
		11:00 m.	-1,02	-0,36	-0,50	0,16	-0,53	-0,48	-0,06	-0,16	-2,03	-0,42	-0,66
		4:00 p.	-1,61	-0,11	-0,75	-0,02	-0,96	-0,37	-0,13	-0,27	-2,94	-0,24	-1,02
		9:00 p.	-1,46	-1,82	-0,65	0,05	-0,78	-0,51	-0,14	-0,27	-2,75	-1,97	-0,93
		1:00 m.	-1,29	-2,92	-0,55	0,15	-0,61	-0,72	-0,11	-0,24	-2,62	-3,04	-0,79
Living Room N-E	Aug 5th	6:00 m.	-0,42	-0,48	-0,70	0,36	-0,27	-0,22	-0,05	-0,04	-0,90	-0,53	-0,75
		11:00 m.	-0,62	-0,72	-0,71	0,01	-0,96	-0,23	-0,74	-0,20	-1,81	-1,46	-0,91
		4:00 p.	-0,52	-0,50	-0,71	-0,02	-1,02	-0,23	-0,78	-0,22	-1,77	-1,28	-0,93
		9:00 p.	-0,47	-0,38	-0,68	0,14	-0,67	-0,22	-0,43	-0,17	-1,36	-0,81	-0,86
		1:00 m.	-0,44	-0,39	-0,70	0,28	-0,45	-0,20	-0,19	-0,08	-1,10	-0,58	-0,78
	Aug 15th	6:00 m.	-0,50	-0,51	-0,39	0,39	-0,19	-0,30	-0,13	-0,03	-0,98	-0,64	-0,42
		11:00 m.	-0,61	-0,65	-0,49	0,07	-0,81	-0,30	-0,72	-0,18	-1,73	-1,38	-0,67
		4:00 p.	-0,58	-0,53	-0,58	0,06	-0,87	-0,29	-0,75	-0,20	-1,74	-1,27	-0,78
		9:00 p.	-0,54	-0,43	-0,47	0,20	-0,54	-0,28	-0,41	-0,14	-1,36	-0,84	-0,61
		1:00 m.	-0,51	-0,44	-0,42	0,32	-0,35	-0,30	-0,24	-0,06	-1,15	-0,68	-0,48
Kitchen S-W	Aug 5th	6:00 m.	-1,29	1,09	-0,83	0,20	-0,57	-0,27	-0,40	-0,09	-2,13	0,69	-0,92
		11:00 m.	-1,26	1,14	-0,76	0,18	-0,58	-0,28	-0,46	-0,15	-2,12	0,68	-0,91
		4:00 p.	-1,38	1,00	-0,86	-0,07	-0,93	-0,28	-0,74	-0,26	-2,58	0,26	-1,12
		9:00 p.	-1,37	1,04	-0,89	0,01	-0,80	-0,27	-0,61	-0,27	-2,44	0,44	-1,16
		1:00 m.	-1,34	1,08	-0,87	0,11	-0,71	-0,26	-0,53	-0,17	-2,31	0,55	-1,03
	Aug 15th	6:00 m.	-1,58	-1,71	-0,60	0,23	-0,51	-0,34	-0,26	-0,07	-2,43	-1,97	-0,68
		11:00 m.	-1,53	-1,63	-0,56	0,21	-0,52	-0,34	-0,31	-0,13	-2,38	-1,94	-0,69
		4:00 p.	-1,71	-1,86	-0,76	-0,07	-0,92	-0,32	-0,64	-0,27	-2,95	-2,49	-1,03
		9:00 p.	-1,67	-1,78	-0,73	0,04	-0,75	-0,31	-0,46	-0,24	-2,73	-2,24	-0,97
		1:00 m.	-1,63	-1,74	-0,66	0,14	-0,65	-0,33	-0,37	-0,15	-2,61	-2,11	-0,81

Table 19 - Temperature reduction in a typical left end apartment considering the single retrofit scenarios and the whole intervention



Graph. 25 - Hours of comfort, according to the Adaptive Comfort Model, of typical top floor apartmens before and after retrofitting

Top Floor Apartment	Date		Δt													
			Outside vegetation_ CDCW	Outside vegetation_ CDOW	Outside vegetation_ ODOW	Outside vegetation +Low-e Glazing	Outside vegetation+ Silver Low-e Glaz.	Outside veg+ Silv Low-e Glaz.+Liv Wall_ CDCW	Outside veg+ Silv Low-e Glaz.+Liv Wall_ CDOW	Outside veg+ Silv Low-e Glaz.+Liv Wall_ ODOW	OutsVeg + SilvLow-e Glaz.+Liv Wall+GrRoof_ CDCW	OutsVeg + SilvLow-e Glaz.+Liv Wall+Gr Roof_ CDOW	OutsVeg + SilvLow-e Glaz.+Liv Wall+GrRoof_ ODOW	ΣΔt CDCW	ΣΔt CDOW	ΣΔt ODOW
Room1 N-E	Aug 5th	6:00 m.	-0,09	-0,80	0,06	0,01	-0,54	-0,60	0,06	-0,02	0,87	0,03	-1,84	-0,36	-0,71	-1,80
		11:00 m.	-0,07	-0,59	0,55	-0,34	-1,19	-0,37	-0,12	-0,07	1,10	0,05	-2,94	-0,53	-0,65	-2,46
		4:00 p.	-0,07	-0,54	0,59	-0,27	-1,10	-0,53	-0,26	0,04	1,32	0,17	-3,08	-0,37	-0,63	-2,45
		9:00 p.	-0,10	-0,71	0,27	-0,16	-0,88	-0,81	-0,17	0,04	1,14	0,14	-2,39	-0,65	-0,74	-2,08
		1:00 m.	-0,10	-0,79	0,14	-0,08	-0,71	-0,82	-0,04	0,01	0,91	0,06	-2,09	-0,71	-0,77	-1,95
	Aug 15th	6:00 m.	0,97	-0,37	0,60	0,14	-0,36	-0,54	0,06	0,00	0,93	0,04	-1,03	1,01	-0,28	-0,43
		11:00 m.	1,02	-0,26	1,33	-0,16	-0,92	-0,31	-0,11	-0,03	1,15	0,09	-1,83	0,94	-0,28	-0,52
		4:00 p.	1,03	-0,29	1,35	-0,13	-0,88	-0,48	-0,23	0,05	1,38	0,18	-1,97	1,05	-0,34	-0,56
		9:00 p.	0,97	-0,36	0,82	-0,03	-0,67	-0,77	-0,15	0,03	1,22	0,14	-1,45	0,75	-0,37	-0,60
		1:00 m.	0,96	-0,40	0,69	0,07	-0,50	-0,76	-0,03	-0,01	0,95	0,07	-1,25	0,65	-0,36	-0,57
Room2 N-E	Aug 5th	6:00 m.	-0,24	-0,81	0,06	0,01	-0,56	-0,37	0,06	-0,03	0,88	0,04	-1,82	-0,28	-0,71	-1,79
		11:00 m.	-0,20	-0,60	0,51	-0,38	-1,30	-0,32	-0,16	-0,02	1,12	0,06	-2,96	-0,71	-0,71	-2,47
		4:00 p.	-0,20	-0,55	0,63	-0,30	-1,17	-0,29	-0,24	0,03	1,36	0,17	-2,96	-0,30	-0,62	-2,30
		9:00 p.	-0,23	-0,69	0,27	-0,17	-0,92	-0,32	-0,12	0,01	1,21	0,17	-2,25	-0,26	-0,64	-1,96
		1:00 m.	-0,23	-0,79	0,13	-0,09	-0,74	-0,37	-0,01	-0,01	0,95	0,08	-2,00	-0,39	-0,72	-1,89
	Aug 15th	6:00 m.	0,83	-0,38	0,59	0,16	-0,37	-0,33	0,07	-0,01	0,94	0,05	-0,99	1,08	-0,26	-0,41
		11:00 m.	0,89	-0,28	1,31	-0,19	-1,01	-0,29	-0,15	-0,04	1,17	0,10	-1,84	0,76	-0,33	-0,57
		4:00 p.	0,90	-0,30	1,22	-0,13	-0,93	-0,26	-0,21	0,06	1,40	0,19	-1,82	1,11	-0,31	-0,53
		9:00 p.	0,85	-0,34	0,80	-0,02	-0,70	-0,29	-0,08	0,01	1,28	0,16	-1,29	1,14	-0,26	-0,54
		1:00 m.	0,83	-0,39	0,68	0,08	-0,51	-0,34	0,01	-0,03	0,99	0,08	-1,13	0,97	-0,30	-0,49
Room3 S-W	Aug 5th	6:00 m.	-0,43	-1,23	0,23	-0,06	-0,82	-0,53	0,05	-0,04	0,86	0,03	-2,37	-0,93	-1,15	-2,17
		11:00 m.	-0,41	-0,81	0,59	-0,09	-0,86	-0,32	-0,06	-0,04	1,06	0,06	-3,10	-0,53	-0,81	-2,55
		4:00 p.	-0,43	-0,71	0,89	-0,40	-1,55	-0,46	-0,34	0,04	1,28	0,18	-3,77	-1,16	-0,87	-2,84
		9:00 p.	-0,45	-1,00	0,29	-0,23	-1,19	-0,72	-0,22	0,04	1,10	0,15	-2,93	-1,26	-1,08	-2,59
		1:00 m.	-0,44	-1,18	0,30	-0,15	-1,01	-0,74	-0,06	0,01	0,89	0,07	-2,62	-1,29	-1,17	-2,32
	Aug 15th	6:00 m.	0,74	-0,41	0,62	0,05	-0,70	-0,49	0,05	0,01	0,90	0,02	-0,95	0,45	-0,34	-0,32
		11:00 m.	0,74	-0,27	1,08	0,03	-0,70	-0,28	-0,05	-0,02	1,10	0,47	-0,78	0,86	0,14	0,27
		4:00 p.	0,74	-0,29	1,61	-0,30	-1,46	-0,42	-0,33	0,07	1,33	0,61	-1,65	0,18	-0,01	0,03
		9:00 p.	0,74	-0,40	0,87	-0,14	-1,09	-0,69	-0,20	0,13	1,17	0,33	-1,27	0,13	-0,28	-0,26
		1:00 m.	0,71	-0,43	0,76	-0,03	-0,87	-0,69	-0,05	0,14	0,91	0,11	-1,26	0,06	-0,38	-0,36
Living Room N-E	Aug 5th	6:00 m.	-0,56	-0,69	0,15	-0,04	-0,55	-0,26	-0,28	-0,01	0,89	0,41	-2,09	-0,48	-0,56	-1,96
		11:00 m.	-0,51	-0,62	0,56	-0,16	-0,73	-0,24	-0,48	0,11	1,16	0,71	-3,05	-0,32	-0,39	-2,38
		4:00 p.	-0,50	-0,61	0,89	-0,23	-0,84	-0,22	-0,58	0,00	1,39	0,99	-3,17	-0,17	-0,19	-2,28
		9:00 p.	-0,55	-0,65	0,49	-0,18	-0,78	-0,23	-0,49	-0,08	1,19	0,72	-2,56	-0,37	-0,42	-2,15
		1:00 m.	-0,55	-0,68	0,31	-0,13	-0,68	-0,26	-0,40	-0,09	0,92	0,41	-2,29	-0,57	-0,66	-2,06
	Aug 15th	6:00 m.	0,50	0,09	0,65	0,12	-0,35	-0,23	-0,22	-0,01	0,92	0,49	-1,08	0,83	0,36	-0,43
		11:00 m.	0,58	0,19	1,25	-0,01	-0,53	-0,21	-0,40	0,05	1,17	0,73	-1,81	1,00	0,52	-0,51
		4:00 p.	0,60	0,20	1,31	-0,08	-0,65	-0,20	-0,50	0,05	1,40	0,99	-1,92	1,15	0,69	-0,56
		9:00 p.	0,52	0,11	0,93	-0,03	-0,58	-0,21	-0,41	-0,07	1,23	0,77	-1,40	0,96	0,48	-0,54
		1:00 m.	0,51	0,10	0,79	0,05	-0,47	-0,23	-0,32	-0,10	0,93	0,49	-1,23	0,74	0,27	-0,53
Kitchen S-W	Aug 5th	6:00 m.	-0,92	-1,04	0,54	-0,27	-1,42	-0,23	-0,74	-0,12	0,82	0,38	-2,76	-1,75	-1,41	-2,34
		11:00 m.	-0,88	-0,99	0,80	-0,22	-1,29	-0,21	-0,71	-0,02	1,00	0,58	-3,33	-1,39	-1,13	-2,55
		4:00 p.	-0,88	-0,97	1,11	-0,78	-2,31	-0,19	-1,66	0,03	1,21	0,81	-3,85	-2,16	-1,82	-2,72
		9:00 p.	-0,95	-1,02	1,22	-0,75	-2,23	-0,19	-1,45	-0,21	1,08	0,67	-3,71	-2,29	-1,80	-2,70
		1:00 m.	-0,93	-1,04	0,86	-0,51	-1,80	-0,23	-1,07	-0,18	0,87	0,41	-3,15	-2,09	-1,70	-2,48
	Aug 15th	6:00 m.	1,36	1,46	0,54	-0,27	-1,42	-0,23	-0,74	-0,12	0,82	0,38	-2,76	0,54	1,10	-2,34
		11:00 m.	1,40	1,51	0,80	-0,22	-1,29	-0,21	-0,71	-0,02	1,00	0,58	-3,33	0,90	1,38	-2,55
		4:00 p.	1,28	1,44	1,11	-0,78	-2,31	-0,19	-1,66	0,03	1,21	0,81	-3,85	0,00	0,59	-2,72
		9:00 p.	1,33	1,48	1,22	-0,75	-2,23	-0,19	-1,45	-0,21	1,08	0,67	-3,71	-0,02	0,69	-2,70
		1:00 m.	1,37	1,47	0,86	-0,51	-1,80	-0,23	-1,07	-0,18	0,87	0,41	-3,15	0,20	0,82	-2,48

Table 20 - Temperature reduction in a top floor apartment considering the single retrofit scenarios and the whole intervention

Notes

1) Cf. Chapter 5, Paragraph 5.4., p.121.

2) For each day an average value of solar radiation on the 24 hours was considered.

3) For each day an average value of solar radiation on the 24 hours was considered.

4) This information was provided by Prof. Bruse and his team via the ENVI-met online users' forum. The software is also provided with an online manual.

5)This occurs as in this situation the spatial and temporal differences can be observed best and, even if there may be a demand to run ENVI-met also with the assumption of an existing cloud cover, this feature will be avoided since it may alter the temperature data.

6) The minimum amount of air changes per hour equal to 0.3 was still considered.

7) Considering the anomalous results, it can be expected that an error of calculation made by the software occurred.

8) Along with experimental studies, a few simulation methods have been explored to evaluate the thermal impacts of vegetated walls that were taken into account for the present research, such as Yoshimi J., Altan H. (2011) and Stav Y., Lawson G. (2012).

9) *"Istruzioni per la progettazione, l'esecuzione, il controllo e la manutenzione delle coperture a verde"* (Instructions for the design, construction, control and maintenance of green roofs).

10) Cf. Chapter 4, Paragraph 4.3.2., p. 85.

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Yoshimi J., Altan H., 'Thermal simulations on the effects of vegetated walls on indoor building environments', in *Proceedings of Building Simulation 2011*, 12th Conference of International Building Performance Simulation Association, Sydney, 14-16 November 2011.

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Photo References

Photo 1 - http://www.bing.com/maps

Photo 2 - Photo of the Author

Photo 3 - Photo of the Author

Photo 4 - https://maps.google.it

CONCLUSIONS

The connections between climate change, sustainability, urban planning and architecture have been the subject of a rich literature in the last decade, and a diffuse awareness exists about the necessity to address social housing towards high environmental standards, according also to the current global directives on sustainable development.

Nevertheless, although indoor comfort and building energy performance simulations, through the use of proper software tools, have been acquiring increasing importance in the last years -thanks to sophisticated building energy assessments-, they still tend to be disjointed from the elements that characterized the surrounding environment, such as the presence of vegetation, types of soil and the albedo values of buildings surfaces, which actually have a significant influence on the environmental conditions of building interior. This is also demonstrated by the fact that, at present, researches on methods for measuring the impact of trees and building-integrated vegetation on microclimate and on thermal comfort are still limited.

However, considering the increasing interest emerging about this field of research, it is expected that over time methodologies and guide lines will emerge out, in relation to different climate conditions.

In this sense, the proposed research aims at suggesting one methodology of this kind, in this way contributing to new knowledge and providing understanding of the environmental, social and economical impacts of vegetation in temperate areas and in particular in the Mediterranean basin.

ENVI-met data generated in the first stage of simulations conducted on the social housing complex Medaglie d'Oro, in Palermo, demonstrate how effective the adoption of vegetation can be for the control of the outdoor comfort levels during the design and the renovation process of micro urban areas. In fact the results of the measurements gave important information about the microclimatic differences among the five scenarios analysed (current situation and four "greening scenarios") related to the social housing complex Medaglie d'Oro and prove that the cooling effect of the area is higher in correspondence of the internal common area of the complex where vegetation is denser. The values registered in this phase of simulation show that, during the hottest days of the year, reductions of temperature up to 3°C can be achieved in the external spaces, which implies the improvement of the outdoor thermal comfort and, consequently, better conditions to promote the community social life.

The environmental advantages of greening are not, however, restricted to improving urban microclimate and social relationships. In fact, starting from generated meteorology data of the first stage, the analyses held at the building and apartment scale with EnergyPlus demonstrate that the effect of shading, radiant interactions and evapotranspiration during hot days, have even a greater impact inside the apartments, with temperature decreasing up to 3.10°C. This implies higher level of indoor comfort and significant consequences on the energy consumptions needed for cooling as well as on the investments needed for the energy improvement of the buildings.

The last simulations, eventually, demonstrate that the use of building-integrated vegetation can provide further amelioration of the indoor comfort. In fact, through the integration of living walls and green roofs and the substitution of windows, a decrease of temperature up to 4.17°C was achieved.

These results demonstrate the validity of the thesis starting assumption, according to which vegetation can be applied as a cost-effective solution for urban and building retrofit in order to improve the environmental conditions of communities situated in temperate areas.

According to the obtained results, this thesis can represent a starting point for the definition and validation of the proposed methodology as a tool for the assessment and design at the urban and building scale.

Fig. 1 - Rendered image of the Medaglie d'Oro complex after retrofitting: view from Via E. Basile

Management process of growth of urban areas and improvement of quality of life are indeed some of the key objectives of planners and administrations. In this regard, the methodology described and proposed in this work, may support local authorities and professionals into the research and the adoption of best retrofit practices for the improvement of the environmental quality outside and inside the buildings stocks, by providing assistance to the decision making process.

Although the scheme was assessed for the city of Palermo, it is expected that it will also contribute to knowledge applicable to other temperate regions and that it can assist in the definition of urban and building retrofit interventions and policies.

The hypotheses advanced not only take into account the environmental but also the economic aspects. The reduced investment capacity of the municipalities, the tendency of moving from "heavy" and centralized welfare policies to "light" local practices have recently led to the emergence of new actors and of new metropolitan governance, focused not only on institutional structures, but also in the presence of private agents, through sustainable partnerships. Public-private partnerships can therefore play a critical role in the application of such methodology, considering that it foresees the realization of punctual interventions whose costs could be divided by different stakeholders.

Fig. 2 - Rendered image of the Medaglie d'Oro complex after retrofitting:view of the common area

In the process of development of this research additional and/or complementary issues and aspects have been arisen. Basing on this work, several suggestions of research and development of further studies can be contemplated such as:

- The assessment of the proposed methodology in other sites situated in the Mediterranean basin or in other temperate areas[1]. This could regard again the case of social housing complexes but not exclusively.
- The validation of the proposed methodology through the effective application of the proposed urban and building retrofit strategies on existing Social Housing complexes, which need to be retrofitted.
- The development of complementary and more specific studies on the aspects related to the choice of plant species and to the botanical field in general. Specifically, in the Mediterranean basin and the subtropical areas, it would be interesting to analyse the behaviour of succulent plants for vertical gardens and green roofs, in order to evaluate possible benefits derived also from the increase of the envelope thermal mass.
- The development of complementary studies on the aspects related to plants maintenance, irrigations systems and possible strategies for water recovery.
- The development of studies related to the Life Cycle Assessment referred to building-integrated vegetation systems.

Fig. 3 - Rendered image of the Medaglie d'Oro complex after retrofitting: view from one of the apartments

Notes

1) More studies have been conducted at the Dipartimento di Architettura of the Università degli Studi di Palermo to verify the validity of the methodology on other Social Housing complexes situated in Sicily. For more details:

- Oddo, M. (2013). *Retrofit e sostenibilità.Recupero energetico dell'edilizia economica e popolare della città di Palermo. Il quartiere dello Sperone a Romagnolo*. Master Thesis. Supervisor: Prof. R. Corrao, Co-supervisor: L. Pastore.
- Calabrò, E., Della Corte, C., Raveduto, I. (2013). *Retrofit e sostenibilità. Influenza della vegetazione sul microclima urbano e ricadute sul comfort delle diverse tipologie di alloggi nel quartiere Cappucinelli a Trapani*. Master Thesis. Supervisor: Prof. R. Corrao, Co-supervisor: L. Pastore.

Different papers related to the topics investigared in this thesis have also been presented in international conferences. For more details:

- Pastore, L., Corrao, R., Heiselberg, P., 'The use of Vegetation for Social Housing Renovations: a cases study in the city of Palermo, in *Proceedings of the 2nd Central European Symposium on Building Physics, 9-11 September 2013*, Vienna, Austria ÖKK-Editions ISBN 9783854373216.
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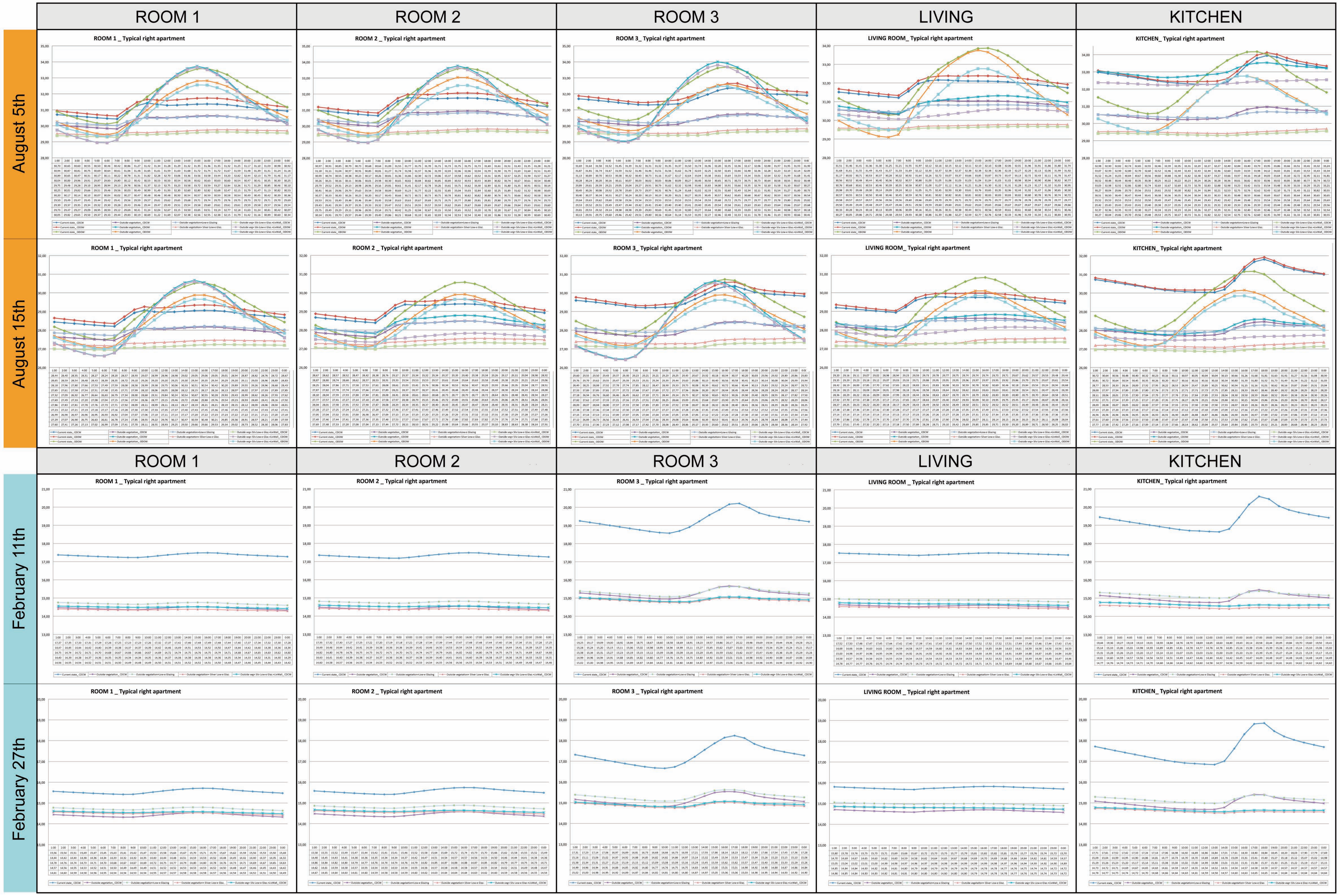
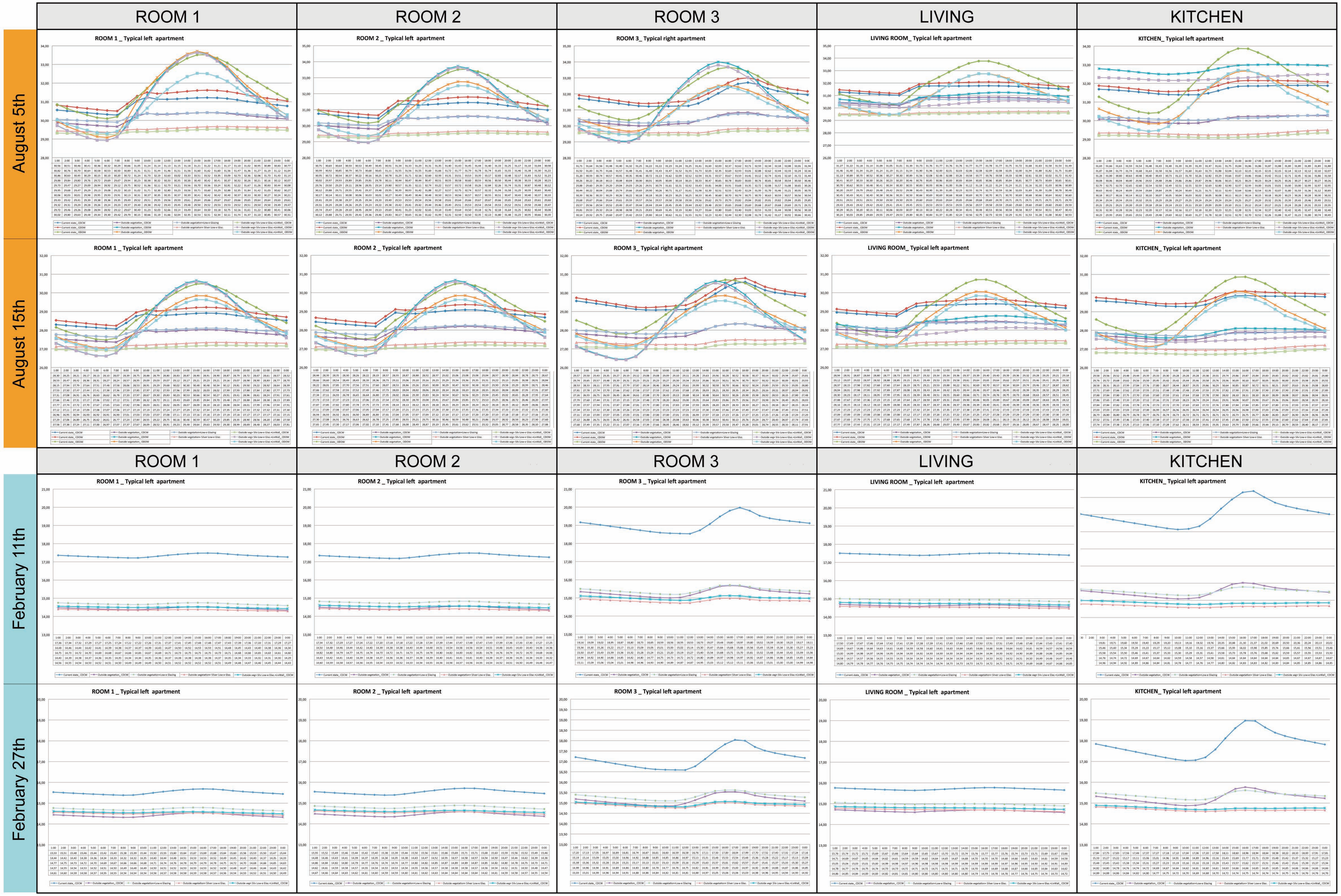
APPENDIX

TYPICAL RIGHT APARTMENT



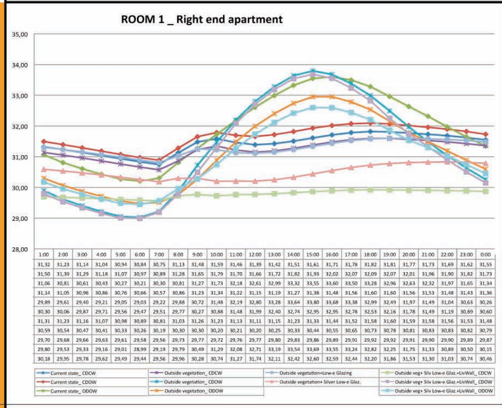
TYPICAL LEFT APARTMENT

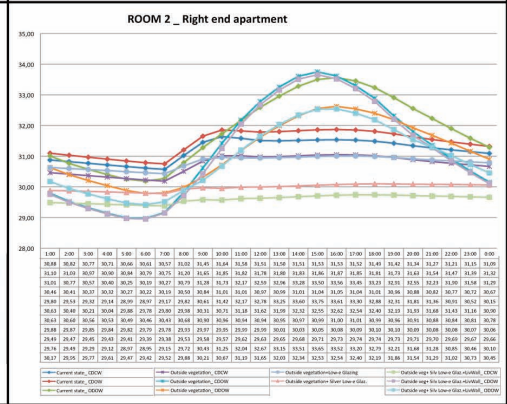


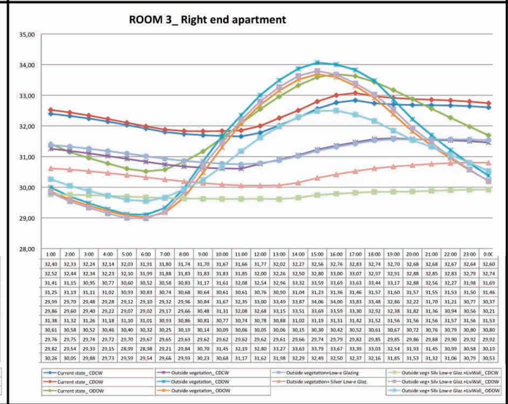
TYPICAL RIGHT END APARTMENT

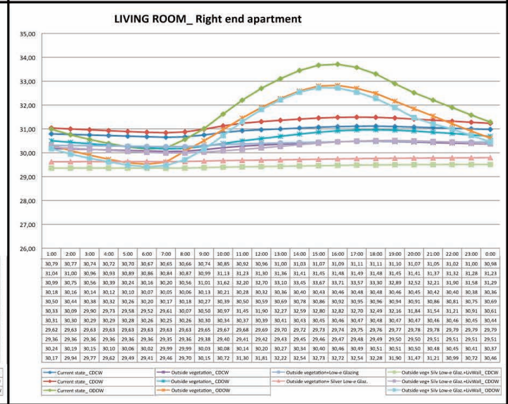
ROOM 1	ROOM 2	ROOM 3	LIVING	KITCHEN

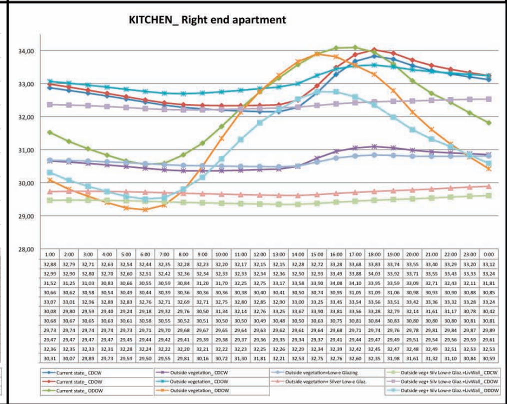
August 5th



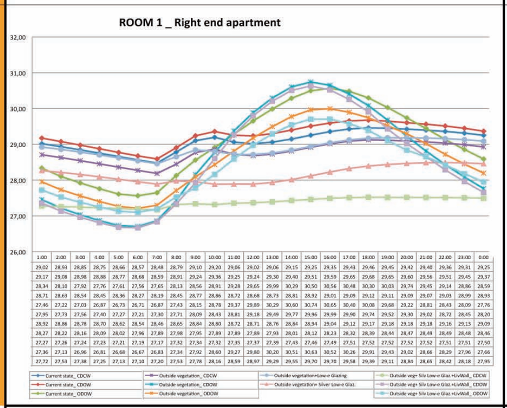


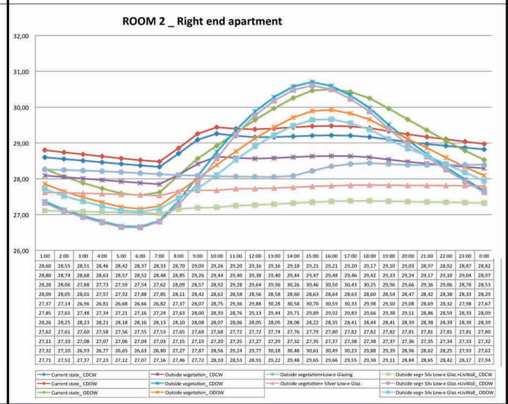


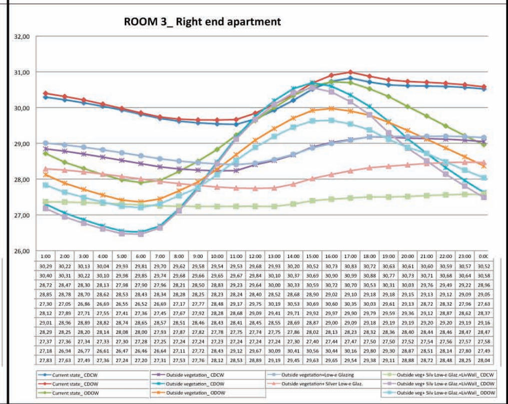


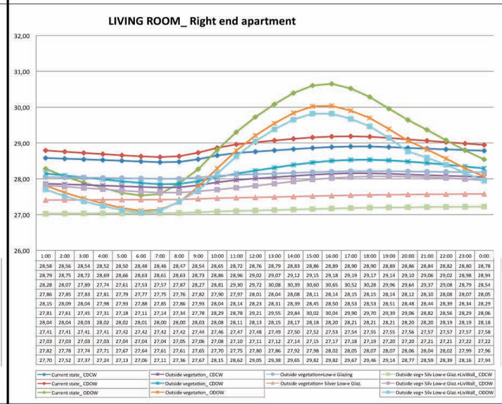


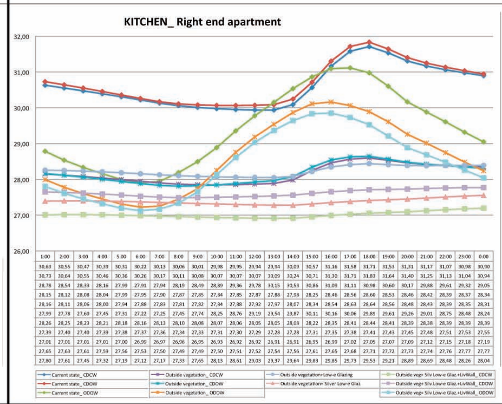
August 15th





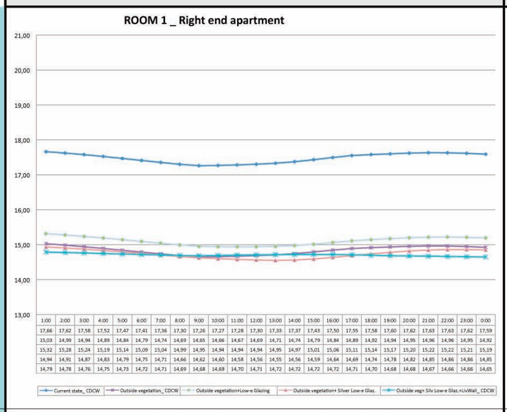


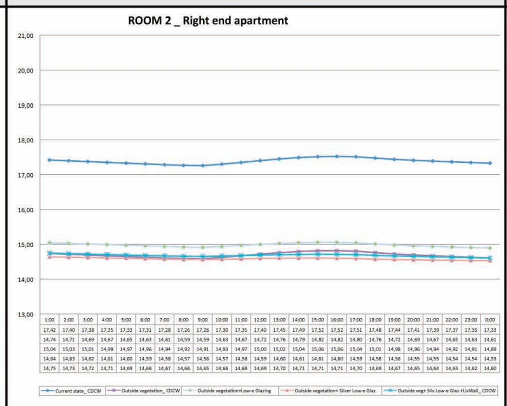


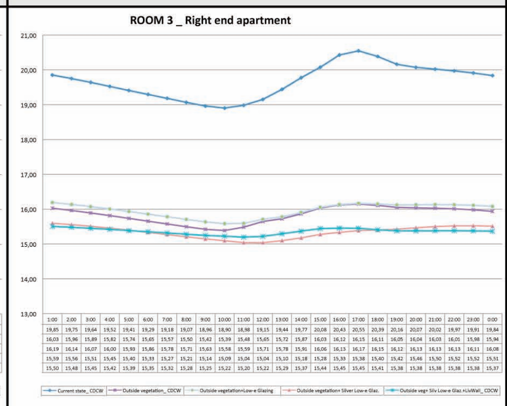


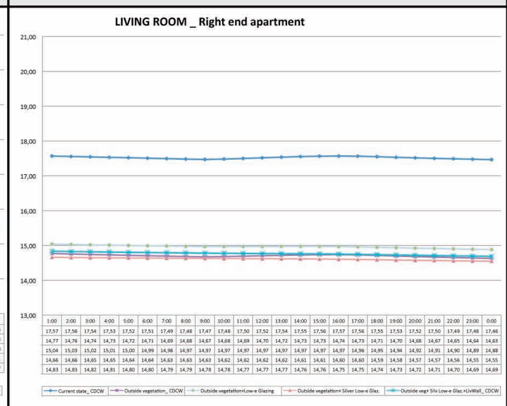
ROOM 1	ROOM 2	ROOM 3	LIVING	KITCHEN

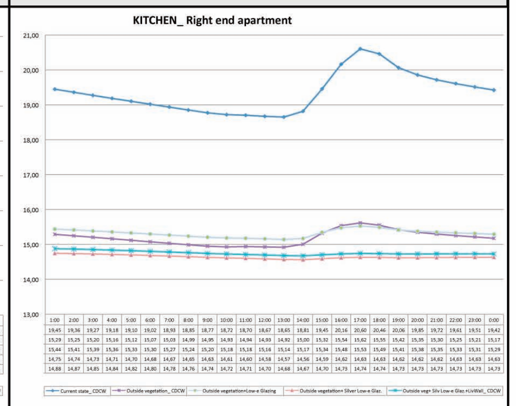
February 11th



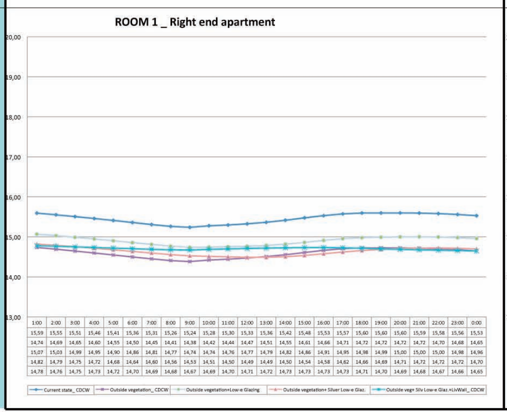


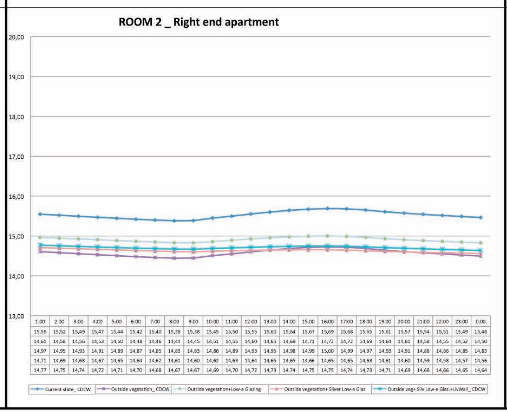


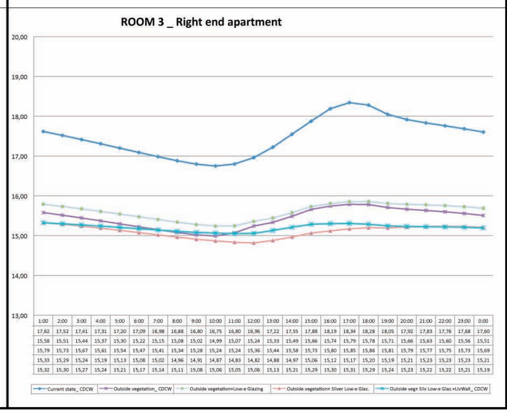


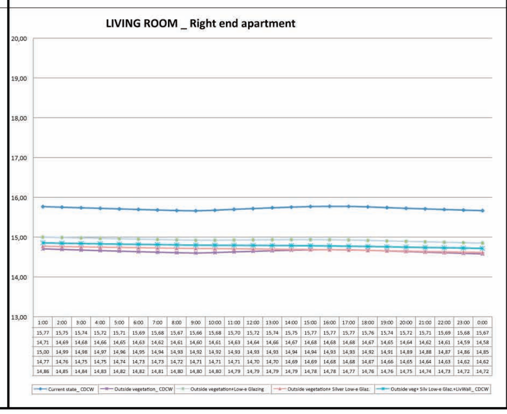


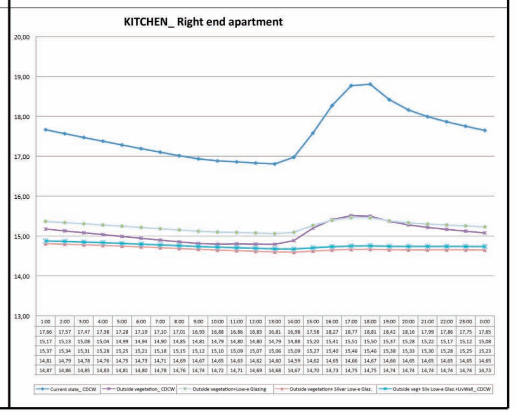
February 27th



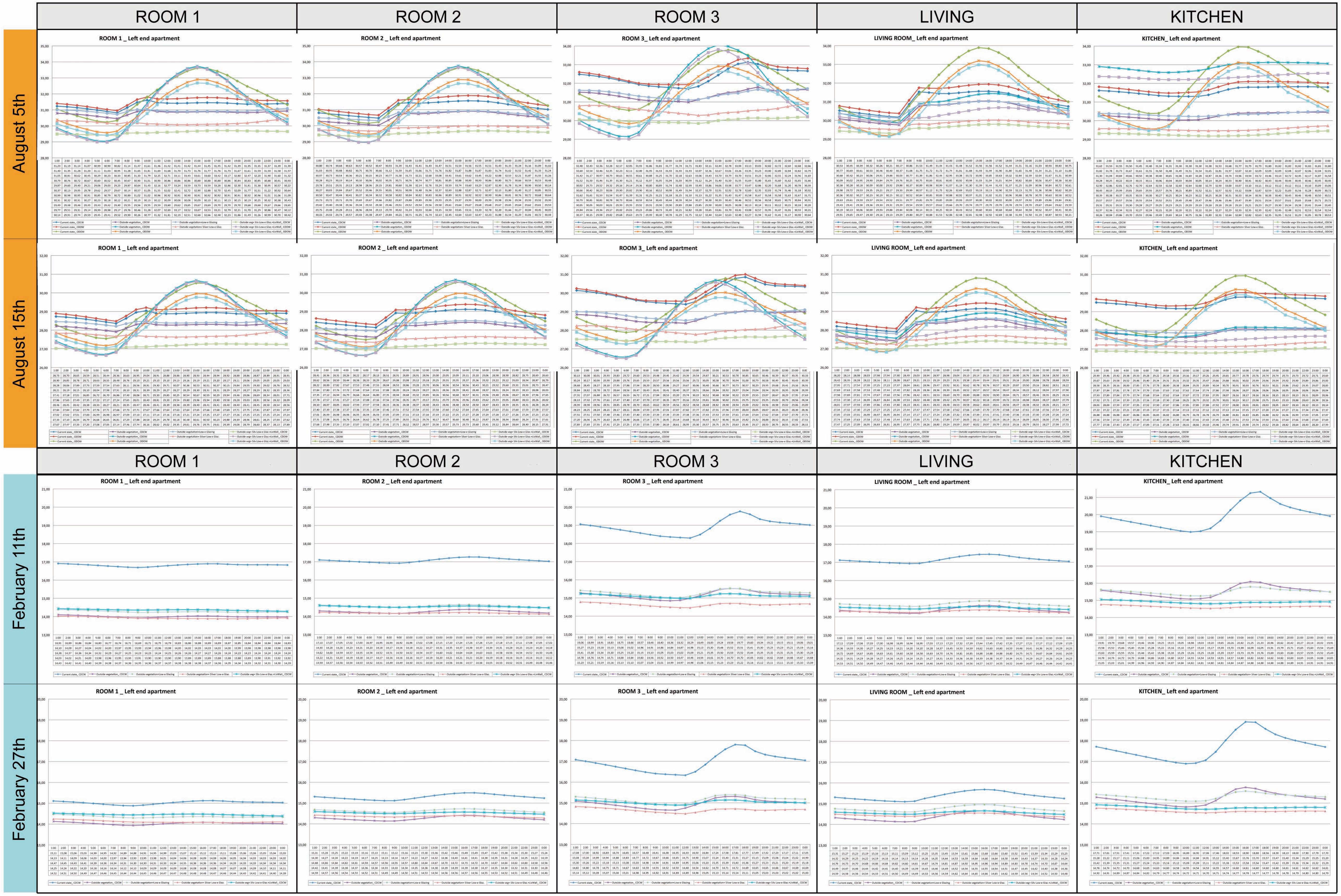




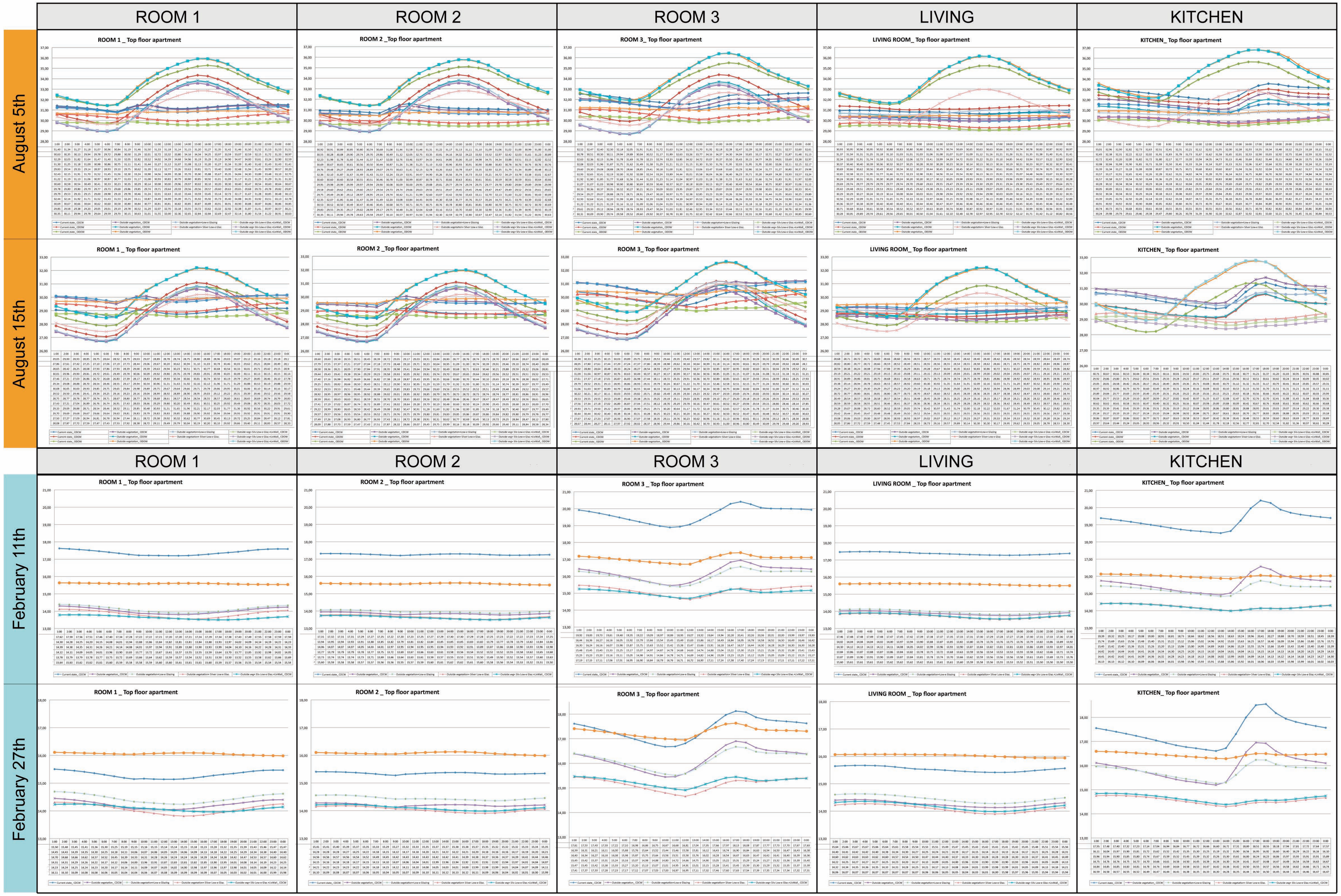


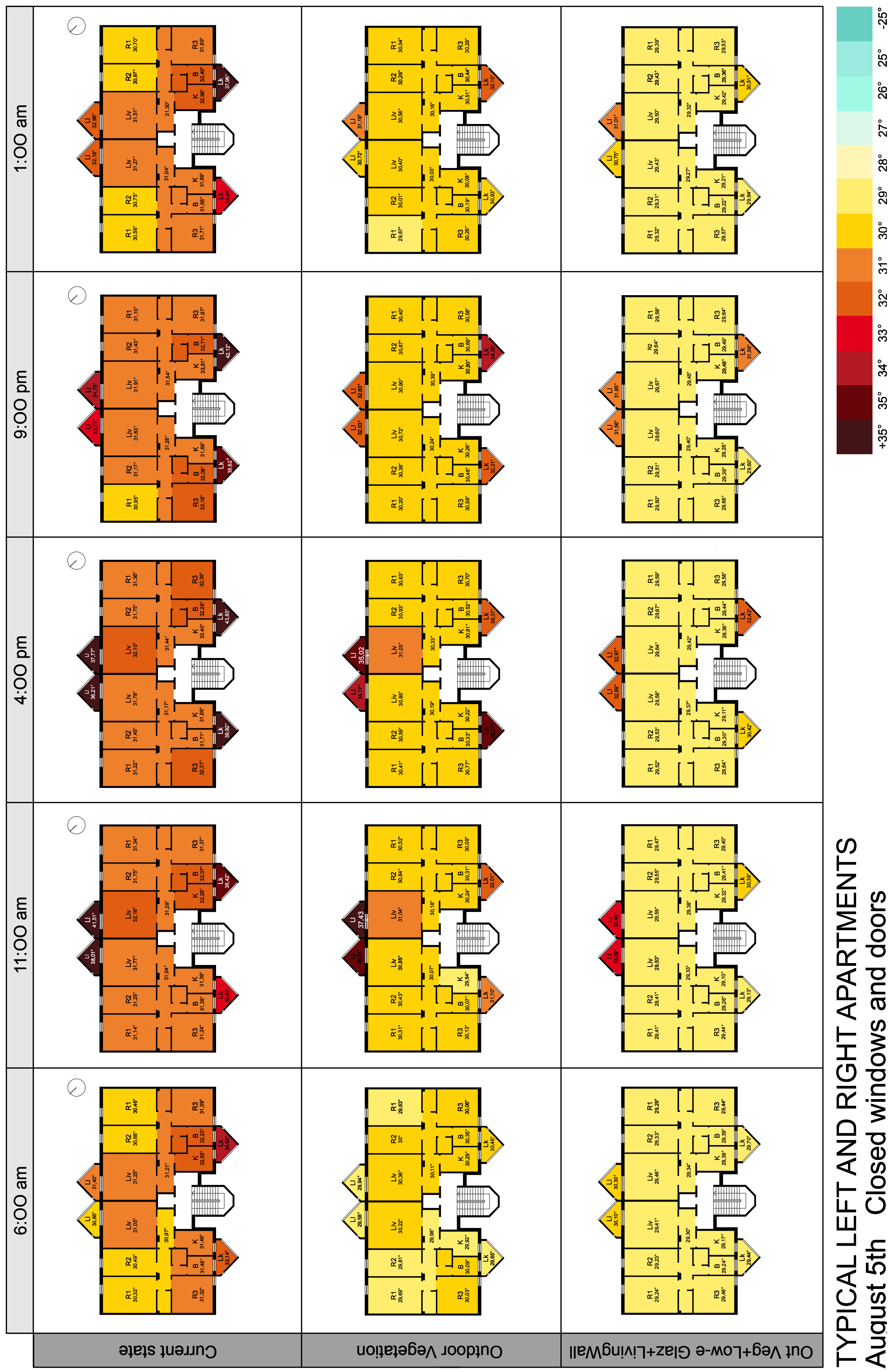


TYPICAL LEFT END APARTMENT

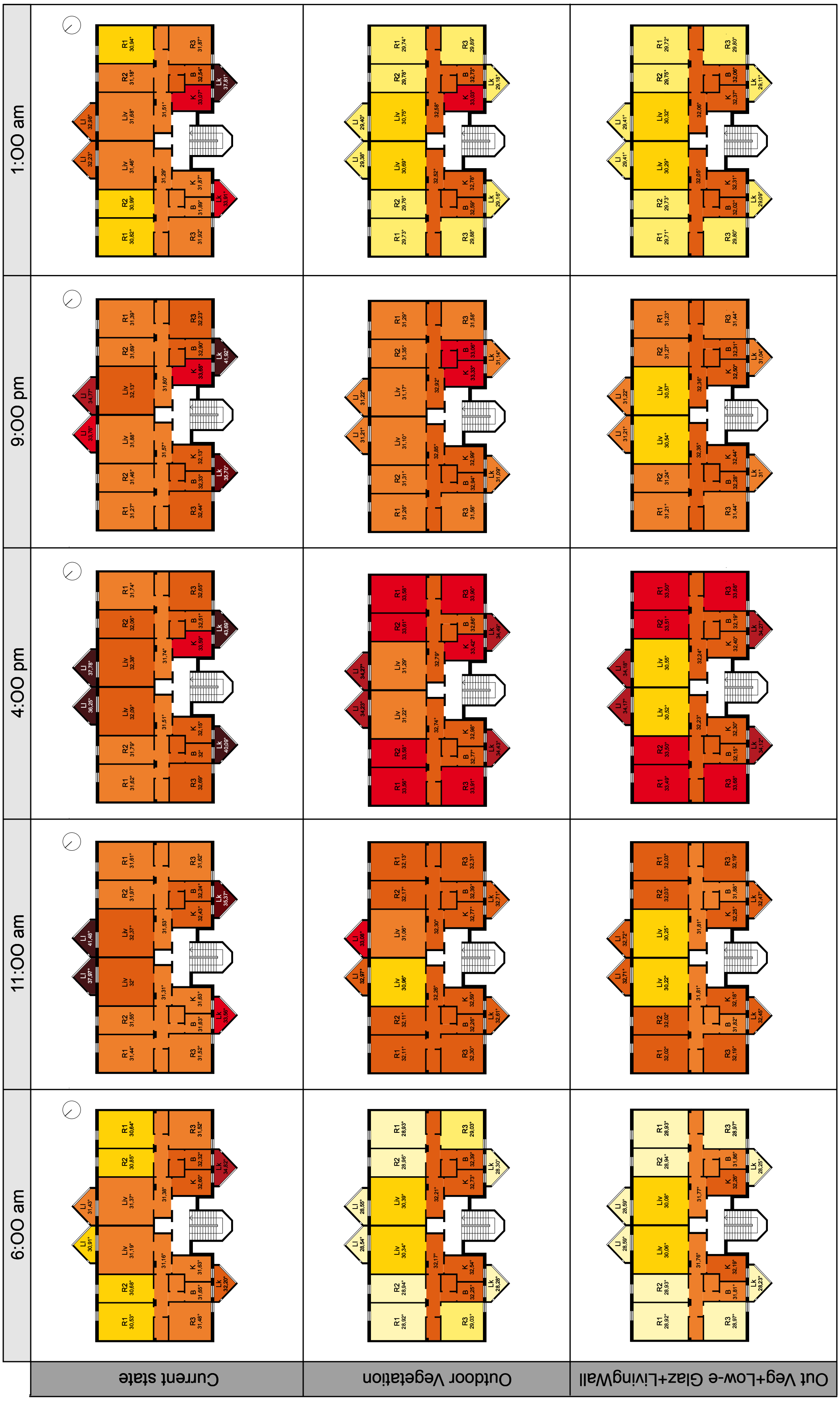


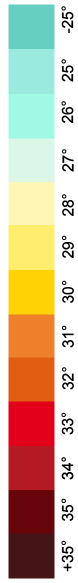
TOP FLOOR APARTMENT



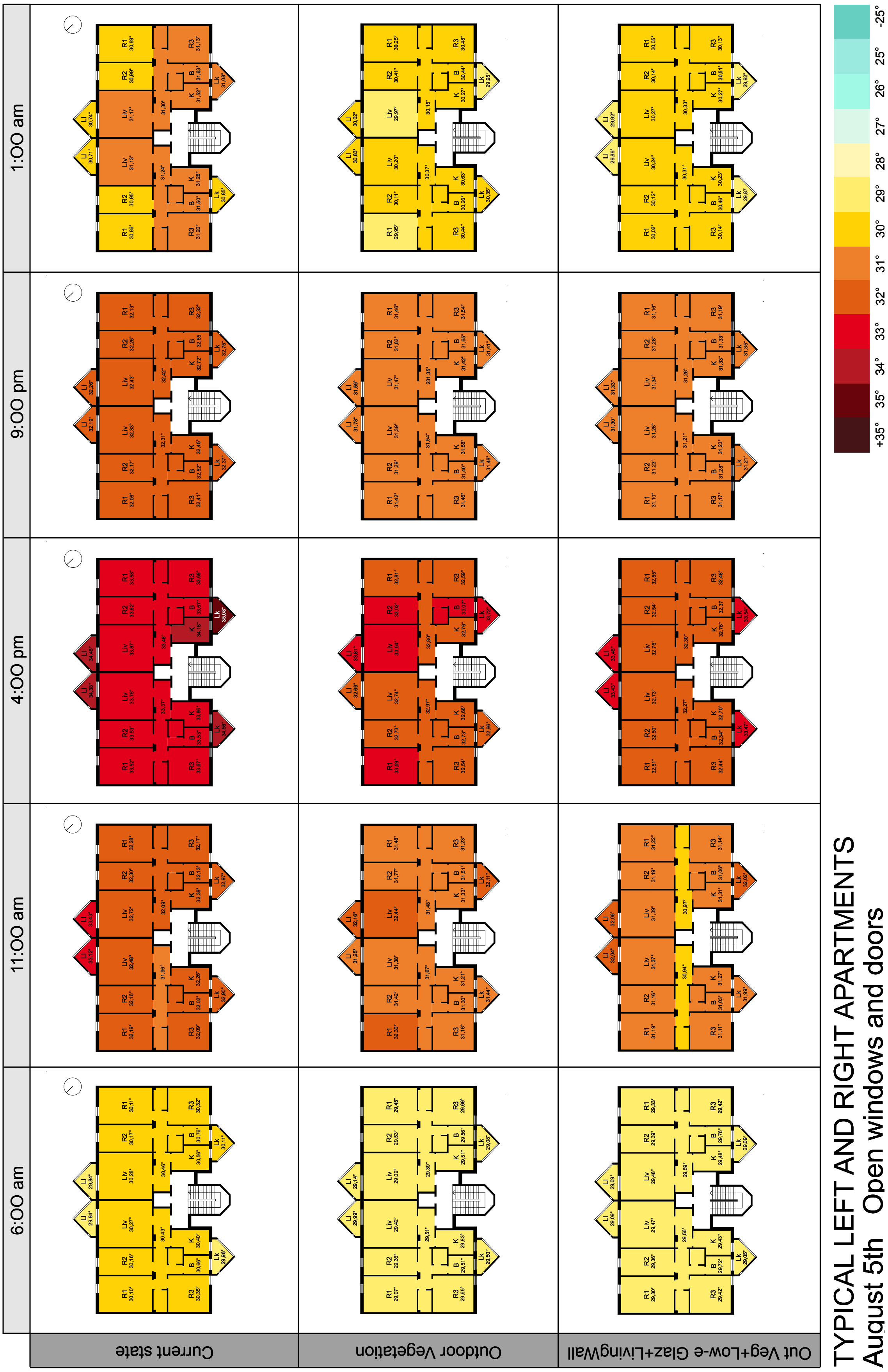


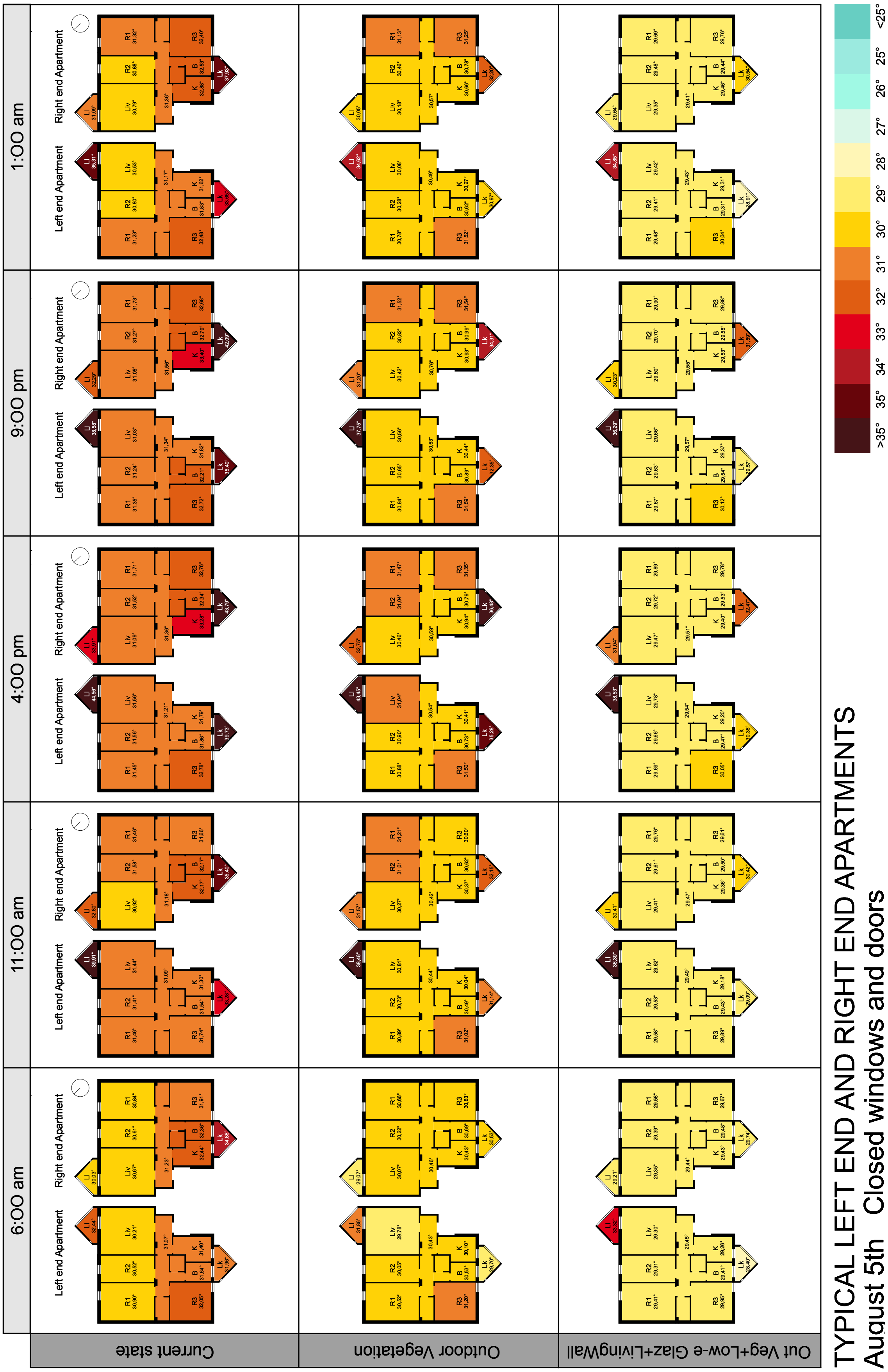
TYPICAL LEFT AND RIGHT APARTMENTS
August 5th Closed windows and doors



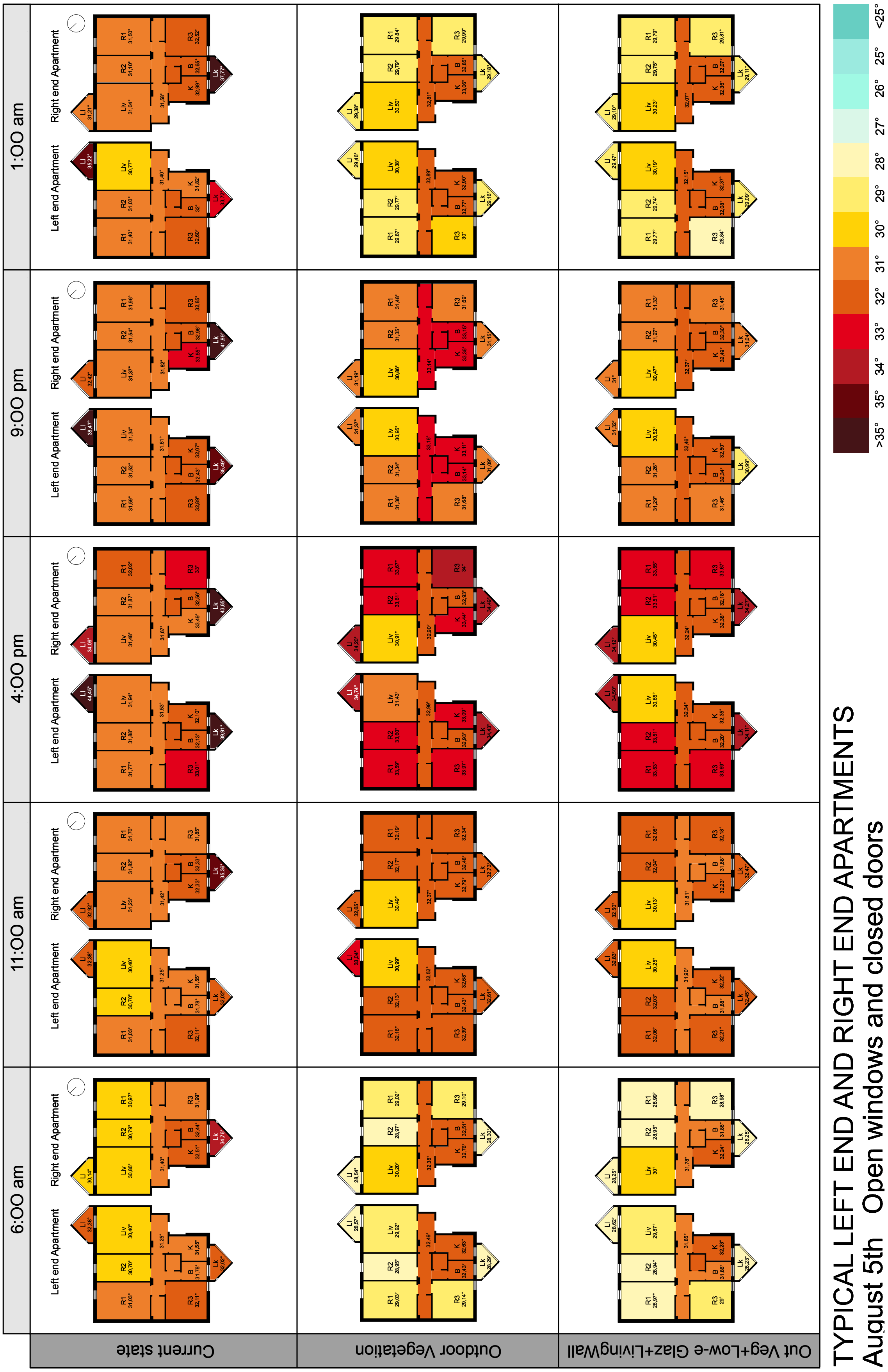


TYPICAL LEFT AND RIGHT APARTMENTS
August 5th Open windows and closed doors

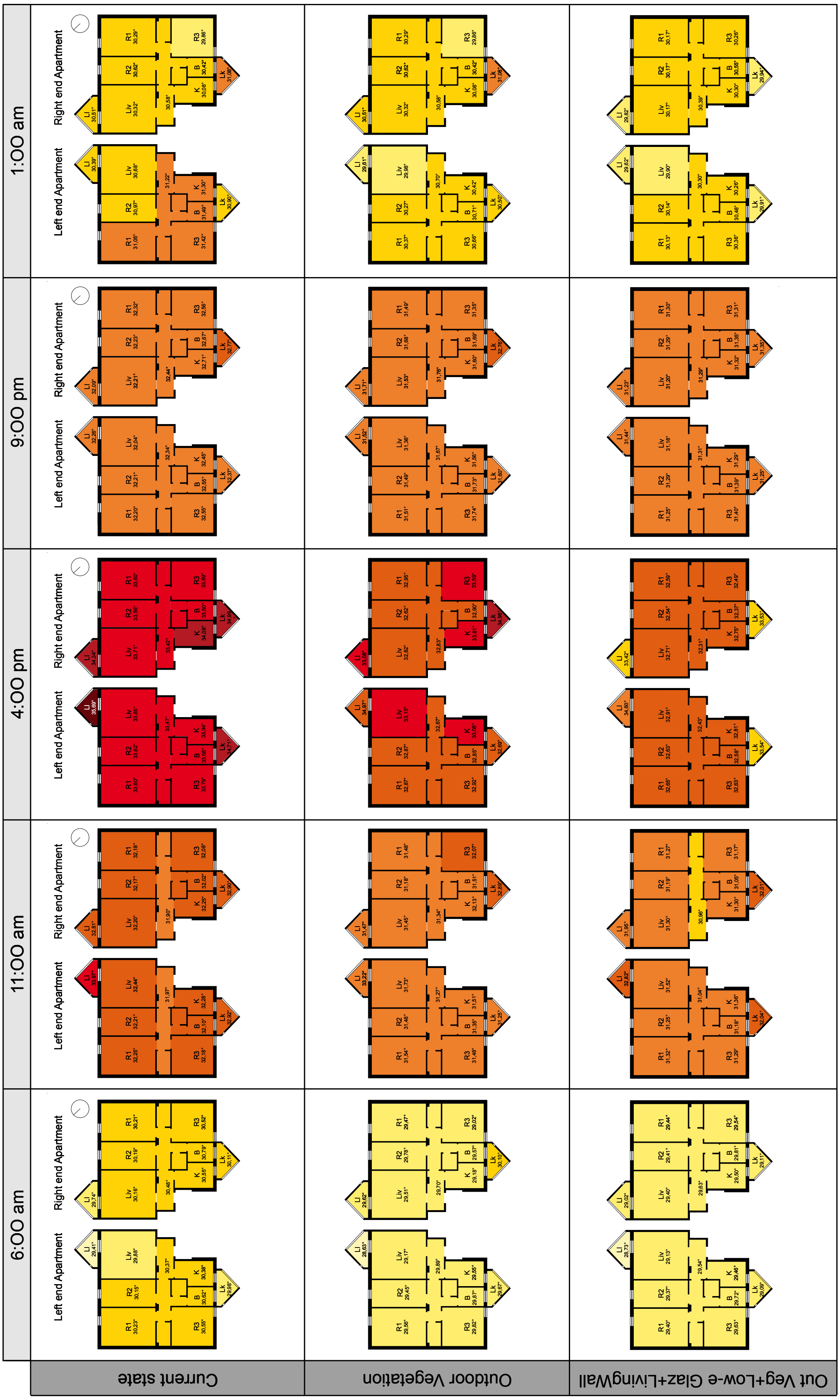

6:00 am
11:00 am
4:00 pm
9:00 pm
1:00 am
Current state
Outdoor Vegetation
Out Veg+Low-e Glaz+LivingWall
+35° 35° 34° 33° 32° 31° 30° 29° 28° 27° 26° 25° -25°
TYPICAL LEFT AND RIGHT APARTMENTS
August 5th Open windows and doors

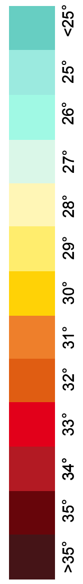


TYPICAL LEFT END AND RIGHT END APARTMENTS
August 5th   Closed windows and doors

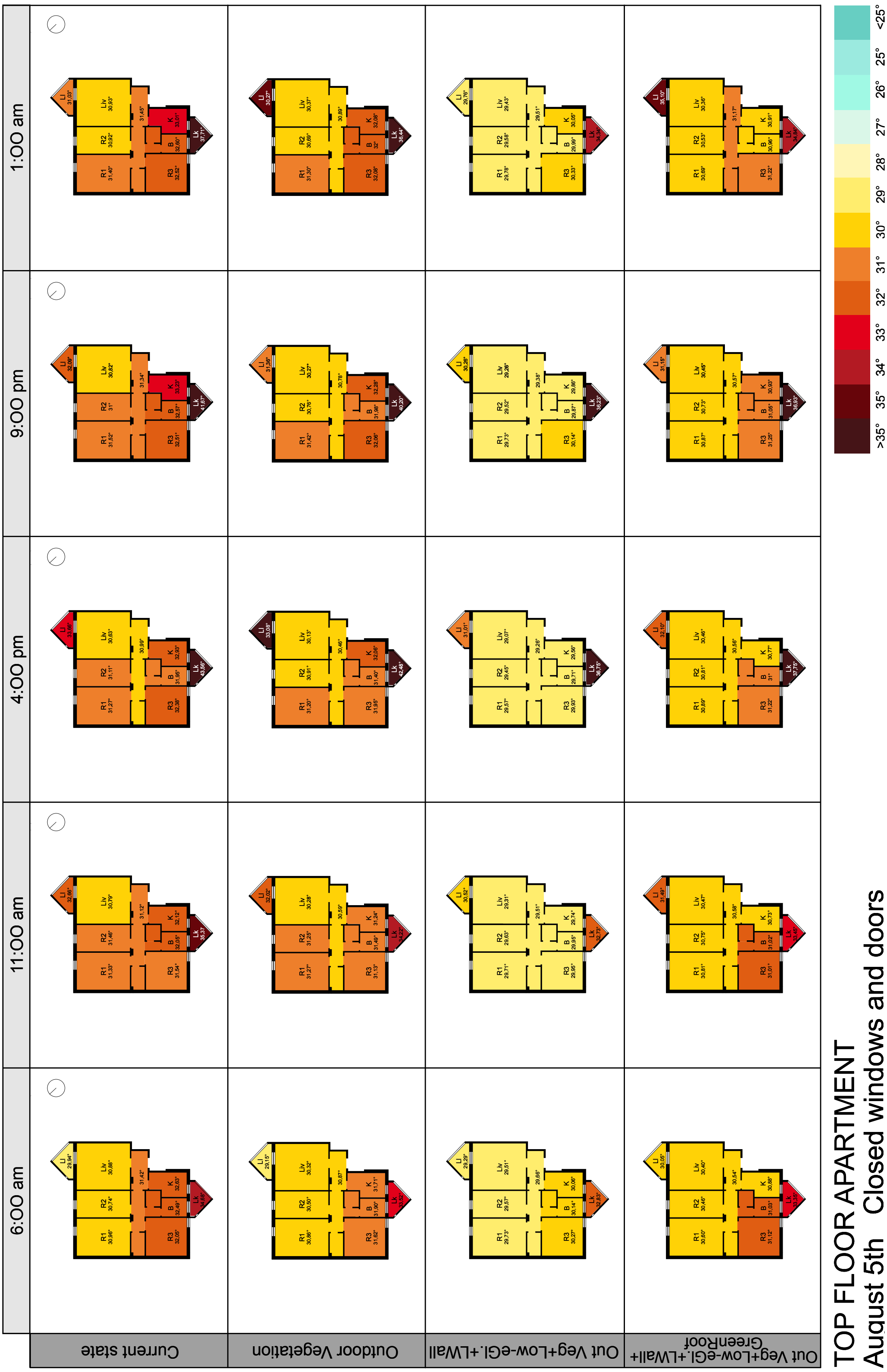


TYPICAL LEFT END AND RIGHT END APARTMENTS
August 5th   Open windows and closed doors

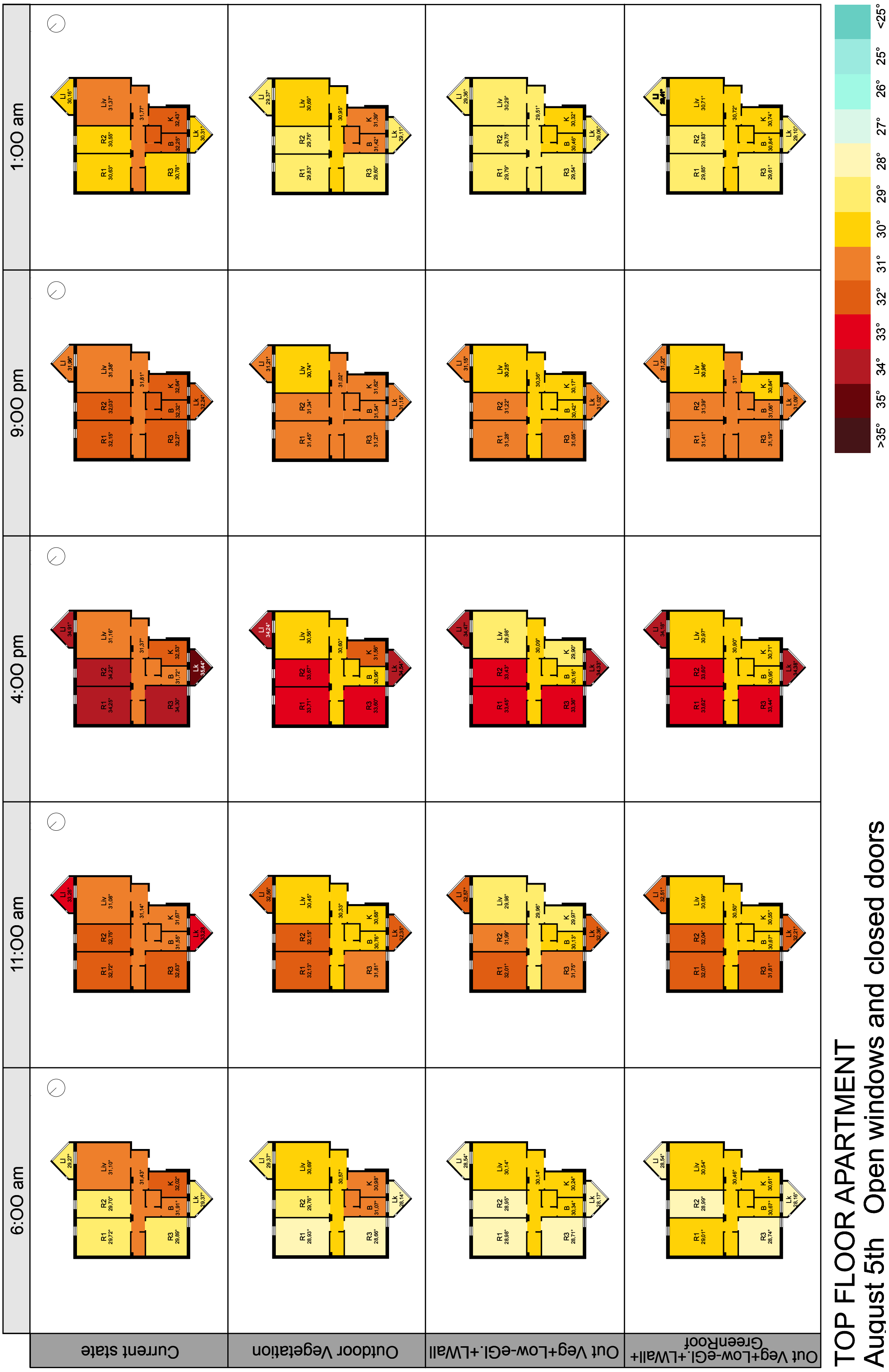




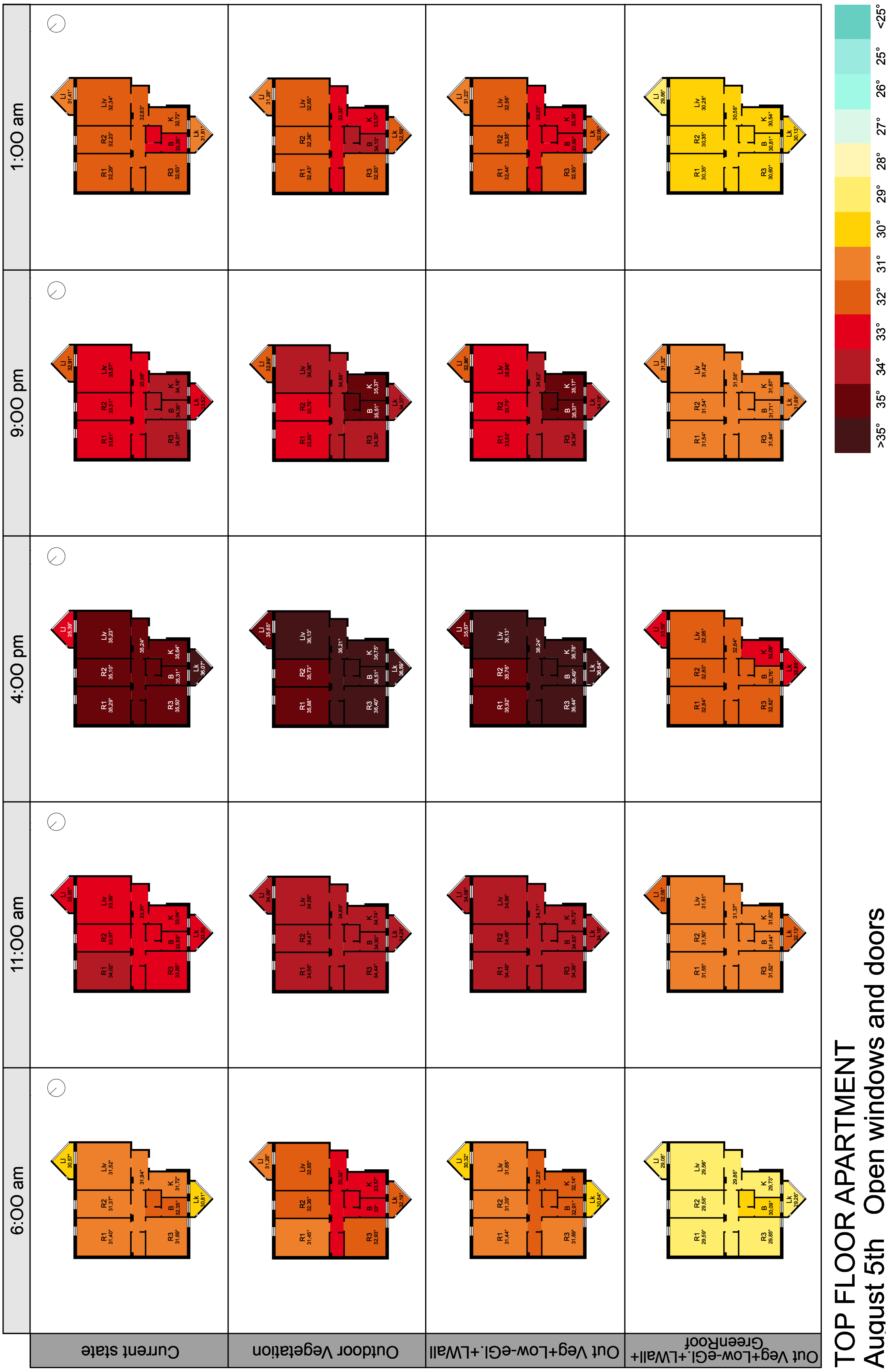
TYPICAL LEFT END AND RIGHT END APARTMENTS
August 5th Open windows and doors



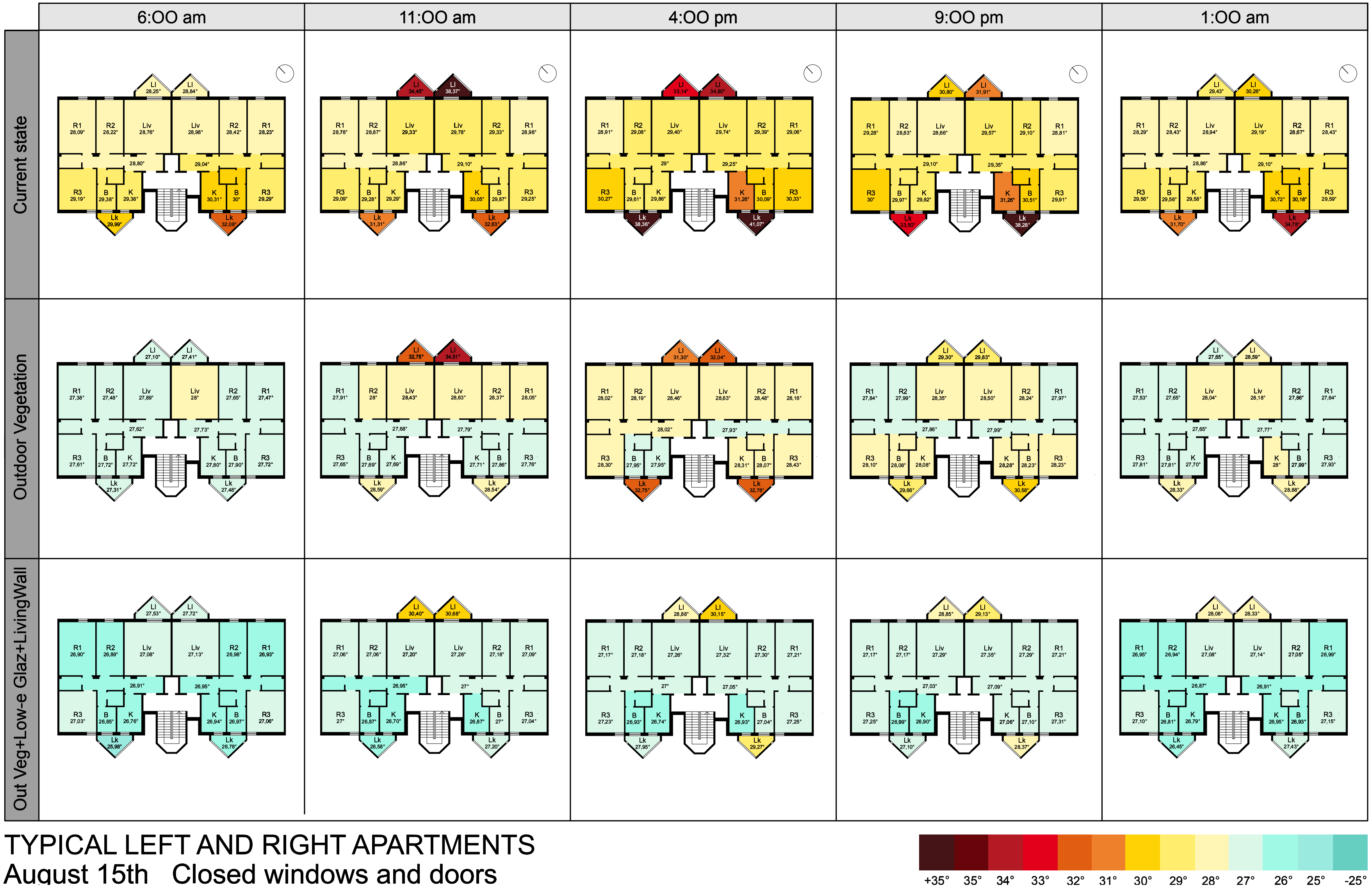
TOP FLOOR APARTMENT
August 5th Closed windows and doors



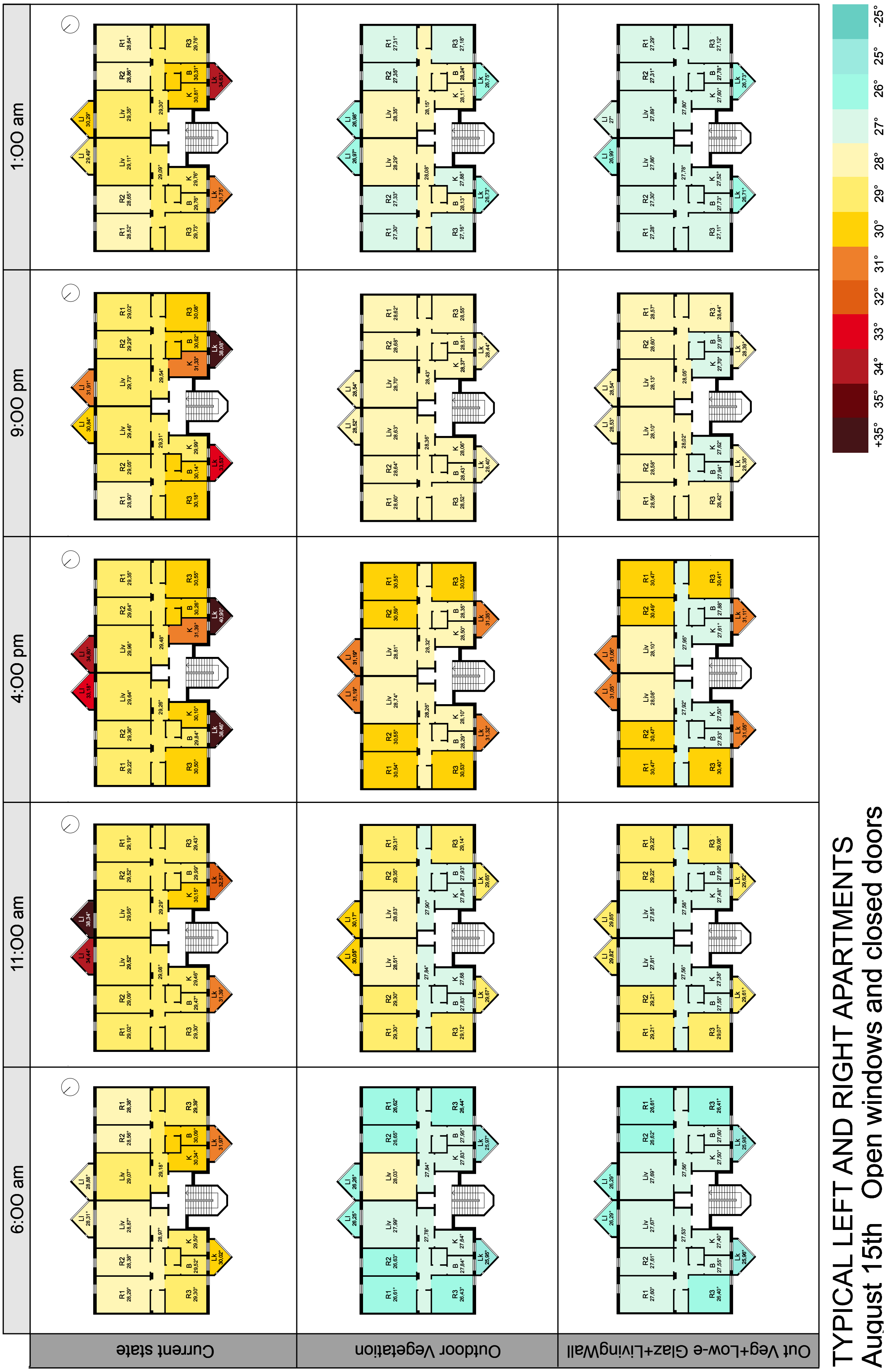
TOP FLOOR APARTMENT
August 5th Open windows and closed doors



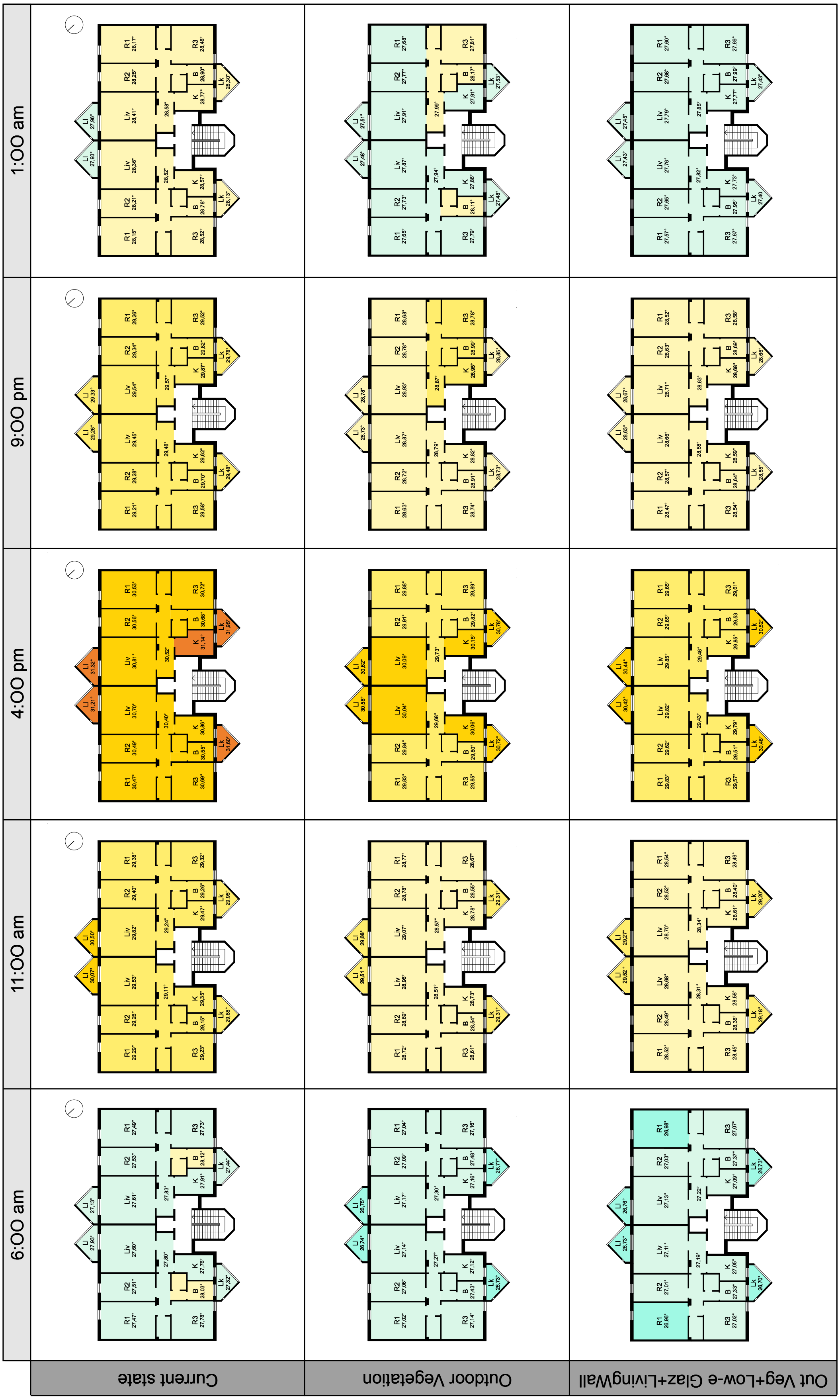
TOP FLOOR APARTMENT
August 5th Open windows and doors

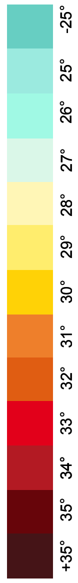


TYPICAL LEFT AND RIGHT APARTMENTS
August 15th   Closed windows and doors

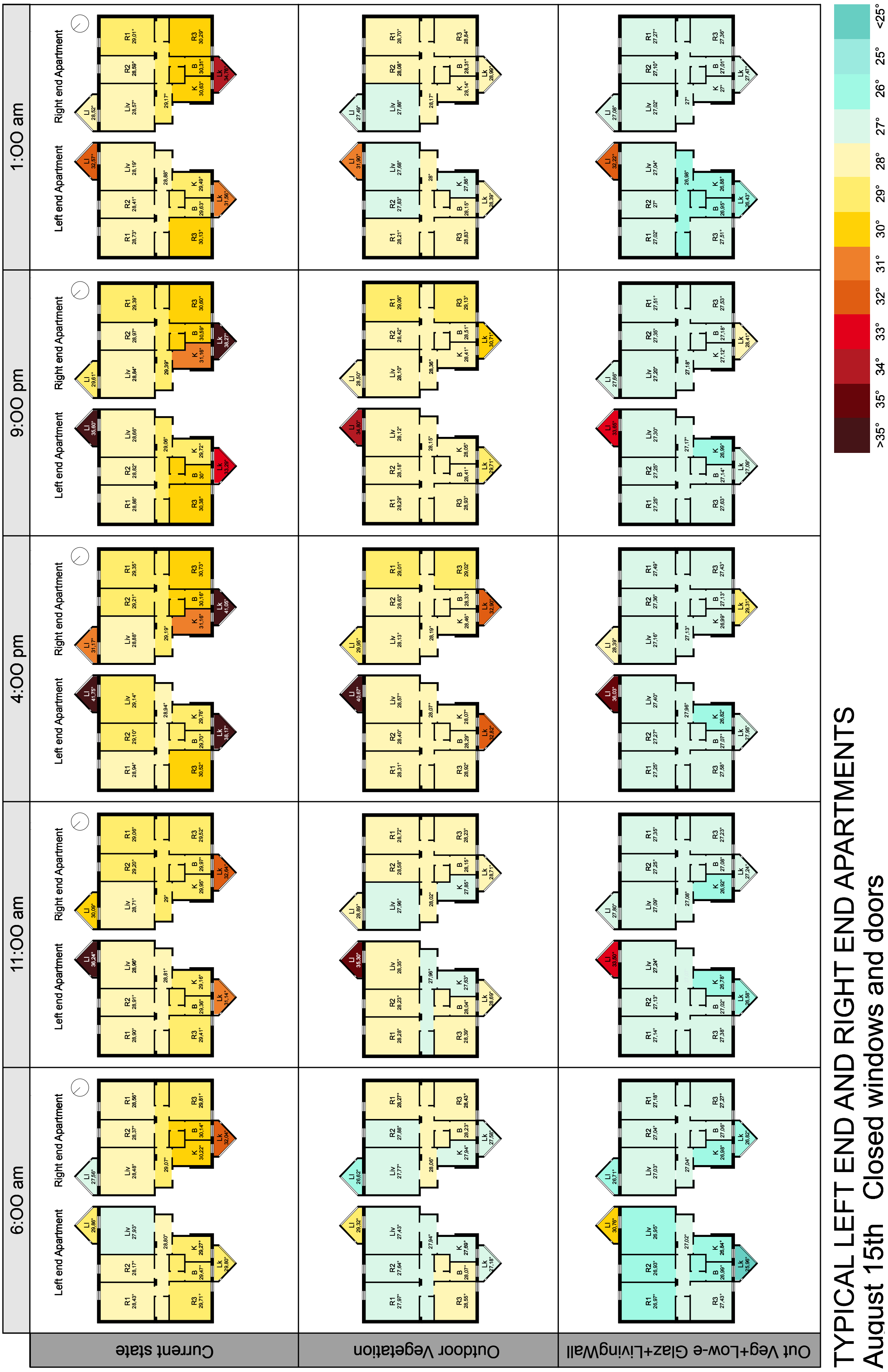


TYPICAL LEFT AND RIGHT APARTMENTS
August 15th Open windows and closed doors

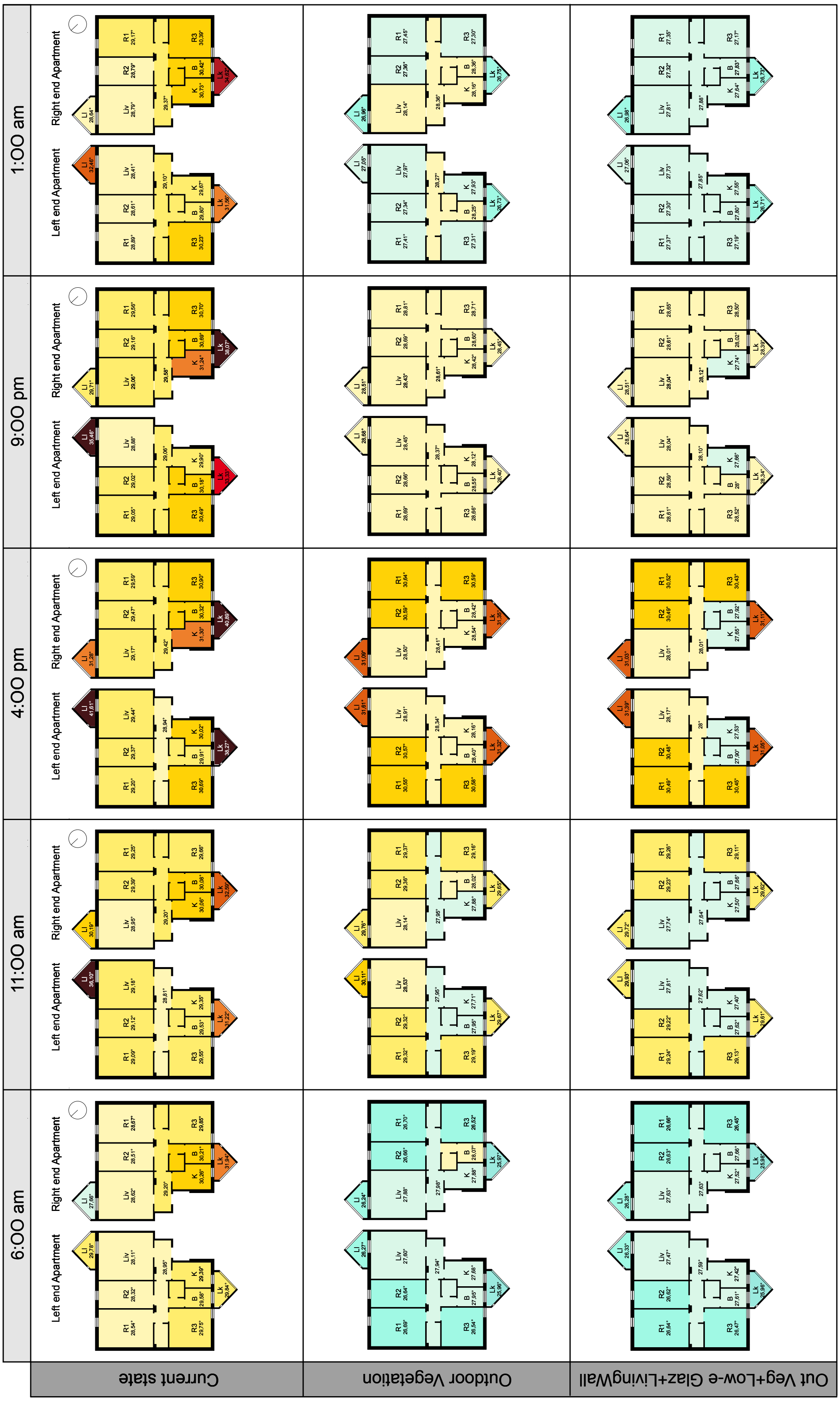


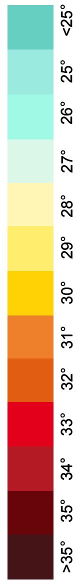


TYPICAL LEFT AND RIGHT APARTMENTS
August 15th Open windows and doors

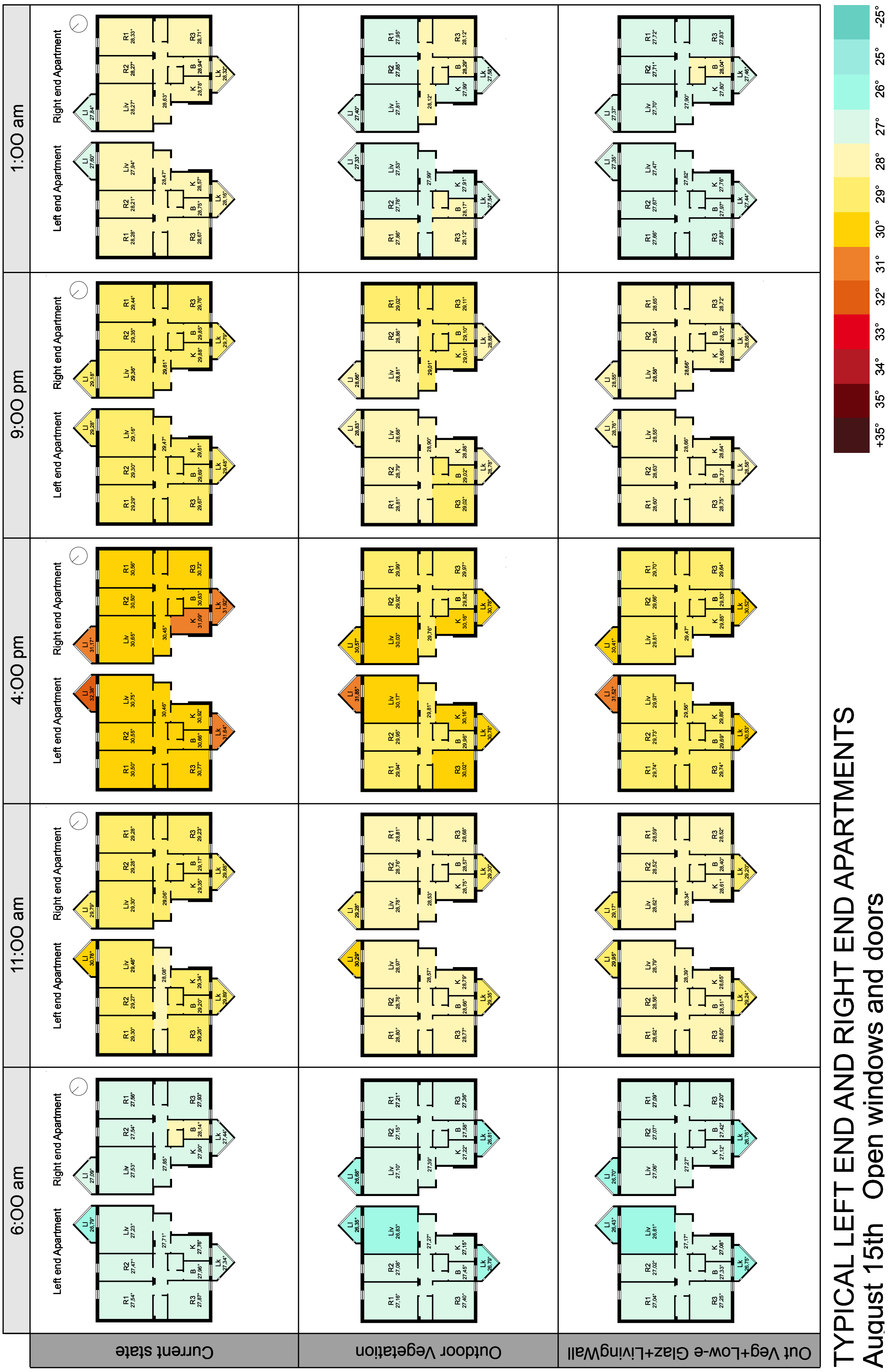


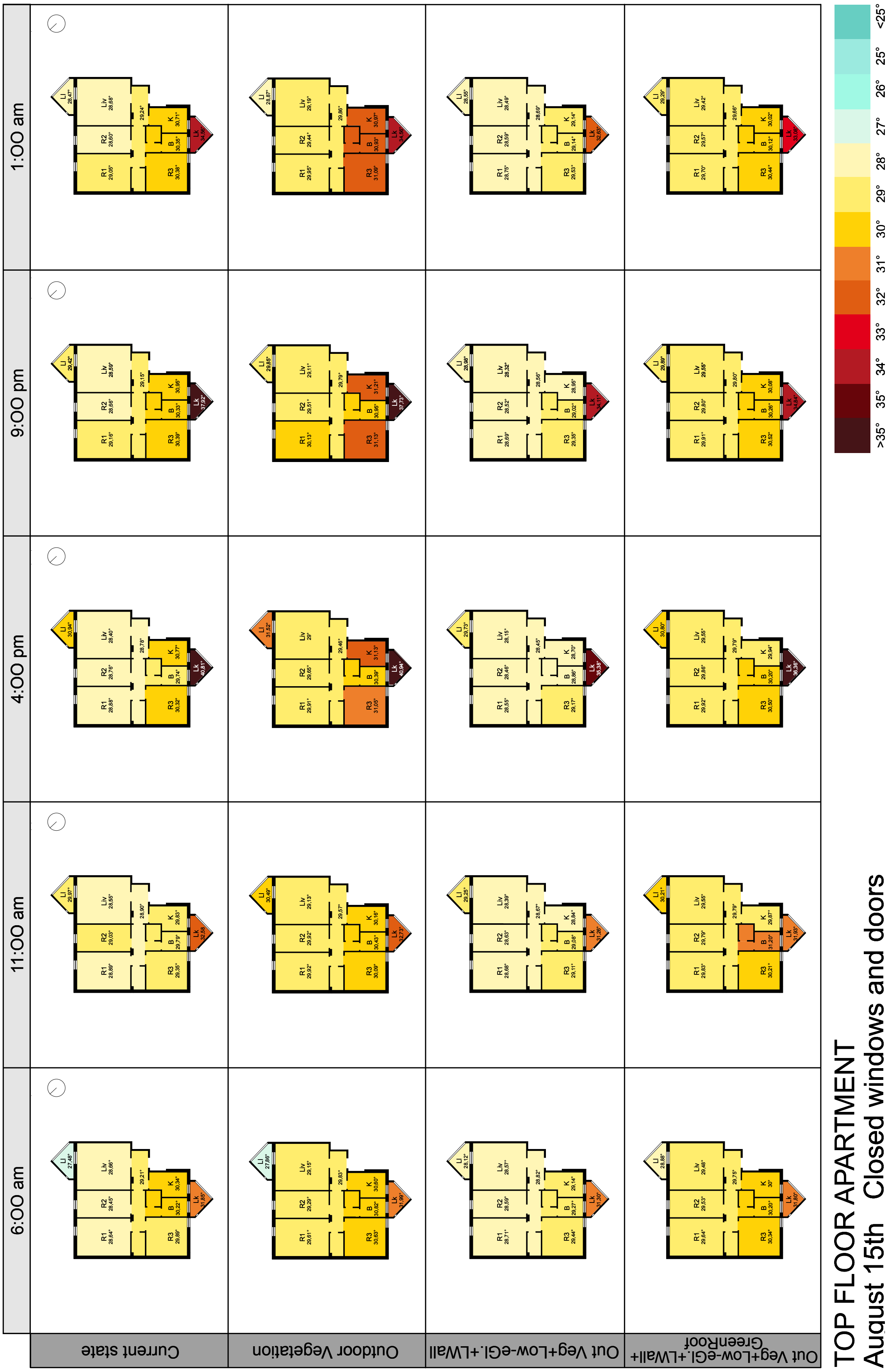
TYPICAL LEFT END AND RIGHT END APARTMENTS
August 15th   Closed windows and doors



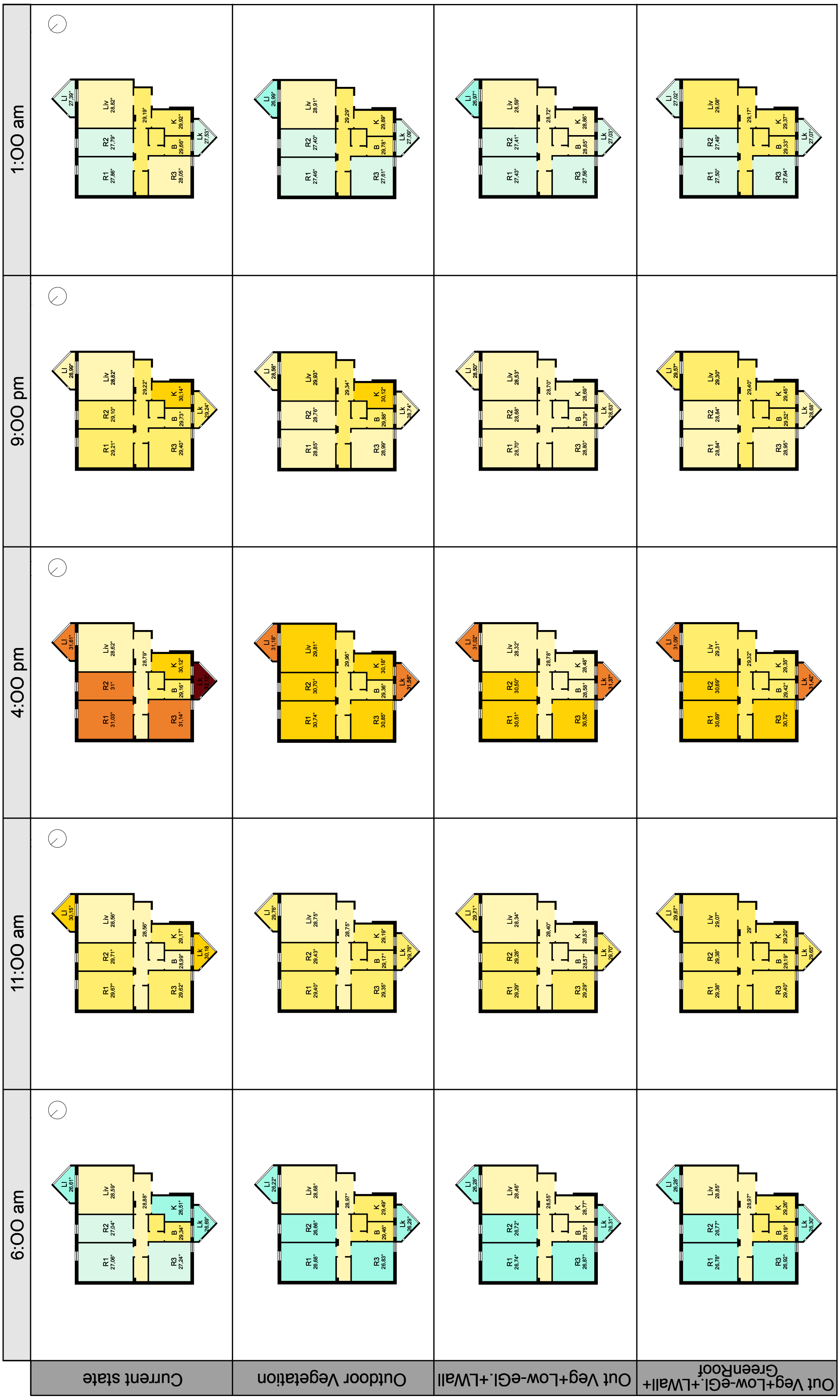


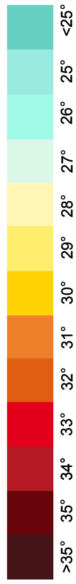
TYPICAL LEFT END AND RIGHT END APARTMENTS
August 15th Open windows and closed doors


6:00 am
11:00 am
4:00 pm
9:00 pm
1:00 am
Left end Apartment
Right end Apartment
Current state
Outdoor Vegetation
Out Veg+Low-e Glaz+LivingWall
-25°
25°
26°
27°
28°
29°
30°
31°
32°
33°
34°
35°
+35°
TYPICAL LEFT END AND RIGHT END APARTMENTS
August 15th Open windows and doors



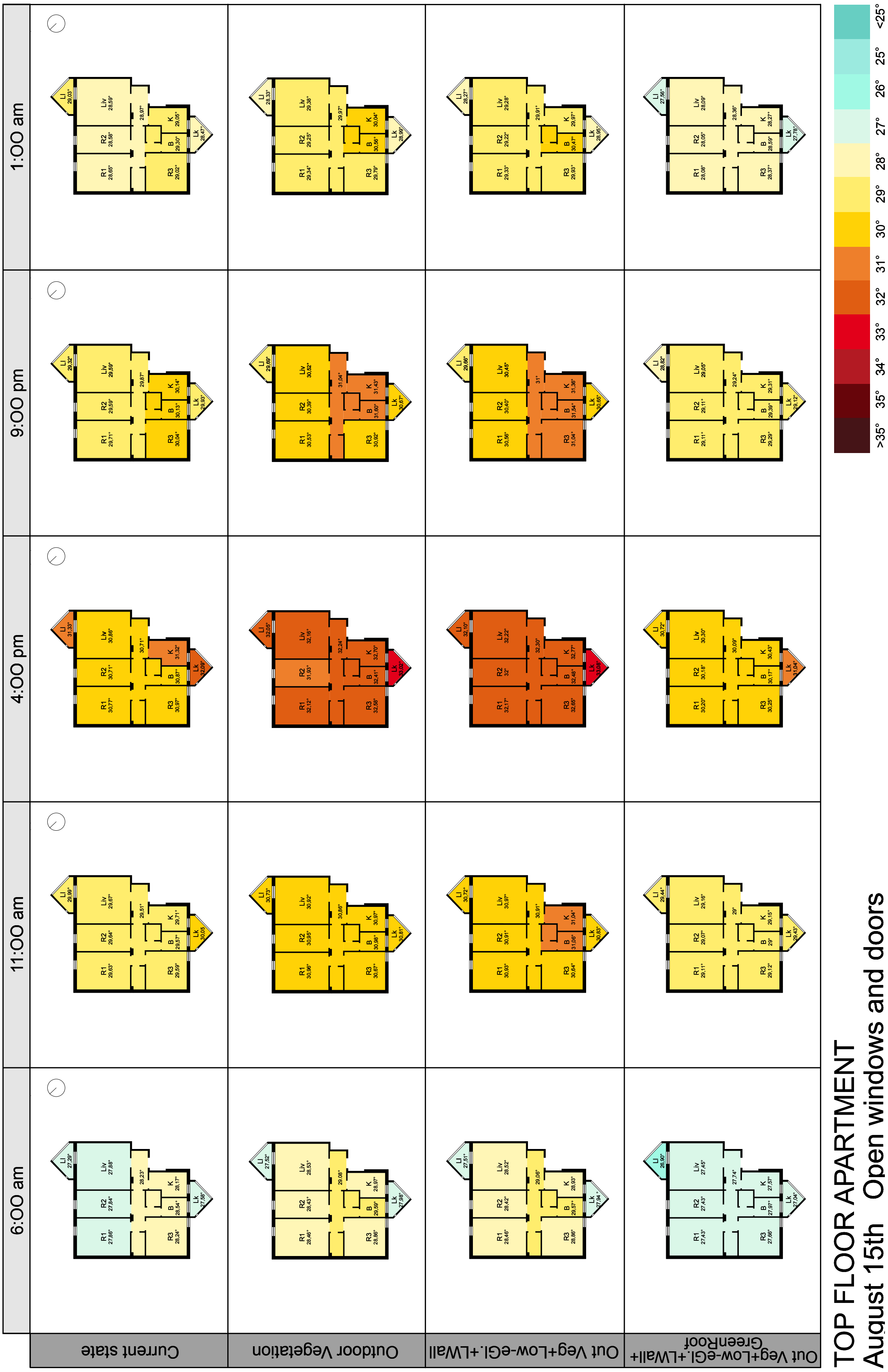
TOP FLOOR APARTMENT
August 15th   Closed windows and doors





TOP FLOOR APARTMENT
August 15th Open windows and closed doors

TOP FLOOR APARTMENT
August 15th Open windows and doors



ABSTRACTS OF CHAPTERS IN ITALIAN

CAPITOLO 1
Obiettivi globali per lo sviluppo sostenibile

Il capitolo offre una panoramica sui principali traguardi raggiunti, a livello comunitario, rispetto ai temi della sostenibilità ambientale e del risparmio energetico.
Vengono descritte le principali iniziative che, a partire dalla crisi energetica degli anni '70, sono state promosse dalla comunità internazionale per ridurre le emissioni di gas serra nell'atmosfera e promuovere un modello di crescita sostenibile, tanto nei paesi sviluppati che in quelli in via di sviluppo.
Particolare attenzione viene rivolta all'incidenza del settore delle costruzioni e, nello specifico, alla posizione dell'Italia e del Brasile, mettendo in luce le principali opportunità che il mondo dell'edilizia offre, oggi, per la tutela dell'ambiente e per il raggiungimento di maggiori livelli di coesione sociale.

CAPITOLO 2
Quadro normativo sull'efficienza energetica e la salvaguardia ambientale: Italia e Brasile

Il capitolo descrive l'iter normativo seguito, negli ultimi decenni, dall'Italia e dal Brasile per la definizione di obblighi di legge, standard e indicazioni finalizzate al controllo dei consumi energetici negli edifici, nonchè le principali misure da adottare per la salvaguardia ambientale, evidenziandone limiti e potenzialità.
Vengono descritti i principali strumenti per la certificazione energetica degli edifici che fanno capo ai due paesi ed i relativi parametri ambientali e/o energetici tenuti in considerazione.
Rispetto al quadro normativo italiano, si fa riferimento, inoltre, alle recenti misure normative adottate per il recupero degli spazi urbani e degli edifici attraverso l'uso della vegetazione.

CAPITOLO 3
Clima, microclima e ambiente costruito

Nel capitolo vengono affrontate le tematiche ambientali che fanno capo al sistema climatico, mettendo in evidenza le relazioni che intercorrono tra clima, riscaldamento globale, microclima e ambiente costruito.
Viene fornita la descrizione del clima in base alle principali classificazioni climatiche (Köppen-Geiger e da Troll-Paffen) al fine, anche, di individuare le caratteristiche climatiche comuni al sud Italia e alle aree subtropicali del Brasile che giustificano la scelta dei due paesi come aree oggetto di studio.
Alla fine del capitolo sono analizzati i parametri che caratterizzano il microclima e le cause del fenomeno "isola di calore" nelle città.

CAPITOLO 4
Comfort e controllo ambientale

Il capitolo fa riferimento ai principali studi condotti sul comfort ed, in particolare, sulle relazioni che intercorrono tra comfort ed ambiente costruito, indagate a partire dagli anni '60 con l'elaborazione dei primi modelli di comfort -*Selective* ed *Exclusive*- applicati alla progettazione architettonica.
Vengono analizzati i principali sistemi per l'incremento del comfort, la mitigazione del microclima e il raffrescamento passivo degli edifici e, infine, vengono descritti i principali metodi utilizzati per la valutazione del comfort secondo gli standard internazionali (modello statico e modello adattivo).

CAPITOLO 5
L'uso della vegetazione nell'ambiente costruito

Nel capitolo vengono descritte le ricadute ambientali che l'uso appropriato della vegetazione può avere per la mitigazione del microclima e l'ottimizzazione del comfort indoor, nonché i benefici sociali ed economici.
Viene fornito un quadro di approfondimento sui principali sistemi di *Building-Integration Vegetation* (*green walls, living walls* e *green roofs*), evidenziandone le caratteristiche tecniche anche attraverso schede descrittive che mostrano alcuni prodotti esistenti oogi sul mercato.
Alcuni casi emblematici di applicazione della vegetazione in progetti a scala di quartiere e/o di edificio, ai fini della mitigazione del microclima e dell'incremento delle performance energetiche degli involucri edilizi, vengono esaminati nel terzo paragrafo.
Infine, viene fornita la descrizione del software di simulazione ENVI-met, utile per la valutazione dell'efficacia della vegetazione sull'incremento del microclima urbano ed utilizzato in questo lavoro di tesi sul caso reale descritto al Capitolo 8.

CAPITOLO 6
Social Housing Sostenibile

Il capitolo indaga il tema del Social Housing in Europa ed in Brasile, in relazione soprattutto all'attuale crisi economica e alle dinamiche che ne hanno ridefinito i parametri di progettazione e gli attori coinvolti nel processo di finanziamento, gestione e manutenzione.
In relazione al caso italiano, viene descritto sinteticamente il contesto storico in cui si inserisce la nascita dello IACP e la sua evoluzione fino ai nostri giorni, nonchè le recenti iniziative di social housing indirizzate verso la sostenibilità ambientale e l'efficienza energetica.
Allo stesso modo, sono esaminate le principali iniziative portate avanti dalle amministrazioni brasiliane e/o da enti internazionali per la promozione di pratiche sostenibili per il progetto del Social Housing e la riqualificazione delle *favelas* in Brasile, riportando soprattutto i casi innovativi della città di São Paulo.

CAPITOLO 7
Esempi di retrofit del Social Housing in Europa

Il capitolo ha l'obiettivo di analizzare alcuni casi emblematici di interventi di retrofit di residenze sociali europee, al fine di evidenziare i sistemi di riqualificazione utilizzati a scala di quartiere e/o di edificio, i programmi attualmente messi in atto nei diversi paesi e i meccanismi di finanziamento.

CAPITOLO 8
Proposta per la riqualificazione del complesso di residenza sociale Medaglie d'Oro a Palermo

Nel capitolo viene descritto l'approfondimento condotto su un caso reale di Social Housing individuato nell'ambito della città di Palermo, al fine di mettere a punto una metodologia per la progettazione e la verifica, tramite specifici strumenti di simulazione (ENVI-met e EnergyPlus), dell'efficacia di interventi di retrofit urbano ed edilizio, condotti a partire dall'utilizzo della vegetazione. Viene considerato, nello specifico, in una prima fase l'impiego di diverse specie vegetali (alberi, arbusti ed erba) per la riqualificazione degli spazi esterni e la mitigazione del microclima e, in una seconda fase, l'utilizzo di sistemi *BIV* (pareti e tetti verdi) per il retrofit degli edifici e l'incremento del comfort termico indoor durante i mesi estivi.

Contemporary cities are more than ever committed to tackle environmental challenges such as the attenuation of the urban heat island phenomenon and the renovation of a large building stock characterized by low indoor comfort levels and increasing energy consumption caused by air conditioning.
Starting from this assumption, this thesis aims at identifying sustainable strategies for the retrofit of Social Housing in temperate areas, with focus on the use of vegetation for the mitigation of the microclimate and the improvement of indoor comfort, in an attempt to encompasse, crosswise, developed and the developing countries.
Through the analysis on a real case of social housing in the city of Palermo, with the use of specific simulation tools (ENVI-met and EnergyPlus), the thesis develops a methodology for the design and the assessment of the effectiveness of plants and Building-Integrated Vegetation systems (vertical gardens and green roofs) used for urban and building retrofit interventions.

Luisa Pastore (1985) graduated in Architectural Engineering at the University of Palermo. She spent the triennium of her doctoral studies between Italy, Brazil and Denmark, where she specialized in sustainable architecture, with focus on the energy retrofit of the existing building stock. Some of her works have been published in books, conference proceedings and journals. Since 2013 she is co-founder of a technological startup and spin-off of the University of Palermo which deals with innovative and energy-efficient building components.