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CLIMATE CHANGE AND THE BUILT ENVIRONMENT

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PREFACE

Since the first meeting of CIB W 108 (climate change and the built environment) in Manchester in 2002, the interest for the issues on adaptation to climate change impacts has been growing in several countries. This question is now addressed at the European level.

When it became more and more likely there was a link between green house gazes (GHG) emissions and potential climate change, the response of our societies was to "turn off" the GHG tap. Two main emitters were identified: transport and the built environment.

Mitigation policies were rather quickly decided. More demanding energy regulations for both new and existing buildings were elaborated and are being implemented since the beginning of the century.

The expected benefits of these policies on climate change mitigation are nevertheless long term and rely on a generalisation of the prescribed measures in all countries at a comparable rate in order not to dilute the efforts of the most efficient countries.

The most recent IPPC reports as well as recent observations confirm that climate change could occur faster than expected. Irrespective of the success of mitigation efforts, there will still be some degree of unavoidable climate change.

As the built environment aims at protecting human populations and goods from climatic hazards, the perspective of mid term modifications of climatic hazards has then to be considered.

This is the aim of adaptation policies: anticipate now the potential (positive or negative) impacts on the built environment due to a modified climate.

The problem is complex as it concerns local long term decision making in a very uncertain global environment. Moreover, such a reflexion cannot, and must not, be disconnected from on-going reflexions and actions on sustainable construction.

The convergence is quite obvious as both climate change issues and sustainability aim at limiting the burden on environment.

CIB W 108 intends to contribute to the elaboration of these adaptation policies to be developed as far as the built environment is concerned. This expert group will in particular contribute to produce knowledge on technical aspects as well as on socio-economic aspects, including costs and benefits of different adaptation options and information on good practices.

CIB W 108 members committed themselves to produce in 2010 a report on adaptation policies in members' countries.

This 2009 W 108 seminar kindly hosted by the Politecnico di Milano reinforces the creation of a stable community on the important issue of built environment adaptation to climate change impacts.

Jean-Luc Salagnac
Coordinator of W 108

Adaptation to urban climate change through design: Early best practices in the tropics and future directions

Rohinton Emmanuel[1]

T1 – Adaptation Strategies and Techniques

ABSTRACT

The haphazard urbanization in much of the tropical belt imposes climatic stresses over and above those imposed by the global and regional climate changes. Primary causes for such urban climate changes are design- and planning-related. While this leads to hope for mitigatory actions, the fact that urban warming is being super-imposed on regional and global warming suggests adaptation is key. The net effect of urban climate changes super-imposed on regional changes in tropical cities is the increasing need for building cooling energy. At the same time, there are cool spots that are the serendipitious by-products of urban geometry (shade enhancement), ventilation patterns, urban parks and light colored urban surfaces. An urban design paradigm that responds to the changing climate by dynamically manipulating the urban morphology is therefore needed. This paper provides early best practice examples and examines the quality-of-life implications of an urban cooling approach for the rapidly growing tropical megapolii. It also explores the next steps, including data needs of rapidly growing tropical cities to mitigate both the urban heat island problem as well as the over-arching regional/global climate change.

KEYWORDS

Urban heat island, tropical cities, cooling strategy, climate change adaptation

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1 INTRODUCTION

The unprecedented rate of urban growth and the sheer size of urbanization in the tropics imposes an urban climate stress over and above that of the "natural" climate which in itself was long considered "problematic" [cf. Trewartha, 1981]. This problem is now being further stressed by the anthropogenic regional and global climate changes. The nature and scale of the problem are delineated by the large numbers of urban dwellers having to be accommodated within tropical urban hotspots and the relatively short time span available to do so. At the same time, cities offer an opportunity for planners, policy makers and designers to enhance the quality-of-life of a large segment of humanity within geographically and politically well-defined boundaries. As humanity turns its attention to adapting life and livlihoods to climate change, an opportunity is presenting itself to enhance the quality-of-life of a large number of people in a region that is both part of the problem and, thankfully, its solution. However,the successful achievement of this goal not only calls for new design paradigms but also data regimes that go beyond the domains of conventional weather station.

2 TROPICAL URBAN CLIMATE

Studies in tropical urban climate are only about 40 years old [cf. Nieuwolt, 1966]. Our knowledge of tropical urban climate comes from a relatively few, but well-studied cities, including those in Brazil, Malaysia, Mexico, Nigeria, Singapore and Sri Lanka (See Emmanuel [2005] for a summary):

- Tropical cities have more intra-urban than urban-rural temperature differences [Fig. 1a]
- The day and night time urban climate variations, while different in all cities, are more pronounced in the tropics: several parts of tropical cities are cooler during the day [Fig 1a & b]
- Macro-level wind which is weak in tropical cities, are further weakened by tropical cities; yet precipitation is greatly enhanced
- Air temperature variations are usually smaller than thermal comfort variations; thus experiential awareness of urban climate anomaly is high among tropical urban dwellers
- Shading remains the key to urban climate change mitigation, followed by enhanced ventilation

On this basis, a clearer contour of the likely mitigatory approach is now emerging with respect to the urban planning and design approaches needed at the city and neighborhood level:

- Enhance shade in public places [Emmanuel, 2005; Emmanuel & Fernando, 2007]
- Devise city-level wind corridor [Ng et al., 2006, Alcoforado et al., 2009]
- Devise specific daytime strategies [Emmanuel & Johansson, 2006]
- Enlarge cool islands using a combination of vegetation, ventilation and shading

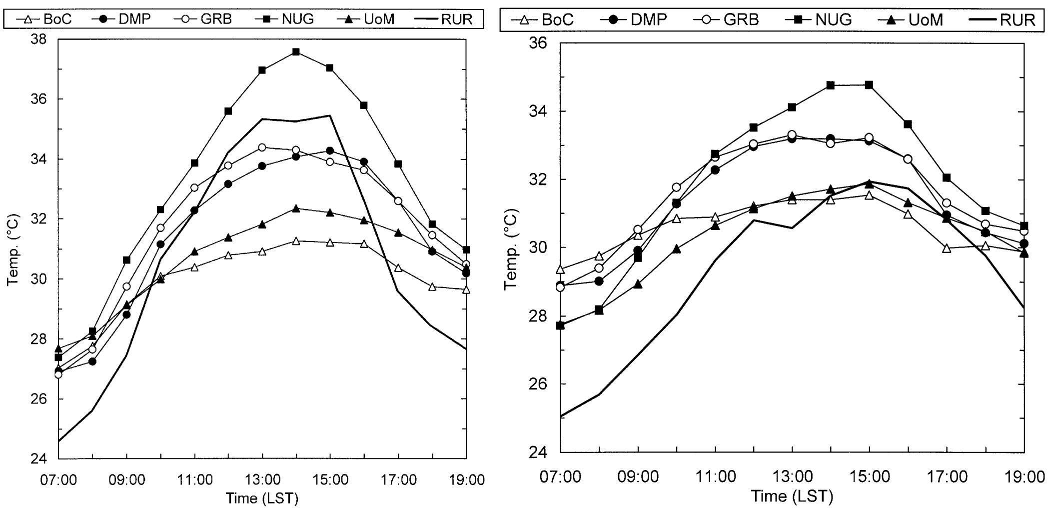


Figure 1: Intra-urban air temperature variations in Colombo (a) daytime; (b) nighttime [Emmanuel & Johansson [2006]. Note: RUR stands for a "Rural" station. Refer Fig. 2 for key

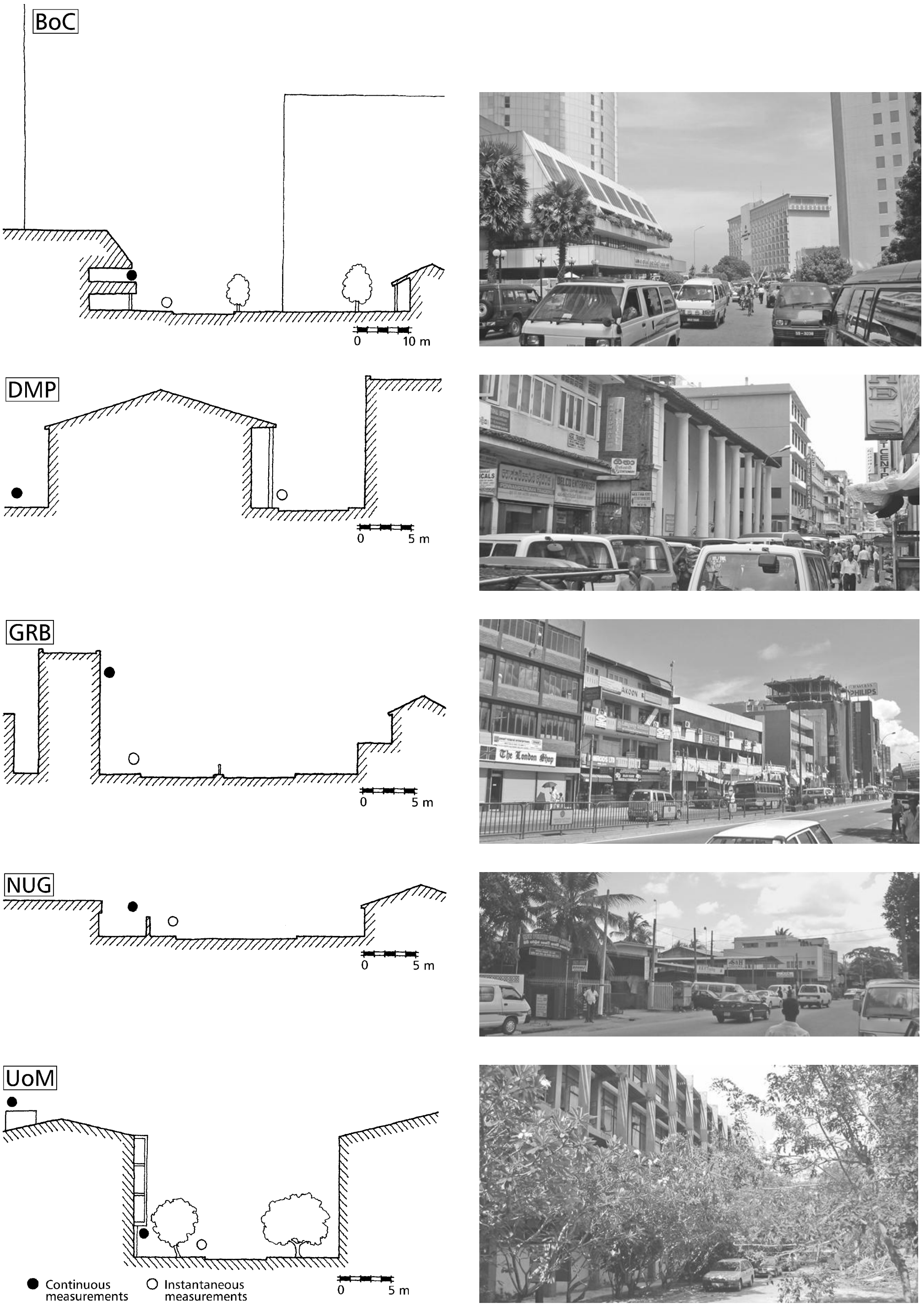
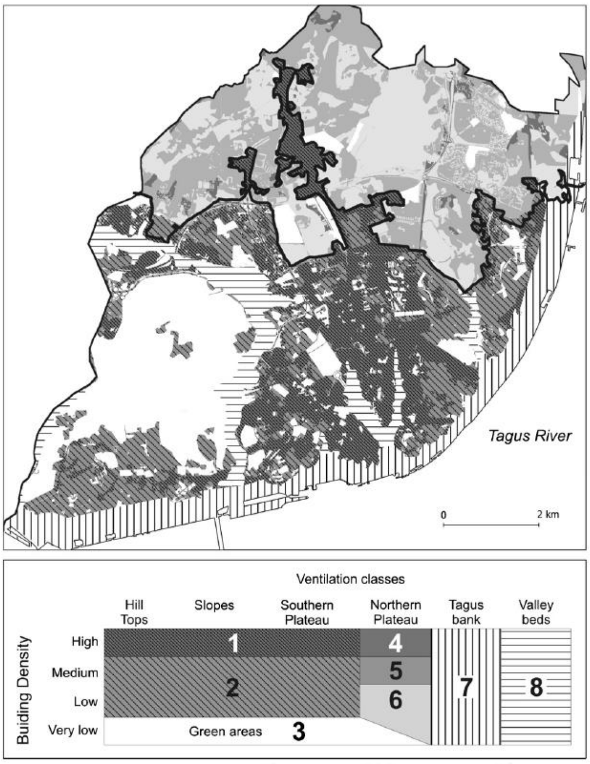


Figure 2. Urban characteristics at measurement sites in Fig. 1 [Emmanuel & Johansson, 2006]

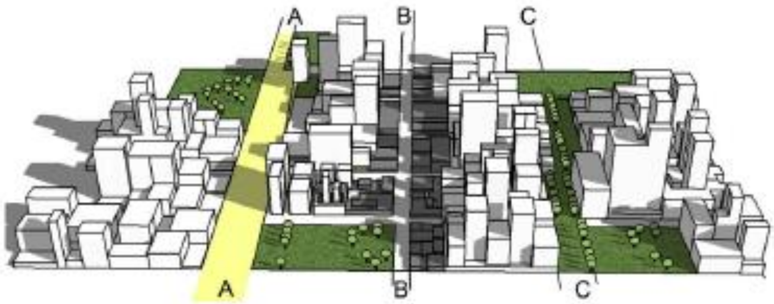
3 DESIGN STRATEGIES

The widespread theoretical understanding of the genesis and nature of tropical urban climate anomaly has led to four broad groupings of design strategies at different urban scales [cf. Fig. 3]:

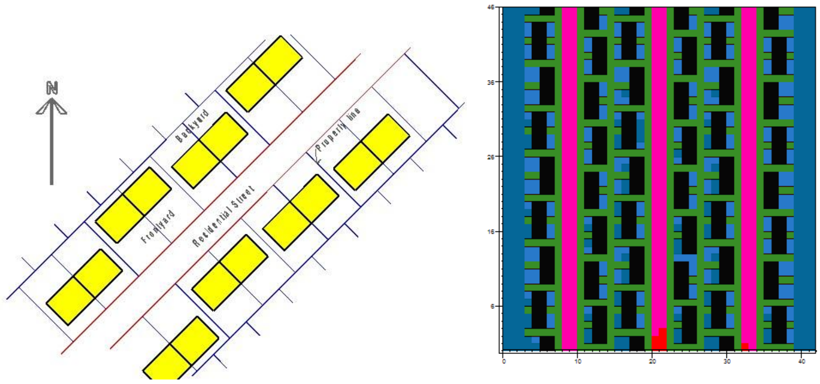
- High density form
- A city-level strategy to boost macro-level air movement
- Neighborhood-level approaches to enhance shading of public spaces
- Urban planning and design with nature (especially, water and vegetation enhancement)



(a) Homogenous climate units for Lisbon, Portugal, based on urban features and ventilation patterns – City Scale [Alcoforado et al., 2009]



(b) Urban ventilation strategies by linking open spaces in Hong Kong – Neighborhood scale [Ng, 2009]



(c) Staggered alignment to enhance neighborhood shading in Anuradhapura, Sri Lanka [Source: Author's previous work]

Figure 3: Broad urban design approaches to mitigate the heat island effect in warm places

It is thus remarkable that within its relatively short history, studies on tropical urban climate have matured to promote the above-mentioned broad themes of design strategies. While this is timely, the nature of urban design is such that re-formulation of cities and neigborhoods takes time and involves a myriad of actors working at different scales of the problem. This would have been acceptable under a 'steady state' weather, but we no longer have that luxury. Mitigatory approaches are needed to be implemented on the ground even as large-scale human migration to cities continue unabated while the regional and global climate itself is becoming warmer. In other words, the design goal (of modulating the negative climatic consequences of urbanization) itself is a moving target, as tropical cities continue their mind-boggling growth trajectories which then fuels a general warming of the background climate. Adaptation will be key to tackle this moving target.

What then are the challenges facing tropical urban climate-sensitive designers in this changing global climate? As a first attempt, a four-pronged approach is proposed in this paper:

- Adaptation is key. Reconcile to the fact that the climatic design goal is a moving target; each development must generate its own shade as cities grow and climate gets warmer;
- Start with a macro wind corridor design, and differentiate in greater details at micro- and neighborhood-scales when cities and neighborhoods grow;
- Neighborhoods do grow and die; use this rhythm to create a planned set of urban lungs that appear in derelict parts of cities as neighborhoods die, and shrink as they regenerate, while keeping an ecologically sustainable core;
- Concentrate on minimum eco-services needed for parts of cities (an urban oasis approach).

4 FUTURE DIRECTIONS

In order to effect the above outlined approach, developement in several fronts are needed. Firstly, the changing nature of global climate coupled with micro-climate variations at city level calls for more detailed and purpose-built data collection regimes [Emmanuel, 2009]. Secondly, the nature of changes are such that climate-sensitive design ought to start at local levels (as opposed to whole-city scale). Third, a greater efficiency can result if one concentrates on climatically-sensitive public places so as to enhance quality-of-life of greater number of urban dwellers [Correa, 1989]. Finally, we need to better integrate the urban climate mitigation/adaptation agenda with the goals of urban sustainability [Mills, 2006].

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Climate Change and Construction Sector SMEs: Vulnerability, Consequences and Resilience

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T1 – Adaptation Strategies and Techniques

ABSTRACT

Climate change has become one of the prime challenges the society has to face in the future. As far as businesses are concerned, it also has added one other important issue that they have to consider as part of their business planning. Climate change is of significant importance particularly to the Small and Medium-sized enterprises (SMEs), which are considered as the most vulnerable among the business community to the effects of climate change. This paper presents the findings of a literature review conducted with the aim of identifying the specific importance of climate change to the construction sector SMEs. The objectives of the paper are to identify the vulnerability of construction sector SMEs to the effects of climate change, their consequences and also to identify the importance of improving resilience and implementing adaptive measures to manage these issues. The paper also outlines the directions of a study undertaken to address these issues as part of an EPSRC funded research project titled "Community Resilience to Extreme Weather Events – CREW". The paper concludes by stressing the importance of improving the resilience of construction sector SMEs to climate change effects and also the importance of collective action in this regard.

KEYWORDS

Climate change, Construction, Extreme Weather Events, SMEs, Resilience

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1 INTRODUCTION

Experiential observations and projections into future increasingly suggest that the global climate is changing and will continue to change in future, largely due to the human interference with the environment over the past few decades. The adverse nature of the effects of climate change has made it one of the prime challenges the society has to face in the future. Given the fact that climate change will continue to happen, even if the mitigation measures are implemented now, has made adaptation to these changes a necessity for the countries around the world.

As far as businesses are concerned, it also has added one other important issue that they have to consider as part of their business planning. Among the business community, climate change is of significant importance particularly to the Small and Medium-sized enterprises (SMEs), which are said to be the most vulnerable to the effects of climate change [Crichton 2006]. As more than 90% of enterprises in construction industry fall to the category of SMEs and as they generate more than one half of employment and turnover in the construction industry, these issues are of special importance to the UK construction industry.

This paper seeks to identify the vulnerability of construction sector SMEs to the effects of climate change and to identify the importance of improving resilience and implementing adaptive measures to manage climate change risk. It briefly discuses an EPSRC funded research study currently underway to address the issue of SME resilience of Extreme Weather Events (EWEs), which are expected to increase in number and severity in future under the changing climatic conditions. The paper concludes by highlighting the importance of SME resilience to climate change effects and also the importance of collective action in achieving resilience.

2 CLIMATE CHANGE AND EXTREME WEATHER EVENTS

The Stern Review [2007] predicts that the average global temperatures could rise by 2-3^{0}C within the next fifty years leading to many severe impacts such as melting glaciers, rising sea levels, decline of eco-systems etc. In addition to the gradual change of climatic conditions, climate change is expected to increase the intensity and frequency of Extreme Weather Events (EWEs) [Munich Re 2007, Stern 2007, Environment Agency 2005]. EWEs cause significant economic and social costs annually in many parts of the world, and the costs of these events are expected to further increase in future under the changing climatic conditions. It is estimated that the global annual cost of weather damage on average is to be in the range of $200–330 billion even now [Dlugolecki 2008]. The Pitt Review [2008] discloses that there were about 200 major floods worldwide during 2007 alone, affecting 180 million people, creating 8,000 deaths and over £40 billion worth of damage. These costs are expected to further increase in future due to the increase of intensity and frequency of EWEs. Given this context, it has become a necessity to enhance the resilience of systems; especially which are vulnerable to the climate change and EWEs, in order to counteract the threat of such events and to ensure the continuous operation of those systems.

3 VULNERABILITY OF CONSTRUCTION SECTOR SMES

Although the concept of vulnerability has been used in different research traditions, a proper agreement over its meaning is still to be arrived at [Gallopín 2006]. For the purpose of this paper, the definition put forward by the Inter Governmental Panel on Climate Change (IPCC) is applicable. IPCC define vulnerability as “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes” [IPCC 2007]. It further identify vulnerability as “a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity”. Following sections briefly look at why the construction sector SMEs are specifically vulnerable to climate change and extreme weather.

3.1 Vulnerability of construction enterprises

Mills [2003] identify construction sector as "perhaps the most vulnerable" to climate change, "with exposures ranging from damage to physical infrastructure to disruption of business operations to adverse health and safety consequences for building occupants". Given the fact that a significant portion of construction activities happen in the open environment, the exposure and sensitivity to climate change is considerably high in construction. For an example, it has been predicted that there will be around 2000-3000 additional business failures in UK as a result of the disruptions caused by the recent heavy snowfall, and that businesses in construction and retail industries are the most likely to be affected [BBC News 2009]. In addition, other factors like large investment, long delivery time, long supply chains running across various industries, quite inflexible sequence of production etc participate towards the increased vulnerability of construction sector enterprises to weather extremes.

3.2 Vulnerability of SMEs

Vulnerability of SMEs arises virtually by definition from the small scale of their human and financial resources [Bannock 2005]. Thus, predictably, SMEs are considered as the most vulnerable section of the UK economy to the impacts of climate change [Crichton 2006]. In addition, previous research reveals that small businesses are not adequately prepared to cope up with the risk of EWEs and other natural hazards and to recover following an event [Tierney & Dahlhamer 1996, Crichton 2006, Yoshida & Deyle 2005, Alesch *et al*. 2001, Dlugolecki 2008]. Further, since a majority of SMEs are local in their operations and rooted in local communities [Bannock 2005], their owners are often hit twice by EWEs; as local citizens and as business owners [Runyan 2006], increasing the vulnerability to failure following an adverse event.

3.3 Vulnerability of construction sector SMEs and consequences

Being the vulnerable segment operating in a vulnerable industry sector has made construction SMEs at high risk of climate change and weather extremes. Climate change and extreme weather can create a variety of effects on construction sector SMEs including disruption to site works directly and indirectly by disrupting site deliveries and utility supplies. Hot weather conditions may increase the risk of heat exposure for workers in the construction sector, increasing health costs and reducing productivity [Burnham 2006]. Insurance may become more expensive or difficult to obtain during the construction process [Sussman & Freed 2008]. In addition to the construction sites being affected, the business premises may also get affected giving rise to costs, loss of data/information etc. Implications like ignoring climate change issues, over-reacting, being unplanned for regulations and standards may also give rise to unforeseen costs and would ultimately lead to business failure [Metcalf & Jenkinson 2005]. Although the list of consequences identified here is not comprehensive, it still gives an idea about the range of negative consequences that EWEs can create on construction sector SMEs and the need for improving their resilience to minimise these consequences.

4 IMPORTANCE OF RESILIENCE

Resilience is defined by the IPCC as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change [IPCC 2007]. In simple terms, it seems to denote the ability of a system to function as usual in the event of a disturbance and the ability to adapt to such disturbances. Being resilient will allow businesses to minimise the risk of a weather extreme affecting their business, to withstand the event if it still affects and also to recover quickly following the event. Particularly, this will allow them not only to minimise the risks, but also to capture the business opportunities arising from such an event.

Given that a significant portion of the construction activities are carried out by SMEs; more than 65% of turnover in the construction industry is generated by SMEs [BERR 2008], a resilient SME network is required specially to carry out the refurbishment, maintenance activities of the existing building stock and for reconstruction following an adverse weather event in order to allow other systems to function properly. Especially it is important that premises of other business sectors are repaired quickly for the economy to function properly following an event like flooding etc. Further, inherent advantages of flexibility and innovation associated with construction sector SMEs will allow them to exploit market opportunities for new products, construction methods which address climate change, EWEs. A recent pilot study conducted by DEFRA has found that local households increasingly prefer local contractors; which are more likely to be SMEs, to install flood defences for them. Thus, it seems that climate change and EWEs present significant business opportunities for SMEs. For them to utilise those opportunities however, they have to survive such an event successfully first. Thus, a resilient SME sector in construction is required for the economy to function as usual and to bounce back following a weather extreme.

4.1 Importance of Integrated Response

Achieving resilience in SMEs however is not an easy task given their resource constraints, perceptions/attitudes and other barriers involved in implementing such measures. Adaptation to climate change is not a high priority for SMEs currently, especially considering the current economic downturn. Further, their perception that the actions of an individual SME will not make a difference is a barrier for them implementing adaptation measures [Norrington & Underwood 2008]. If they are involved in an integrated response to climate change, it will eliminate this perception, resulting in better adaptation. Further, the pressure coming from other community partners involving their customers and competitors, authorities etc will also positively affect the uptake of adaptive measures by the SMEs. More importantly, the solutions reached in collaboration with all the major stakeholders of a community will lead to better and concentrated response, leading to enhanced resilience at the community level.

5 SME RESILIENCE TO EXTREME WEATHER EVENTS

As part of the Engineering and Physical Sciences Research Council (EPSRC) funded “Community Resilience to Extreme Weather – CREW” research project, we investigate how the SMEs respond to EWEs, and how their individual and collective actions along with other community groups (households and local authorities) can achieve community resilience to EWEs. The study is undertaken via a participatory approach involving SMEs and business organisations representing SMEs, to obtain a broader understanding on how to improve their resilience to EWEs. Although the focus of the research is not specifically on construction sector SMEs but on SMEs in general, SMEs in construction will be paid special attention due to the increased vulnerability of their activities to EWEs, and the significant effect that their activities have on adaptation agenda.

6 CONCLUSIONS

Changing climatic conditions are expected to further increase the intensity and frequency of EWEs, which are capable of creating a variety of adverse effects on a community affected. SMEs, which are not adequately prepared to cope up with the risk of EWEs and to recover following an event, are highly vulnerable to failure in the event of EWEs. Due to the nature of its operations, construction industry SMEs are significantly vulnerable for climate change and EWEs. EWEs can create a number of negative effects on construction sector SMEs and some positive consequences as well. Being resilient will allow the SMEs not only to minimise the vulnerability to negative impacts but also to capitalise the positive impacts successfully. Thus, improving their resilience is important in order for them to prevent EWEs from affecting them, withstand the effects and also to recover from the aftermath. This is of particular importance as the activities of the construction sector have a diffusing effect on the activities of other industries, especially in case of climate change and extreme weather.

ACKNOWLEDGEMENT

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Day-care centre and nursery school in Milano: a low energy design in temperate climate

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T 1 – Adaptation Strategies and Techniques

ABSTRACT

A new 120 children nursery school in Milan was designed as a prototype building with an extremely low energy consumption and the possibility to change its layout over the years.

The site is characterised by cold winters, hot summers and long shoulder seasons. This prompted the research and design team of Politecnico di Milano to consider this school as exemplary for similar interventions in *temperate climates*.

The main design goal, from the point of view of energy efficiency, was to extend as far as possible the period of the year when the building provides indoor comfort *without the use of additional energy*.

Very good results were obtained through the orientation and morphology of the school – with classrooms facing south – and through a very close integration between the building fabric and the mechanical systems. The envelope is thermally very efficient in both its opaque and transparent parts, allowing for heat conservation in winter, while effective shading and the enhancement of natural ventilation through solar chimneys will provide comfort for most of the warm season. Mechanical ventilation with heat recovery will be combined with an underfloor radiant system fed by a groundwater heat pump.

The school is now under construction.

KEYWORDS

Energy efficient building, strategies for warm climates, climate sensitive envelope.

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1 INTRODUCTION

While in continental Europe the basic design principles of low-energy design are well established, and are proven by thousands of working buildings, the temperate climate of Northern Italy (Milan) poses different challenges and requires a specific approach. If winters are rather cold, requiring heat conservation in the building as in central Europe, shoulder seasons tend to be mild and relatively long, while summers are characterised by high daytime temperatures and rather warm nights. A climate sensitive building in Milan, then, should broadly perform as follows:

- reduce heat loss and exploit solar energy in winter;
- be neutral in the mid-seasons, when outdoor temperature is comfortable and keeping windows open is enough to feel good inside;
- provide good shading and ventilation (protection from overheating) in summer, at least in non-extreme weather conditions, when cooling systems can be avoided.

In particular, the building envelope – and especially the transparent elements – should be able to modulate the energy and mass flow according to the season (solar gain, shading, night heat loss, ventilation, etc.).

All these issues were the starting point for the design of a day-care centre and nursery school for the City of Milan, that a multi-disciplinary group of Politecnico di Milano developed in 2005-06 in the framework of a research project funded by the State (PRIN 2004).

2 DESIGN GOALS

In approaching the design, the overall goal was to provide very good comfort levels, in all seasons, while minimising the environmental impact of the building. This was related, in particular, to fossil energy use, that is a critical issue in a polluted large city such as Milan. The whole design process was informed by the following hierarchical principles:

- reduction of the fossil fuel use ("*be lean*");
- increased use of renewable resources ("*be green*");
- rational use of energy ("*be clean*").

These were transformed in a design approach that put particular emphasis on the idea of extending the period of the year when the building provides indoor comfort in free running mode. The idea that drove the design was "heating the whole childhood centre with a heating system sized for a single apartment". Concentrating on the passive design of the building was all the more important given the expected increase of global temperatures in the next decades, so future-proofing was another concern of the design team.

It was immediately apparent that this challenging task required, from the start, a very close integration of architecture and engineering issues. The main issues about the integrated design approach included an architectural language embedded with the mechanical and structural concepts and an internal layout that would enhance cross ventilation (for the mild period of the year). Moreover, dynamic simulations were to be performed to predict the energy consumption for heating and cooling and the consequent carbon emissions.

3 SITE ANALYSIS AND LAY-OUT OF THE BUILDING

The site of the new building lies close to the edge of the city, in a North-West sector crossed by railways. A former school building, dating from the 1960's, occupied the site but was destroyed by a fire in 2005. The area is roughly square, with the sides running diagonally at 45° from the North. A row of tall trees runs on the South-East side, providing some shelter from the low morning sun, while some residential blocks lie East and do not provide any obstruction to the site.

One of the early decisions was, thus, to orientate the building with the long side containing the classrooms facing almost perfectly South (fig. 1). This would facilitate solar control on the glazing to the classrooms, allowing for some winter sun to enter the building, while making summer shading easier thanks to the higher position of the sun in the sky.

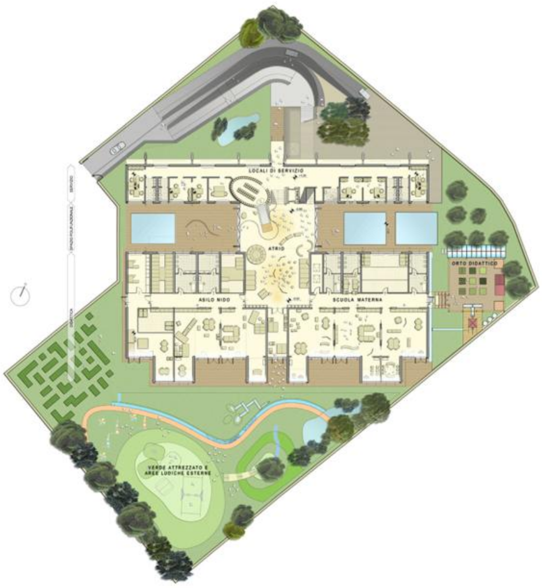

Figure 1. Ground floor plan of the school.

a

b

Figure 2. Scheme of functions and cross section of the building.

The building includes a day-care centre, a nursery school, a "baby parking" space and the associated administrative space. The floor area of the final design is 1 800 m^2 and is designed to accommodate 120 children. The building is organised loosely in the shape of an H, with the larger wing accommodating the learning spaces on a single floor, and the northern one devoted to offices and support spaces stacked on three levels. The link between the wings is the double-height atrium, designed to enhance natural ventilation and to host common activities (Fig. 2a).

The abundant underground water resources prompted early discussions with the design team about the possibility of exploiting this source for heating and cooling of the building, using a water-to-water heat pump. A study into the underground water chart showed that both the water table under the project site and a nearby canal, suitable for collecting the waste water, were available.

The use of a heat pump had a great potential for the reduction of the environmental impact of the building, because of:

- the high thermal performance it can deliver (both in winter and, if required, in summer with a reverse cooling cycle);
- the absence of direct CO_2 emissions, while electrical power used can be offset with photovoltaic panels (net zero emissions);
- the active contribution in controlling the water table level (a recent concern in Milan) and the potential for the revitalization of the nearby canal.

4 PASSIVE DESIGN AND BUILDING ENVELOPE

4.1 Passive solar design

The building incorporates a range of passive environmental design concepts, aimed at reducing the use of fossil fuels and the consequent carbon emissions.

In the main, single-storey wing, classrooms face South in order to maximise heat gain from the sun during winter time, while the North-facing services (i.e. the kitchen, the laundry rooms, the dormitory areas) act as a thermal buffer. The size of the classroom windows was defined balancing solar gain in winter and protection from overheating in summer: in fact, due to the high internal gains in classrooms, shading was required to avoid uncomfortable temperatures even in the shoulder season. This is why the size of windows was limited to the regulatory requirement (1/5th of the floor area) and shading was provided not only from the top, but also from the sides thanks to boxes containing laboratories.

The three-storey block at the back of the complex, containing mainly offices, is more exposed to direct solar radiation and is shaded with external retractable blinds, allowing for local adjustment of lighting conditions and control of glare inside the building.

4.2 The envelope of the building

The envelope of the building was designed to minimise heat losses during the winter, adopting insulation levels that are significantly higher than the ones required by the national legislation in force during the design phase (D.Lgs. 192/05, first national implementation of EPBD).

Table 1. U-values of the envelope components (all values in $W \cdot m^{-2} K^{-1}$)

Component	From 01/01/2006, national legislation	From 01/01/2008, regional legislation	School, via Brivio, Milano
Opaque vertical	< 0.46	< 0.34	0.28
Opaque horizontal	< 0.43	< 0.30	0.26
Windows	< 2.40	< 2.20	1.43

Cavity construction on a metal sub-structure was adopted for most of the envelope in order to integrate the insulation layers in a relatively thin wall. Cold bridges were eliminated through the use of two independent structures and a continuous layer of thermal insulation just behind the external cladding. A ventilated cavity behind the rain screen cladding reduces the thermal load on the walls due to solar radiation in summer.

The energy concept that was adopted is based on a very insulated, lightweight envelope that keeps heat loss by transmission at very low levels, while thermal mass is provided in the concrete floors that receive solar radiation from the windows.

4.3 Natural ventilation

The position of the windows and the shape of the building (e.g. the tilted roof of the double-height atrium, fig. 2b) are specifically designed to enhance natural ventilation (by cross ventilation and stack effect), improving comfort conditions in free running mode. This strategy will also be implemented through a solar chimney installed at the top of the atrium roof. Each of the two units of the chimney includes three channels 1 m x 0.20 m each, realized in 0.2 mm steel sheet painted black. The chimney is divided in three segments, each with a different inclination in order to optimize the performance of the system with varying heights of the sun. The six inlets of the chimney ducts are managed by the control system of the building and their step-by-step operation allows for the regulation of the air flow. The solar chimney was analysed with TRNSYS and the Alfonso & Oliveira simplified formulas.

5 MECHANICAL SYSTEMS AND CONTROLS

Winter thermal comfort conditions are provided by a mechanical ventilation system with heat recovery, coupled with radiant panels in the floor. This combination minimises electricity consumption in pumps and fans. Floor radiant systems allow both for lower air temperature – thus reducing overall energy consumption – and for high levels of thermal comfort, as the mean radiant temperature is higher than with conventional systems. Moreover, the warm floor surface is particularly suitable for children playing around.

A groundwater heat pump system supplies both hot water in winter for space heating and DHW and chilled water for cooling during the warmest parts of summer. During most of the year, a 20 m^2 surface of evacuated solar thermal collectors, located on the tilted South-facing roof, is sufficient to provide hot water for DHW.

In the area of the roof looking South, the aluminium sheets are combined with a system of solar power generation using a laminated photovoltaic system that will partially offset the electrical consumption of the building.

One of the strategies underlying systems design was to avoid the over-use people often do of energy supplies (e.g., leaving windows open or lights switched on). Each space of the school will be equipped with presence detectors coupled to daylight sensors, controlling both the electricity and the thermal energy supply. The flow of primary air supply will be regulated by presence and CO_2 sensors, while it will stop when windows are open thanks to contact detectors. Artificial light will only be used as an integration to natural light, thanks to the daylight sensors that will regulate dimmers on the lamps: the overall lighting level will be that required for the specific tasks, without any over-use of electricity.

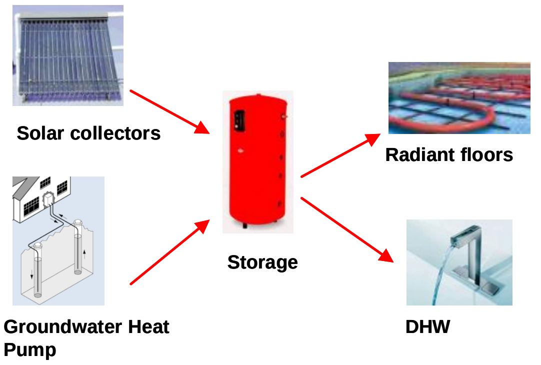

Figure 5. Concept of heating system.

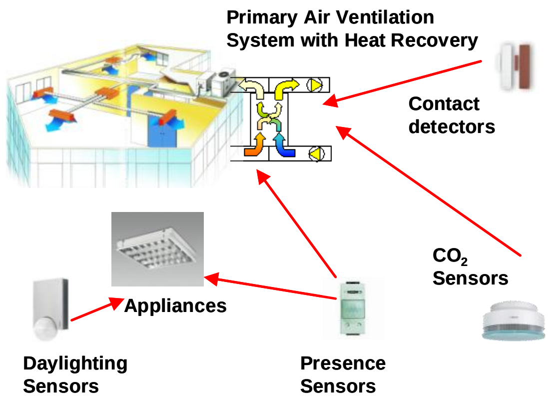

Figure 6. Concept of control and system integration.

6 ENERGY SIMULATION

The energy strategies were evaluated using VisualDOE v. 4.1, building energy simulation software based on DOE-2 dynamic code (v. E-119). The building volume was divided in ten macro-thermal-zones, based on orientation, position in the building, use, occupation schedule and related HVAC systems. The simulations were performed on an hourly basis (TRY climatic data), taking into account solar radiation, shading coefficients and internal gains based on the occupation patterns of the rooms over the whole year. The latter also determine whether the systems are working or not, as these are activated by the presence of people. In order to simulate the presence of the radiant floor heating, the indoor air set points have been appreciatively considered two degrees lower than the conventional values. Calculations were performed over the gross areas of the single macro-zones.

Significant electrical energy savings (30%) were obtained thanks the control systems: the comparison of the annual demand patterns with a conventional school are shown in picture 8. From the thermal point of view, 20 $kW \cdot h \cdot m^{-2}$ is the calculated annual heating energy load for the building (this includes 5.5 $l \cdot s^{-1}$ per person as minimum primary air supply, with 70% heat recovery efficiency). The monthly energy loads are plotted in picture 7.

For the entire winter season, a consumption of 8043 kW·h of electrical energy for the groundwater heat pump was estimated. Referring to a conventional gas heater, calculations showed a reduction of 53% of primary energy (national grid has 39% efficiency) and 50% of GHG emission respectively.

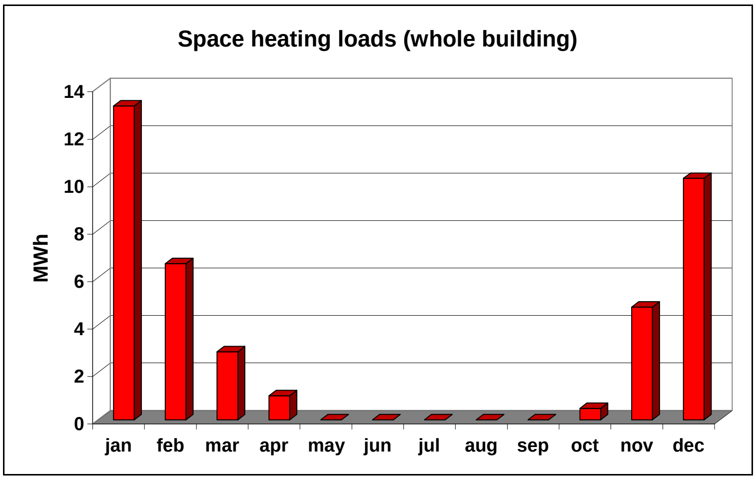

Figure 7. Monthly heating energy demand.

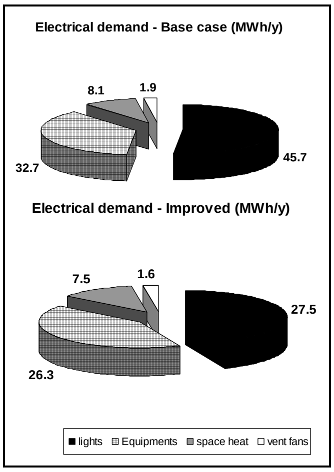

Figure 8. Comparison of electrical demand patterns.

7 CONCLUSIONS

In current practice, energy efficiency should be a key issue in a building design process. This, in fact, is the only possibility to supply energy to the building from renewable sources only, or to offset carbon emissions with an equivalent quantity of energy sold to the grid. This goal requires an integrated design approach since the initial phases of the project.

The design of this case study started from the optimization of the building orientation and internal layout in relation to solar radiation. The coordinated design choices about envelope, thermal mass, ventilation and mechanical systems mean that in summer and mid seasons the building should provide higher thermal comfort if compared to a conventional building. Solar panels provide carbon-free hot water for domestic use and, in part, for the supply to the radiant system, while photovoltaic panels will partially offset electricity from the grid. The balance between a high-quality envelope and small-size systems kept the overall cost of the building in the normal range for a standard public school.

This building can thus be seen as a step forward in the definition of energy-efficient, low-carbon solutions for a temperate climate and an urban site, even though it is clear that "green building" solutions cannot be replicated without adaptations in other situations.

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House for a charity in Lodi: a model of energy-efficient building in the climate of Pianura Padana

Ettore Zambelli[1], Matteo Ruta[1]

T 1 – Adaptation Strategies and Techniques

ABSTRACT

This experimental building located in Lodi (Italy), opened in April 2008, hosts a community for young people, offices and a small conference hall.

This building was designed as a model for an energy-efficient mixed-use building in the temperate climate of Pianura Padana. It is characterised by a very small winter heating demand, a limited cooling need and the passive exploitation of the external conditions during shoulder seasons.

In particular, energy efficiency during the heating season is given by a very insulated envelope (average U-value of 0.11 $W \cdot m^{-2} \cdot K^{-1}$), high-performance windows (average U-value of 1.4 $W \cdot m^{-2} \cdot K^{-1}$), south-facing glazed elements that improve direct solar gains and thermal storage capacity in the concrete floors. Underfloor radiant systems are used to maintain the indoor comfort conditions.

During the cooling period a large central skylight, located above the double-height living area, can be opened to promote natural ventilation. Overheating is prevented thanks to shading from the shape of the building itself, from the "umbrella roof" and from innovative shutters. The installation of a "solar façade", which incorporates PV panels, allows for the exploitation of renewable energy.

The building is A-rated according to the labelling scheme of Regione Lombardia and has earned three prizes for energy-efficient architecture.

KEYWORDS

Energy efficient building, strategies for warm climates, climate sensitive envelope.

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1 INTRODUCTION

This experimental building located in Lodi, in Northern Italy, which officially opened in April 2008, will hosts a community for young people, offices and a small conference hall (Fig. 1). The object is one of the first examples of a low-energy building in the area and, in general, an example of limited energy consumption building in a temperate climate. It is characterised by a very small winter heating demand, a limited cooling need and the passive exploitation of the external conditions during mid-seasons.

Figure 1. North elevation: the variety of the volumes and the materials that compose the complex.

This small but singular building seems to have the willing to strongly express the result of the fusion of three design guidelines: energy saving, experimental technological innovation and the search for a subsequent architectural characterisation. These definition can be easily read in this architectural organism that is blatantly didactic and they have resolved in a synthesis.

The lay out of the spaces is functional and appropriate (in relation with the particular category of users): all gravitate around a double-height living room which is the real focus of the collective life to be spent in the centre: a large kitchen, the dining room that has been conceived as an extension of the living room and acts as a filter toward the covered outside space where in the summer it is possible to put the dining table: the bedroom for the children and for the teachers; the balcony on the first floor overlooking the living room; the toilet areas. The ground floor of the public spaces (conference hall, the library and the offices) is segregated and separated not only by the architectural form and by the colours but also by the entrance since a independent flow of external and internal users has been devised both towards the office and towards the conference hall (Fig. 2).

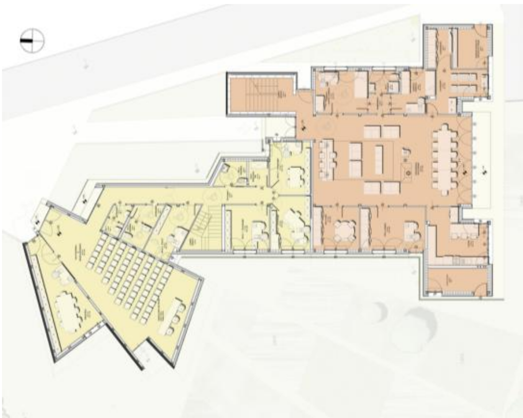

Figure 2. Ground floor plan.

The energy savings and the technological innovation are already evident in the lay out and the morphology of the building. This faces south with a solar wall equipped with photovoltaic panels installed; it also allows for natural ventilation through a skylight and thanks to the double height living room. Different technological innovations have been used in the design for this centre: composite structure of steel and lamellar wood; vertical enclosures composed of sandwich panels of wooden sheet with inserted polystyrene and finished by various typologies of ventilated walls that are hanging from horizontal panels (these panels are composed for 12 cm polyurethane with ventilating supporting runners that remove cold bridges); windows with high insulation (U = 1.1 $W{\cdot}m^{-2}{\cdot}K^{-1}$); metal roofing lifted from the hyper-insulated "box" of the body of the building in order to efficiently intercept the summer solar radiation and inclined towards the inside to facilitate the collection of the rainwater to irrigate the allotments and the gardens; underfloor heating. The willing to experiment new technologies has also suggested the adoption of different materials for the ventilated envelope: fibre cement with different colours, terracotta tiles and prefabricated render.

The objective of energy saving and environmental comfort is the one that has been most actively sought after also through the contribution of various engineering work streams and with the scientific support of BEST Department of the Politecnico di Milano as well as the significant assistance of the manufactures that provided the supplies for the project. This project consisted in a strongly experimental process that has involved different manufacturers and suppliers interested in contributing to a very interesting programme as well as testing the application of their most innovative solutions.

2 DESIGN STRATEGIES

The main design goal of the experimental programme was to create a building with extremely low energy consumption and lmited environmental impact, not just importing design strategies from central Europe, but adopting an approach suited to the temperate climate of Northern Italy.

In particular, energy efficiency during the heating season is given by a very insulated envelope (average U-values of 0.11 $W{\cdot}m^{-2}{\cdot}K^{-1}$), rain screen façade, windows with thermal break (in wood and aluminium, with average U-values of 1.27 $W{\cdot}m^{-2}{\cdot}K^{-1}$), south-facing glazed elements that improve direct solar gains and thermal storage capacity in the concrete slab floors. Under floor radiant systems are used to maintain the indoor comfort conditions. During the cooling period a large central skylight (shaded with external roller blinds when required), located above the double-height living area, can be opened to enhance natural ventilation (Fig. 3).

Figure 3. Longitudinal and trasversal section.

Overheating is prevented thanks to shading from the "solar façade" (facing South), from the "umbrella roof" and from innovative, adjustable shutters. The installation of a "solar façade", which incorporates PV panels (estimated energy production of the photovoltaic system: 1.6 kWp) and ready for hot water generation, allows for the exploitation of renewable energy (Fig. 4).

Figure 4. Detail of the inclined wall with integrated photovoltaic panels.

There are various systems that regulate the solar contribution whilst reducing the energy consumption of the building during the summer and winter periods. The inclined roofs (wings) that project up to 2.20 m and the facades (the overall cantilever is of about 3.50 m) enable a natural shading during the summer hottest hours when the solar irradiation is at its peak and allow the use of the free solar gains during the winter months. The testing of technological facades solutions led to the design of a new shading system to protect the transparent vertical enclosures: a "technological shutter" that will be soon installed allowing to increase, when shut, thermal insulation and to control sun light radiation (light flow and thermal radiation). The system is composed of an aluminium frame and thin adjustable blades made of a fibre cement panel (that reminds of the façade cladding) and polystyrene. This has a double function: to shade the solar radiation in its two vertical and horizontal components. The vertical radiation is stopped thanks to the orientation of the blades whilst the horizontal is reduced by blocking systems that allows the shutter to open towards the outside. The skylight at the centre of the roof of the double-height living room allows during the course of the day a good luminous comfort (500 lux) thus reducing the energy consumption as a result of the artificial lighting. To avoid overheating and any greenhouse effect external roller shutters have been installed with sensors that control the light requirements and the incident radiation. Any active cooling system is made unnecessary because of performances of the building fabric.

Energetic and thermal simulations show the synergy between transparent openings, insulated opaque envelope, shading systems, thermal mass and mechanical systems in order to limit the energy consumption to 24 $kW \cdot h \cdot m^{-2} \cdot y^{-1}$. These values are well below Italian standards and place this building in "A class" according to the rating system adopted in Lombardy.

Table 1. Energetic values

Heated gross Volume	*3101 m^3*
Net area	*723 m^2*
Heat loss surface	*1887 m^2*
Ratio S/V	*0.61 m^{-1}*
CO_2 emissions	*3.5 $Kg \cdot m^{-3} \cdot y^{-1}$*
Primary energy use	*6 $kW \cdot h \cdot m^{-3} \cdot y^{-1}$*
U-value average walls	*0.11 $W \cdot m^{-2} \cdot K^{-1}$*
U-value average roof	*0.22 $W \cdot m^{-2} \cdot K^{-1}$*
U-value basement slab	*0.34 $W \cdot m^{-2} \cdot K^{-1}$*
U-value average windows	*1.27 $W \cdot m^{-2} \cdot K^{-1}$*

The whole building is going to be monitored to control the achievement of hygrometric and thermal comfort and the reliability of the design approach used, but it is already prize-winning with Next Energy Award 2006 and EuroSolar 2006. The efficient and passive behaviour of this building is the result of an accurate and integrated design by a research group at Politecnico di Milano, led by Prof. Ettore Zambelli with Matteo Ruta, Matteo Brasca, Gabriele Masera and AIACE (Milan).

3 INNOVATIVE INSULATING PANEL

The experimental building in Lodi was the opportunity, for the same research group, to test new technologies including, among the others, an innovative insulating system for ventilated façades (rainscreen cladding). Starting from an existing system for roofs (composed by a metallic profile integrated to a polyurethane panel encased by an embossed aluminium cover) the idea was to try to use it in vertical position, for façades. The work started with discussion and investigation on the geometry of the panel. The goal was to set the best dimension and thickness of the panel, to customize it to different façade claddings and fit it to the typical joints (corner, windows etc). Theoretical research followed with mechanical studies and experimentations: the horizontal metallic profile had to be correctly dimensioned to easily fix the cladding, to support the loads and to resist in time. The last step of this phase was to optimize the shape of the metallic channel from the point of view of both economy and air movement in the cavity (with CFD calculations), in order to provide a correct ventilation, and a reasonably cheap substructure. The result of this research is a new product, light and quick to install, cheap, adaptable to different cladding materials (fibre cement board, terracotta tiles, rendered panels, etc.), easily recyclable and maintainable, durable and performing. These elements are already available on the market since the beginning of 2009 (Fig. 5).

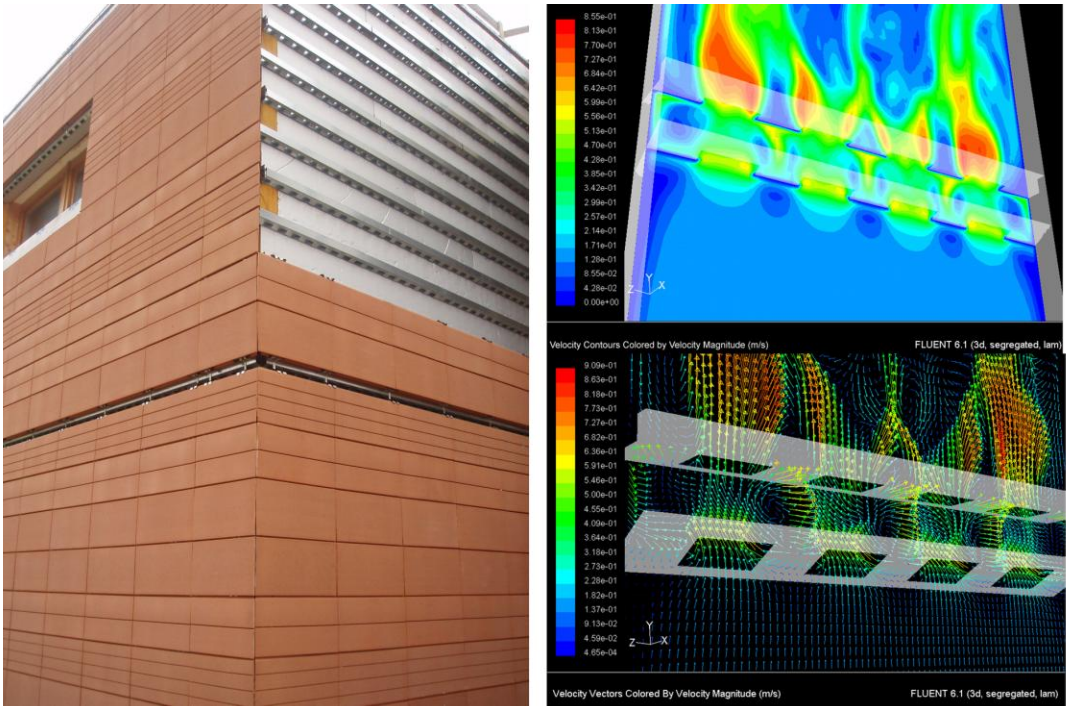

Figure 5. The new insulating panel: a picture from the building site and image simulations of the natural ventilation.

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Effects of tall building envelope technologies and design strategies on the urban microclimate in hot arid regions

Sameh Monna[1]

T2 – Mitigation Strategies and Techniques

ABSTRACT

The effects of tall building envelopes on urban microclimate are enormous, as tall buildings cast many shadows on the other buildings and streets, the use of green walls and roofs affects the microclimate air temperature, the highly glazed buildings facades can flash brilliant reflections, tall buildings in different orientation can block or channel the wind creating artificial wind patterns, and the massive amount of concrete and pavements contribute to the urban heat island.

This paper is directed to the study of various tall building envelope technologies and design strategies and their influence on the hot arid urban microclimate. The effects of coating materials with high and low albedo on the air temperature, surface temperature and urban heat island, the tall buildings large scale have a significant influence on the urban microclimate due to the large mass of concrete, glass and steel used in tall building envelope; these cause the so called urban heat island. On the other hand, some technologies and design strategies have a positive influence on the urban microclimates, like: the use of green walls and roofs, shading elements, self shading and orientation. It's found that these could decrease the urban heat island in hot arid climate.

KEYWORDS

Urban microclimate, building envelope, tall building, design strategies, technologies

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1 INTRODUCTION

1.1 Tall and high rise buildings

ASHRAE technical committee for tall buildings defines tall buildings as those higher than 91 m height. "*We can define a high-rise building as essentially a tall building with a small footprint and small roof area with tall facades*" [Yeang, 1999]. The building can defined to be high or low rise with respect to the height of the surrounding building, for example if the buildings in the city are around 4 stories then 12 stories or more may be a tall buildings. In some cities like New York and Hong Kong the tall buildings are 40 stories plus, the council on tall buildings and urban habitat CTBUH consider 150 meter and above as a high rise building.

Tall buildings have unique engineering façade and systems, these systems make tall building different from low-rise building and need attention in design, construction and use phases. "*Special attention needs to be focused on the ecological design of the skyscraper building type more than on other intensive urban building, in which many of the well-known ecologically responsive technical solutions are common*" [Yeang, 1999]. The reason that this kind of building has large effect on the built environment and urban microclimate; tall buildings cast many shadows on the other buildings and streets. In addition, the highly glazed buildings facades can flash brilliant reflections, streets lines with tall buildings can block or channel the wind create artificial wind patterns, massive amount of concrete and pavements contribute to the urban heat island and increase the local air temperature. These factors have an effect on the energy demand for tall buildings cooling and heating.

1.2 Environmental effects of height

Because the atmosphere (from the sea level to 11 km) changes with altitude, The temperature decrease with altitude with a rate of 1°C per 150 m, barometric pressure decrease more slowly and wind speed increase with altitude (table1). These environment factors have a significant effect on the annual total cooling and heating loads for tall buildings [Ellis & Torcellini, 2005]

Table 1. The effect of altitude on air temperature, pressure and wind speed, and the significant effect especially for wind speed that should be taken into consideration for tall buildings design strategies

Variable	*1.5 m*	*284 m*	*Absolute difference*	*Percent difference*
Air temperature	15°C	13.15°C	1.85°C	12.3%
Barometric pressure	101 325 Pa	97 960 Pa	3 365	3.3%
Wind speed	2.46 m·s^{-1}	7.75 m·s^{-1}	5.29 m·s^{-1}	215%

1.2.1 Air temperature

In urban areas the air temperature is higher than the surrounding rural country due to urban traffic, urbanization, and the decreasing of vegetation and trees. The well-known phenomenon of heat island causes the temperature difference, and increases temperature in urban area especially during summer period. The impact of urban heat island on energy demands for cooling is tremendous; the urban heat island is increasing significantly, which negatively impact urban productivity and urban living conditions. The exterior surface temperature of urban buildings can exceed 60°C in summer season causing energy consumption for cooling to be up to 30-40% greater [Chen Zhi et al. 2007]. On the other hand, the air temperature is decreases with altitude as its clear in the above table and this happen in tall buildings, this will influence the energy for cooling, heating and natural ventilation in the upper levels for high rise buildings over 150 m.

1.2.2 Wind pattern

Beside the effect of altitude on wind speed (table 1: the higher wind at the upper levels of tall towers presents a potential opportunity to use it in turbines), the presence of tall buildings effects as shelter deceasing in general the wing speed and allowed the modifying of the airflow. In addition, streets lines with tall buildings can block or channel the wind create artificial wind patterns. On the other hand, higher wind speed increases the convection coefficient and the amount of infiltration which increase the heat transfer (U value) by 8%.

1.2.3 Solar radiation

Solar radiation is divided in to three regions: the ultraviolet, visible and the infrared rays, and they are considered regions of Short-wave. Most of the ultraviolet region which possesses approximately 6% of the solar spectrum (wavelength range 0.29 μm-0.38 μm) is absorbed by ozone. The visible region (wavelengths 0.38 μm-0.78 μm) has approximately 46% of the entire solar spectrum. The infrared radiation (wavelength range 0.78 μm-2.5 μm) owns approximately 43% of the solar spectrum. Under direct-beam clear-sky the amount of solar radiation increases with altitude for horizontal surfaces. For vertical surfaces, solar radiation composed of direct, diffuse from the sky and diffuse from the ground [ASHRAE 2005], for tall building while the direct and diffuse radiation from the sky are likely increasing, the diffusion radiation from the ground is likely decreasing since there are thicker air mass to travel through. The effect of the modification of solar radiation absorbed, transmitted, and reflected due to the technologies and design strategies, like reflective and high emittance coating materials on the tall buildings energy demand and outdoor comfort have to be evaluated.

2 TALL BUILDING ENVELOPE TECHNOLOGIES AND DESIGN STRATEGIES

2.1 The influence of coating materials;

Building envelopes function as an environmental filter; they form a skin around the building structure and manipulate the influence of the outdoor on the indoor environment, they include the entire building component that separate the indoors from the outdoors, the envelope of the building consist of the exterior walls, roofs and windows. For tall buildings walls cover more than 90% of the envelope and highly influence the outdoor microclimate.

Albedo is the ratio of the value of solar radiation reflected by the building surface to the total value projecting on the building surface [Chen Zhi et al. 2007], the larger the albedo of the surface materials the smaller the irradiation energy which absorbed it. The buildings with high albedo materials can improve the indoor and outdoor thermal environment effectively. A great increase of albedo combined with shading of trees can reduce the energy use for air conditioning by 40% in the cases studied. For example it is found that white coatings with an albedo of 0.72 were 40°C cooler than black coatings with an albedo of 0.08 in the early afternoon of clear summer day [Chen Zhi et al. 2007]. Akbari [2003] found that it would save 33 $kW{\cdot}h{\cdot}m^{-2}$ of energy per day and 8.4 $kW{\cdot}h{\cdot}m^{-2}$ per year when the albedo of the roof was changed from 0.26 to 0.72. Simpson and McPherson [1997] monitored the roof temperature on 1/4 scale model buildings and suggested that white roof 0.75 albedo were up to 20°C cooler than grey 0.30 albedo, or silver 0.50 albedo and up to 30°C cooler than brown 0.10 albedo roofs. Synnefa et al. [2007] estimate the effect of using cool coatings on energy loads and the thermal comfort in residential building in various climatic conditions, and found that using cool materials on the building roof in hot climates could save up to 90% on the cooling loads and decreasing the hours of discomfort for almost up to the same percent.

Table 2. Calculated mean value of albedo for different coating materials [Chen Zhi et al. 2007]

Material	*Albedo*	*Material*	*Albedo*
Cement	0.21	Yellow coating	0.54
Blue coating	0.25	White napped tile	0.71
Reddish-brown coating	0.36	White smooth tile	0.78
Deep red tile	0.43	White coating	0.86

Considering the increase of high rise buildings in cities, the heat absorbing and heat releasing of wall facing materials and not only the roofs are one important factor influencing the urban heat environment during summer, that impact the indoor and outdoor microclimate environment. For this reason applying such technologies should be evaluated for tall buildings in hot arid climates. In conclusion researches show that exterior surface with high albedo remains cooler when exposed to solar radiation because they absorb a little solar radiation and reflect more to the space. In addition wall facing materials with high albedo could control the temperature of walls effectively and thereby control the indoor temperature. Increasing the solar reflectance is typically more beneficial in hot climates where cooling load dominates most of the year. Special attention should be given to tall building envelope coating materials in hot arid climates due to its large surface exposed to the solar radiation and its effect on the urban heat island, indoor environments and cooling loads.

2.2 The influence of large scale and height

The urban environment imposes additional environmental factors because of shadings and reflection from the surrounding buildings. The large scale of tall buildings can result in excessive input data [Ellis & Torcellini, 2005]. In recent studies the built form, especially the envelope, was also found to have a significant effect on the microclimate behaviour. The envelope ratio or the ratio of the open ground area to the envelope area has an effect on the heat environment, studies show that the smaller the envelope ratio the cooler the built up unit, at maximum the built form effect relative to meteorological reference station is about -0.75 K in street houses and as a large as -2.4 K in closed courtyard at 15:00 [Shashua-Bar et al. 2006]. It can be seen that the tall buildings can have a positive effect due to shade it provide in hot climates. Other factor is the building heights, as the temperature degreases by height and the wind speed is increased this could affect the cooling loads and internal thermal comfort on the upper floors and allows passive ventilation. The taller the building in hot climate the greater the decrease in temperature, air density, and potential moisture and the higher the reduction in cooling energy use. Further studies should be done to evaluate the effect of this factor on the cooling load and outdoor comfort for tall buildings in hot arid climate.

2.3 The influence of green walls and green roofs

Urban spaces are expanded dramatically; the large modern cities, their structure, materials and general lack of vegetation affect the climatic characteristics of urban spaces causing a significant rise of the urban environment temperature known as the heat island effect especially in climate with a hot season. A recent study [Alexandri & Jones 2008] on the effect of green walls and green roofs on temperature decreases in different climates (Fig. 1) shows that air and surface temperature lower significantly in al climates examined when walls and roofs covered with vegetation. Surface temperature decreases on the south wall from 18.5°C maximum and 14.3°C daytime average for Riyadh to 9.8°C maximum and 5.6°C daytime average for Moscow. For the green wall case, air temperature decreases reaches 5.1°C maximum and 3.4°C daytime average for Riyadh and 2.6°C maximum and 1.7°C daytime average for Moscow.

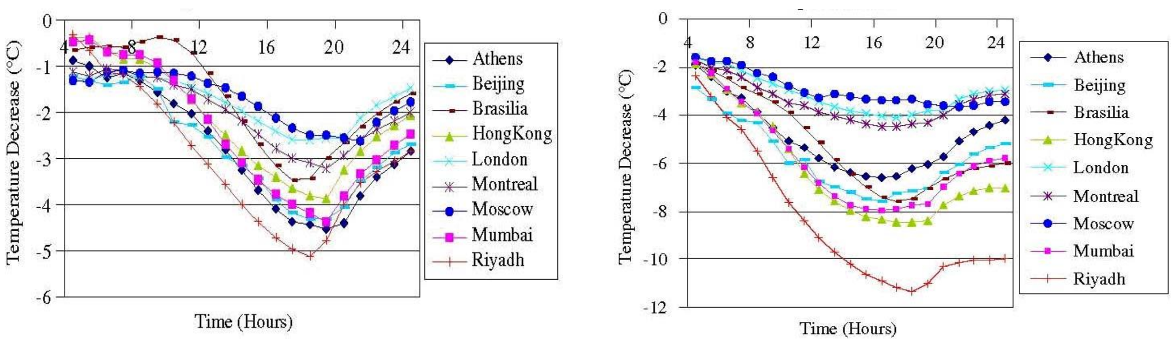

Figure 1: On the left, air temperature decreases in canyon due to green walls, and on the right air temperature decrease in canyon due to south oriented walls covered with green, the various results in different climate zones show that the highest influence was for hot arid climate. Source: [Alexandri & Jones 2008]

We can conclude that the hotter and drier the climate is the more important the effect of green roofs and green walls on the heat environment and improves outdoor and indoor thermal comfort. On the other hand, it can decrease cooling loads demands inside the buildings due to microclimate modification. Due to the same study in Riyadh for example the high cooling loads decrease of the magnitude of 90% by applying green roofs and walls. The study shows also that for all climate examined, green walls has a stronger effect than green roofs inside the canyon, while green roofs has a greater effects at roof level and the urban scale.

2.4 The influence of shading and orientation

Minimizing the effect solar radiation within the hot urban environment may often be desirable in urban design criterion, the effect of buildings orientation and buildings heights are crucial factors on shading in hot arid climates due to high altitude solar radiation and high air temperature. After exposing the building to summer solar radiation for a certain period the building itself acts as a heat source and to the rising of the air temperature including the inside temperature [Akbari et al. 1997]. Bourbia and Awbi [2004] indicated that in hot arid climates, the air temperature of the north-south orientation street during day is lower than other sites and that the peak street temperature was 2.5-3.5 K lower than the reference temperature of the meteorological recording, While the air temperature of the east-west street was higher by up to 4 K than the north-south orientation street. In conclusion, the decrease of air temperature can be achieved by correct orientation of building for shading, while ensuring adequate sky view factor in order to moderate the harness of the climate.

Solar access to the street can be decreased by increasing the height to width ratio, floor and wall shading fraction increase with increasing the height to width ratio [Bourbia & Awbi 2004]. Todhunder [1990] considers that the micro scale urban geometry, like the street to building height and width relationships, their orientation and shading potential of urban mass are more important than the albedo and surface characteristics effects.

3 CONCLUSION

From the study above it can be concluded that technologies and design strategies for tall buildings have different influence on the hot arid urban microclimate. Green walls and green roofs, high albedo materials, shading strategies, building height to width and building orientation have a positive effect on the inside and outside air temperature in hot arid climate. On the other hand, factors like huge mass, glazing and low albedo materials have a negative influence. Most of these technologies and design strategies and their effects on the urban microclimate are examined for low and medium rise buildings, for these reason further studies are necessary to calculate the effect of tall building envelope technologies and design strategies on the urban microclimates. On the table below, the evaluation of various technologies and design strategies and their influence on the hot arid urban microclimate as high (+), medium (0) and low (-).

Table 3. The effects of building envelope technologies and design strategies on the outdoor comfort and cooling loads in hot arid climate.

Technologies and design strategies	*Outdoor comfort*	*indoor comfort/Cooling load*
Coating materials	**0**	+
Large scale and height	-	-
Green walls and green roofs	+	+
Shading and orientation	+	**0**

4 ACKNOWLEDGEMENT

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Effects and implementation of measures aiming at impacting urban climate

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T3 – Policies

ABSTRACT

The surface energy balance and its modelling can help to understand the generation of urban heat island and contributes to identify some possible mitigation actions such as an environmentally aware urban planning, a development of vegetation or some “cool” materials in pavements and buildings. Simulations suggest that sensible heat flux (QH) is the most sensitive term of the energy balance. The increase of the roof albedo or of the vegetation rate might cause the most important reduction of QH above the roofs level compared to the other mitigation strategies. The diurnal evolution of road impacts with width modifications illustrates the importance of radiations captured inside the canyon.

KEYWORDS

Urban heat island, energy balance, simulations, urban planning.

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1 INTRODUCTION

The world is becoming more and more urbanized and over half the world's population is living in urban areas. Concentrated activities, high traffic as well as urban topology contribute to deteriorate local environment and to impact urban climate. The thermal balance in urban environment differs substantially from that of rural areas. As a consequence, air temperatures in urban areas are higher than the temperatures of the surrounding rural country: this is urban heat island (UHI).

Higher urban temperatures may reduce the heating load of buildings and increase the comfort of the residents during winter but in summer they induce stronger energy demand for cooling. Moreover, long lasting extreme temperature periods, specially during the night, may drive to a dramatic situation for residents. During the summer 2003 heat wave, when nearly 15 000 people died in France, the extra mortality reached a 141% peak in the Parisian urban area [Hémon and Jougla 2003]. UHI, atmospheric pollution and thermal quality of buildings influenced this great urban mortality [Besancenot 2002, Institut de Veille Sanitaire 2004, Salagnac 2007]. Due to global warming, heat waves are likely to be more intense and more frequent during the course of the 21st century according to Intergovernmental Panel on Climate Change (IPCC). To respond to this new climatic situation, adaptation solutions are needed. The mitigation of UHI is one of them.

Urban climate issues then need to be taken into consideration by urban designers. To achieve an integration of urban climate stakes in urban design, a good understanding of physical phenomenon is necessary. Based on simulation works, this paper focuses on the generation of UHI, its possible mitigation (with an environmentally aware urban planning, a development of vegetation and some "cool" materials in pavements and buildings).

2 ANALYSIS OF THE URBAN HEAT ISLAND

2.1 The surface energy balance

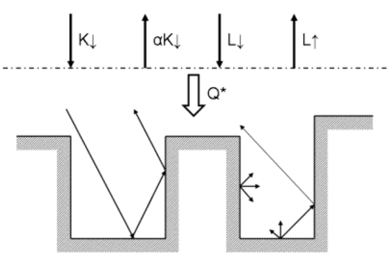
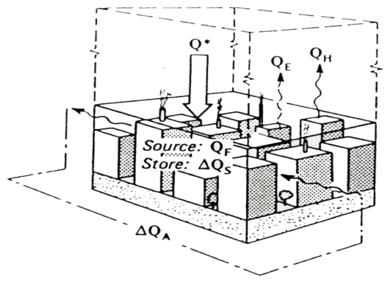
<table>
<tr><td>a) Radiation balance</td><td>b) Energy balance [Duchêne-Marullaz 1980]</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>$Q^* = L{\downarrow} - L{\uparrow} + (1 - \alpha)\, K{\downarrow}$</td><td>$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A$</td></tr>
<tr><td>K↓: direct solar radiation arriving,
L↓: atmospheric longwave radiation arriving,
L↑: longwave radiation exiting from the canopy,
αK↓: reflected solar radiation exiting (α is surface albedo[1])</td><td>Q*: net all-wave radiation at the top,
Q_F: anthropogenic heat flux,
Q_H and Q_E: respectively turbulent heat fluxes for sensible and latent heat,
ΔQ_S: sensible heat storage by the elements,
ΔQ_A: net local advection (the heat advection through the sides of the control volume)</td></tr>
</table>

Figure1. The surface radiation and energy balance for an urban area.

The heat generated by and contained in the city can be presented with the surface energy balance (SEB) which takes all the exchanges of energy into account (fig 1.a), including radiative heat fluxes (fig 1.b). The SEB is applied to a control volume extending from the ground to the top of the urban

1 Albedo: hemispherically and wavelength-integrated reflectivity. When sunlight hits an opaque surface (simple uniform as well as heterogeneous and complex), some of the energy is reflected (this fraction is the albedo = α), and the rest is absorbed (1- α). Low-α surfaces become much hotter than high-α surfaces when exposed to sun radiation.

canopy layer. Each SEB's term is modified in the urban environment and contributes to the formation of the UHI.

2.2 Net all-wave radiation (Q*) and anthropogenic heat (Q_F)

Q* represents the short and long-wave radiation captured by the city. The incoming short wave solar radiation was reported to be attenuated by air pollution over urban areas [Peterson and Flowers 1977]. This attenuation is compensated by the rather low albedo of the city (viewed above the rooftops), which can be estimated around 0.15 [Oke 1978], and is so often lower than in countryside (0.2 for vegetation; 0.11 to 0.15 for forest; 0.25 to 0.3 for bare ground [Najjar *et al.* 2005]).

Human activities, like traffic, industries, heating for buildings or people metabolism, release heat which can be a significant contributor to the urban SEB and then play a great role in creating UHI. The values of Q_F vary from area to area and depend on various factors such as built and population densities, whole population in the city, energy use, economical development, industrial activity, transportations systems, or climate [Oke 1978, Taha 1997].

Some values of the annual average anthropogenic heating for selected city were reported [Taha 1997]: 53 $W \cdot m^{-2}$ for Chicago, 21 $W \cdot m^{-2}$ for Los-Angeles, 117-159 $W \cdot m^{-2}$ for Manhattan in New-York city, 99 $W \cdot m^{-2}$ for Montreal, 127 $W \cdot m^{-2}$ for Moscow, 43 $W \cdot m^{-2}$ for Budapest. In Toulouse (France), Q_F estimates are around 70 $W \cdot m^{-2}$ during winter and 15 $W \cdot m^{-2}$ during summer [Pigeon *et al.* 2007]. Simulations in Philadelphia suggest that Q_F contribution to the nocturnal summer and winter UHI is respectively 0.8°C and 2–3°C [Fan and Sailor 2005]. The daytime urban energy budget is dominated by incident solar radiation.

2.3 Turbulent heat fluxes (Q_H, Q_E), heat storage flux (ΔQ_S) and net heat advection (ΔQ_A)

The densely built-up urban areas, the waterproofing of urban surfaces and the lack of vegetation are responsible for increased sensible heat flux (Q_H) and decreased latent heat flux (Q_L), the heat consumed to evaporate water. Sensible heat flux is supplied by Q_F and heat storage in built environment (ΔQ_S). The turbulent heat fluxes vary with respect to Q* [Oke *et al.* 1992].

ΔQ_S depends on the materials, structure and geometry of the urban surface, and also on Q*. Its nocturnal release is a major contributor to the UHI. The direct measurement of ΔQ_S is currently not possible and is often calculated as the residual to the SEB equation; ΔQ_S combined to conductive-convective exchange of Q_H "has been shown to account for over 90% of the daytime net radiation at highly urbanized sites" [Roberts *et al.* 2003].

"Net heat advection could be referred to as the inaccurate measurements due to spatial gradient in temperature, humidity and wind" [Rizwan *et al.* 2008]. ΔQ_A is considered negligible for sites with extensive and relatively homogeneous horizontal shape [Roberts *et al.* 2003] so it is often neglected in urban studies [Oke *et al.* 1992, Pigeon *et al.* 2007].

3 MITIGATION OF URBAN HEAT ISLAND

An UHI is "the mutual response of many factors which could broadly be categorized as controllable and uncontrollable factors" [Rizwan *et al.* 2008]. Urban design and structure related parameters (sky view factor, green areas, building materials) as well as population related variables (anthropogenic heat, air pollutants) are controllable factors. Season, diurnal conditions, wind speed, cloud cover are uncontrollable variables. Mitigation measures concern four domains: buildings, open spaces (pavements, green areas), space organization, and human activities. Three kinds of measures are discussed in this article: environmentally aware urban planning, development of vegetation and "cool" materials in pavements and buildings.

3.1 Environmentally conscious urban planning and development of vegetation

The localization of the city has of course a main impact on urban climate [Bitan 1992] but this factor could only be controlled for new towns. The street design, the canyon geometry, which could be represented by sky view factor (SVF) or the H/W ratio (with W the width of the urban canyon and H its height) and the total system albedo, influence urban climate [Oke 1981, 1988].

The impacts of trees could be divided into: shading of buildings (sunlight is intercepted before it warms a building) and ambient cooling (evapotranspiration cools air). The meteorological impact of large-scale tree-planting programs has been simulated with a mesoscale meteorological model in ten U.S. metropolitan areas [Taha *et al.* 1996]. The simulations showed that, on average, trees can cool down cities by about 0.3 to 1°C at 2 p.m.; in some simulation cells, like in Los Angeles, with five millions additional trees in the metropolitan area, the temperature decreased by up to 3°C.

3.2 "Cool" materials in pavements and buildings

The albedo of a city may be increased if high albedo surfaces are chosen to replace more absorbent materials.

Simulations in the Los Angeles Basin (United States) with the Colorado State University Mesoscale Model (CSUMM) and under various initial conditions suggest that with an increase from 0.30 to 0.50 of urban surfaces albedo (sloped roofs, flat roofs, and roads), the peak summertime temperature reductions is between 2 and 4°C [Rosenfeld *et al.* 1995].

Mitigating measures for New York City's heat island with urban forestry, living roofs[2], and light surfaces have been studied in six different areas [Rosenzweig *et al.* 2006]. A regional climate model was used in combination with observed meteorological, satellite, and GIS data to determine the impact of each of the mitigation strategies on surface and near-surface air temperature in the New York Metropolitan Region over space and time. Average near-surface air temperature reductions for New York city could reach 1.3°F (0.7°C) with light surfaces or ecological infrastructure *id est* urban forestry, grass, street-to-trees (curbside planting) and living roofs. For mid-Manhattan west, the reduction could reach 1.9°F (1.1°C) with ecological infrastructure.

3.3 Simulation tools

To evaluate the impact of such measures on UHI mitigation, we use two surface schemes which parameterize the surface exchanges: the Town Energy Budget (TEB), an urban surface scheme following the canyon approach [Masson 2000] (fig. 2), and the Interaction Soil Biosphere Atmosphere (ISBA), a vegetation scheme [Noilhan and Planton 1989], both developed by Météo-France/CNRM. TEB simulates the urban energy balance by combining individual energy budgets for walls, roads, and roofs. It uses surface and substrate radiative, thermal, moisture and roughness properties, and canyon geometry to simulate the effects produced by the presence of buildings. TEB is also forced with atmospheric and radiation data from above roof level (solar radiation, air temperature, wind velocity, cloudiness and precipitation).

For areas with urban and green surfaces, average values of fluxes are calculated according to the fraction of each surface type in the area.

[2] A living roof, or green roof, is a vegetated roof or a roof with vegetated spaces, and so is a roof which is covered in turf, flowers, grasses, and sometimes shrubs or trees.

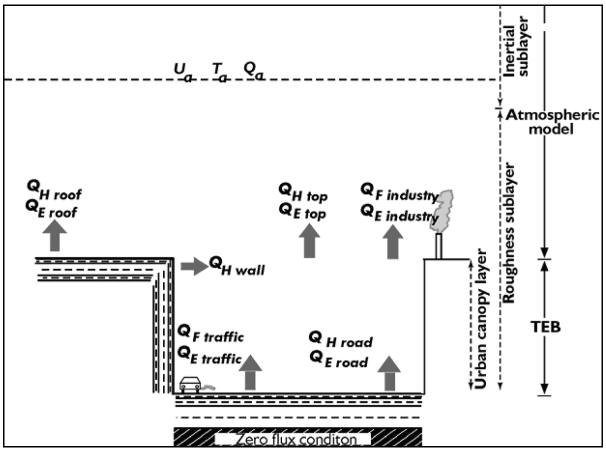


Figure 2. Representation of the individual surfaces for which energy budgets are resolved by TEB [Masson 2000, Roberts *et al.* 2004]. The scale on the right shows the scale of the model, relative to atmospheric layers and meso-scale models.

3.4 Parametric study

Using TEB allows to carry out a parametric sensitivity analysis for selected factors presented in table 1. We analyze the energy balance of a city and some different mitigation strategies (table 1) at town scale during the the 30th June 2006 in Paris (a dense urban area). We chose this day, a sunny day without precipitation and with a maximal temperature around 29°C, to have good conditions for a temperature rise in urban surfaces and so good conditions for strong urban heat island.

Table 1. Scenarios for the sensitivity study of the energy balance to urban characteristics.

	"Cool" materials			Vegetation	Urban planning[a]	
	Roof albedo	Wall albedo	Road albedo	Vegetation rate %	Road width (m)	Building height (m)
Case 0: Paris	0.60	0.40	0.10	17%	15	30
Case 1 / Case 2	0.75/ 0.9	0.40	0.10	17%	15	30
Case 3 / Case 4	0.60	0.55 / 0.7	0.10	17%	15	30
Case 5 / Case 6	060	0.40	0,25 / 0.4	17%	15	30
Case 7 / Case 8	0.60	0.40	0.10	26% / 34%	15	30
Case 9 / Case10	0.60	0.40	0.10	17%	10 / 30	30

For each case, the new value of the modified element is in grey.
[a]TEB uses four criteria to describe urban geometry: building height, rugosity length, building fraction (fractional artificial area occupied by buildings: $a_{bât}$ = roof surface / roof and road surface) and building aspect ratio (walls surface / roof and road surface)

In the TEB model, three sources of anthropogenic heat releases (Q_F) are considered: the traffic, the industries and the domestic heating. Traffic and industries heat releases are two sources to add to Q_H and Q_E (fig. 2). In winter, domestic heating is simulated by limiting the evolution of the internal temperature inside the building with a minimum value of 19°C (no maximum value) [Pigeon *et al.* 2006]. We neglect net heat advection (ΔQ_A). So the energy balance is: $Q^* + Q_F = Q_H + Q_E + \Delta Q_S$.

In our simulations, Q_F, the anthropogenic heat releases, is for traffic equal to 37 $W{\cdot}m^{-2}$ during the day and 0 $W{\cdot}m^{-2}$ at night and for industries is equal to 0 $W{\cdot}m^{-2}$ (there is no industry in Paris).

4 RESULTS AND DISCUSSION

Figure 3 depicts daily variation of energy budget above roof level below different urban surfaces described in table 1. As seen in the figure, Q_H is the most sensitive term of the energy balance.

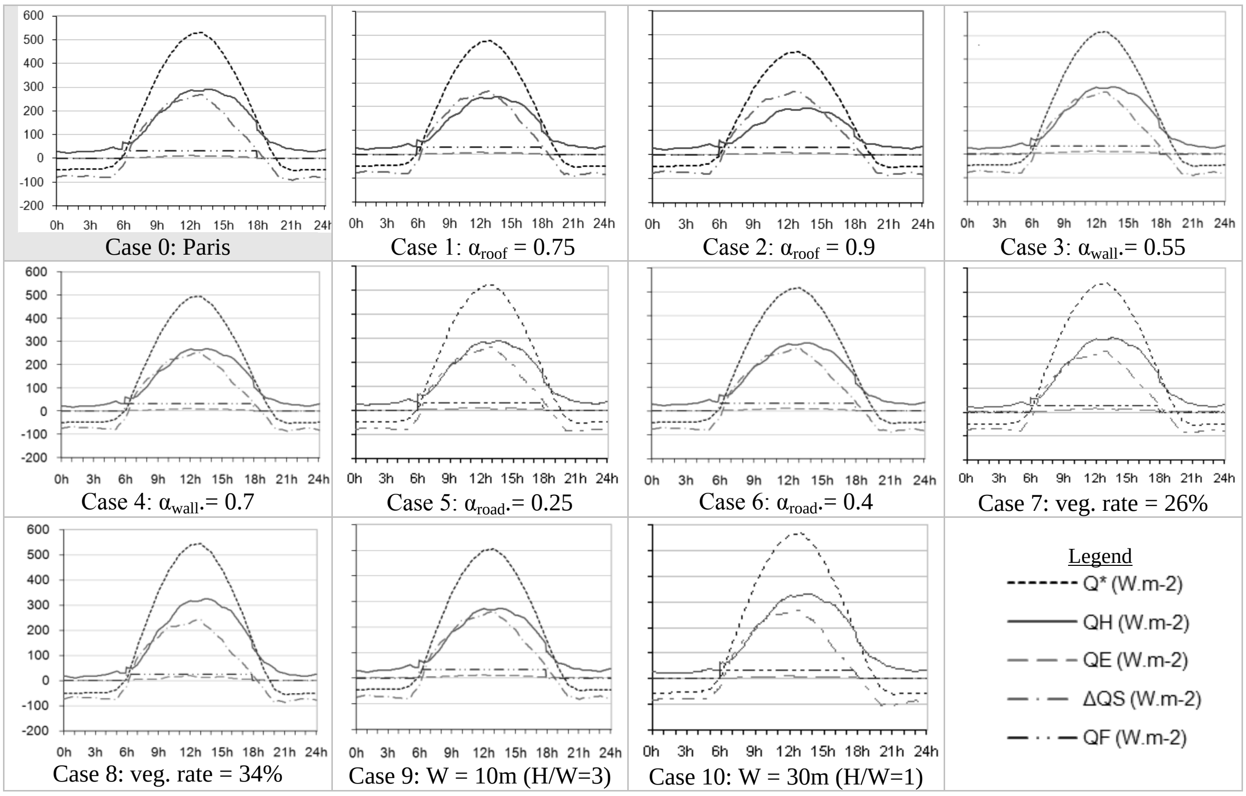


Figure 3. Energy budget above roof level for different cases.

With regard to the albedo modifications, simulations suggest that roof albedo has the most important impact on the energy balance. This can be explained by the fact that inside the canyon and not on the roofs, reflected radiations are partly trapped. In the case of a roof albedo of 0.9, the most important decrease in Q_H occurs during afternoon, at 1.00 pm, when it is the highest. This decrease is about 35%. In the case of a roof albedo of 0.75, the decrease is only by about 17%. Q_H decrease with wall or road albedo modification is less than 19%. Net storage heat flux (ΔQ_S) and net all-wave radiation (Q*) are also modified by albedo changes. The maximum ΔQ_S occurs at 1.00 pm, and reduction in the case of a roof albedo of 0.9 is less than 10%. The maximum Q* occurs at 1.00 pm too, and reduction in the case of a roof albedo of 0.5 is about 20%.

With regard to vegetation rate modifications, simulations show foreseeable Q_L increase but Q_H decrease during the night and increase during the day because of dry vegetation in our experiences. ΔQ_S and Q* are not really modified. Q_L differences principally occur during the day and are maximal at noon. Q_L increase is around 50% during the night and 30% during the day for a vegetation rate of 26%. For a vegetation rate of 34%, Q_L increase is around 100% during the night and 60% during the day.

With regard to road width, or H/W ratio, simulations show that differences between cases evolve during the day. In the early morning (before 6 am), Q_H is more important for the situation with the highest H/W ratio. During the day, this happens for the situation with the lowest H/W. Extreme values of ΔQ_S are more important for the situation with the lowest H/W ratio. These can be explained by the fact that during the day, there are more sun on surfaces in the widest canyons and so more heat is stored. It depends on material properties too. This stored heat is released during the night and Q_H increases. At 4 am, the Q_H decrease between the narrowest and widest canyons is about 50%; at 9 am the Q_H increase between the narrowest and widest canyons is about 50%.

5 CONCLUSION

This study aimed at analysing the impacts of different UHI mitigation strategies (urban planning, vegetation and materials) on the energy budget during a day of June 2006 in Paris.

The simulations suggest that Q_H is the most sensitive term of the energy balance. The increase in roof albedo or in vegetation rate causes the most important reductions of Q_H above the roofs compared to the other mitigation strategies. The roof albedo increase implies an urban albedo increase and so a decrease of Q*, ΔQ_S and so Q_H. The vegetation rate increase implies a Q_L increase. Road width, or H/W ratio, modifications impacts are not the same during the day or the night. Radiations captured inside the narrowest canyon are more important than inside the large one which explains the diurnal evolution.

The interest of this approach is to identify some promising ways to mitigate the UHI and to define the order of magnitudes of effects that can be expected. Further work could concern feasibility issues of such measures, considering economic (investments and maintenance costs), technical (realisation and maintenance of high albedo surfaces) as well as of urbanism (possibilities and limitations due to urban rules) aspects.

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Heat-wave in Paris and climate change: cross-disciplinary approach of vulnerability and adaptation

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T3 – Policies

ABSTRACT

The EPICEA project is a joint collaboration between the City of Paris, the French Meteorological Office (Meteo-France) and the Building and Scientific and Technical Centre (CSTB) to quantify the impact of climate change over the city of Paris as well as the influence of building on urban climate and on adaptation strategy. A first goal is to evaluate the evolution of the urban climate of Paris and its area with regard to climate change. A second goal is to realize a precise analysis of the 2003 heat-wave over Paris using a meso-scale atmospheric model and a specific urban surface scheme. The ultimate goal is to assess the climatic impacts during heat-wave periods that could result from actions on urban parameters (geometry, radiative characteristics of surface…). This information will allow the mapping of heat-wave vulnerability.

KEYWORDS

Downscaling Paris area scale, climate change, urban heat island, heat-wave.

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1 INTRODUCTION

One way to assess the impacts of climate change at a large scale is to study precisely an extreme weather event that happened over the concerned area and may become more frequent in the next decades. The case of extreme heat-waves meets these requirements. IPCC scientists agree that warm extremes imply an increased frequency of heat-waves (IPCC, 2007). The EPICEA project (Study of the Impacts of Climate Change on the scale of the Paris area) aims at analyzing such heat-waves which may have severe health consequences. For instance, during the heat-wave period (from 8 to 13 August 2003), a mortality peak was observed in Paris (InVS, 2004a).

2 EPICEA PROJECT

The EPICEA project intends to contribute to urban adaptation strategy development to climate change impacts. Funded by the City of Paris, this project offers a very innovative approach in this regard as it aims to both assess the vulnerability of a large city like Paris to a changing urban environment in the context of change climate, and establish quantitative relationships between the organization of a territory and its associated climate. Planned for three years (2008 to 2010), this project involves two public establishments, the French Met Office, which is a key player in climate change research and modeling of urban meteorology and CSTB (Building Scientific and Technical Center), which carries out researches on the impact of climate change on the built environment. The EPICEA project has three objectives. The first concerns the evolution of urban climate in the perspective of global climate change. The second is the study of the 2003 extreme heat-wave over Paris and the third is the study of the link between the urban built environment evolution and urban climate. These research works will contribute to the definition of adaptation policy to face more frequent heat-waves in the perspective of global climate change over the Paris area. Progresses in the assessment of the vulnerability of urban areas are also expected. The most noticeable effect of urban built environment on local urban climate is the emergence of higher temperatures in city centers, forming an urban heat island where temperature decreases from the center to the periphery (Escourrou 1991; Cantat, 2003; Charabi, 2000). The project aims to establish links between land use, urban climatology and factors related to health risks, including increased mortality during heat-wave (Besancenot, 1997 and 2002 and Schär et al. 2004, O'Neil et al., 2003, Basu and Samet, 2002). The research works aim to establish quantitative relationships between the development of a territory, the land use (buildings, roads, green spaces, ...), the urban climate and related health risks, in order to be able to integrate urban climate issues in future city developments.

3 METHODOLOGY

The first phase of this project is to quantify changes in the urban climate over Paris in the perspective of global climate change. Climate change projections from global model simulations of ARPEGE-Climate in its stretched version are used. They are developed by the National Center for Meteorological Research (CNRM) of the French Met Office (Fig. 1).

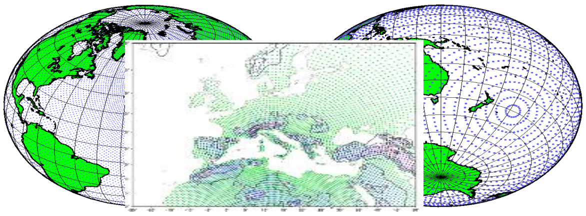

Figure 1. Digital Model global climate: example of ARPEGE-Climate (50km resolution on Western Europe and 450 km on the South Pacific) (Source: French Met Office).

The 50 km spatial resolution over France used for these simulations is not suitable for the simulation of climate description at the city scale. Our goal is to propose a more relevant model at the regional level than that used at a global scale (Lauffenburger, 2007). Identifying climate change impacts at very small scale requires down-scaling techniques. In this project, we use a statistical-dynamical downscaling scheme based on weather types (Boé, 2006) and a statistical correction according to observed values (Déqué, 2007). To represent the energy and water exchanges, we use the pattern of the surface model Town Energy Budget (TEB) developed by CNRM (Masson, 2000) for the urban tissue, and the pattern of surface ISBA (Interaction Soil Biosphere Atmosphere), also developed by CNRM, for natural areas. Both surface models are forced by the SAFRAN system (Quintana Segui et al., 2007), which allows an analysis of atmospheric forcing over geographically and climatically homogeneous areas, using both observations and analysis of operational models of the French Met Office with a resolution of 8 km (Fig. 2). SAFRAN is a pattern used to interpolate on an hourly basis and in each a grid, eight meteorological parameters (temperature at 2 m, humidity at 2 m, wind at 10 m, infrared and visible radiation, liquid and solid precipitation and cloud cover). The validation of meteorological model output is realized by comparing the observations from the meteorological station network of the French Met Office (123 stations in Ile-de-France area, including 11 stations in Paris). Mapping occupancy soil databases (Corine Land Cover and Ecoclimap) are used to represent the urban Ile-de-France area.

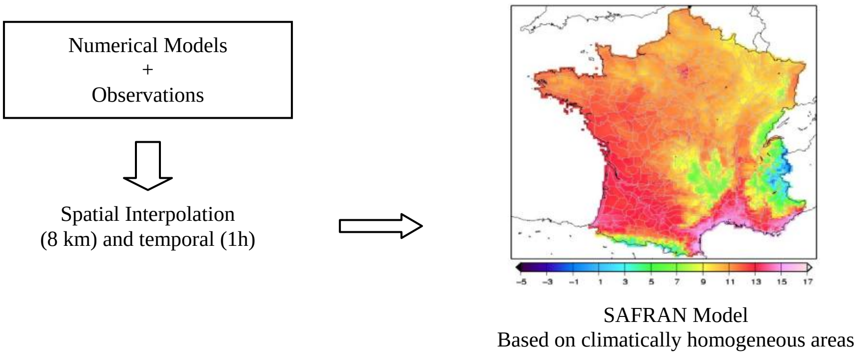

Figure 2. Overview of SAFRAN (Source: French Met Office).

These tools are used to first simulate urban climate for a recent period (1970-2007) (Masson, 2000) and to further introduce global climate model simulations resulting from the French Met Office ARPEGE-Climate model in order to simulate urban climate in the future (2070-2100).

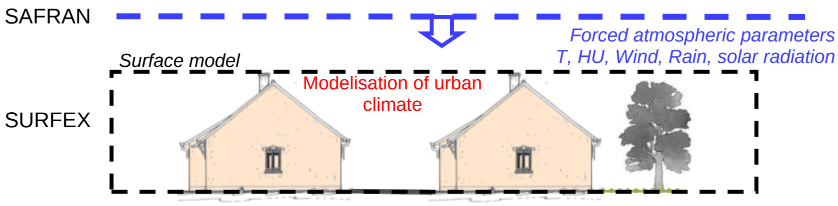

Figure 3. Representation of the functions of the simulation tools used for urban climate over long periods of time (SURFEX includes the TEB city representation) (Source: French Met Office).

The second part of the EPICEA project concerns the analysis of the 2003 heat-wave, with a focus on the peak period from 8 to 13 August 2003. The simulations are carried out using TEB as an interface scheme for the non-hydrostatic model MesoNH research tool, which allows kilometric scale climate simulation (Lafore et al., 1998). In order to better represent the Paris urban tissue, a high resolution (250 m) description of the TEB parameters has been developed using the Paris Urbanism Agency (APUR) database. A more realistic representation of the built environment as well as of the vegetation of urban space and of anthropogenic heat sources is then allowed. The aim is to prepare for the 2003 heat-wave mapping over the Paris area with a Geographic Information System (GIS). This GIS will collect results from climate simulations, data on urban space and the 2003 observations of the extra-mortality (Fouillet, 2007; Rey, 2007). Future results will contribute to design decision making tools to adapt the Paris urban area, in the perspective of global climate change.

4 PREVIOUS RESULTS

An innovative aspect of this project is the quantification of the relationship between the characteristics of the urban built environment and urban climate, with a comparison between simulation and observations during the 2003 heat-wave (Fig. 4).

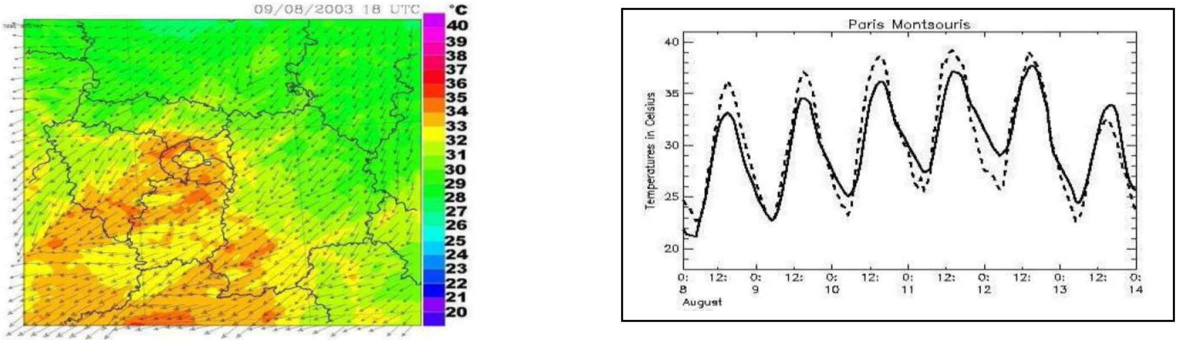

Figure 4. Simulation of the phenomenon of urban plume on 9 August 2003 at 18UTC (Temperature at 2 m superimposed wind at 60 m) (field size: 180 x 180 km) (left figure) and comparison of hourly temperatures from 8 to 14 August 2003 between observations from the Montsouris-Paris meteorological station (dashed) and simulations with the atmospheric model MESO-NH research coupled with the pattern of city TEB with resolution of 2 km (solid line) (right) (Source: French Met Office).

Through a strong collaboration with APUR, a 250 m x 250 m representation of the Paris urban tissue has been achieved. Factors such as green surface (Fig. 5), height of buildings, roof area and roofing materials (zinc, tile patio, slate), road surface, water surface are taken into account. This information is part of the GIS mapping of Paris (Fig. 6).

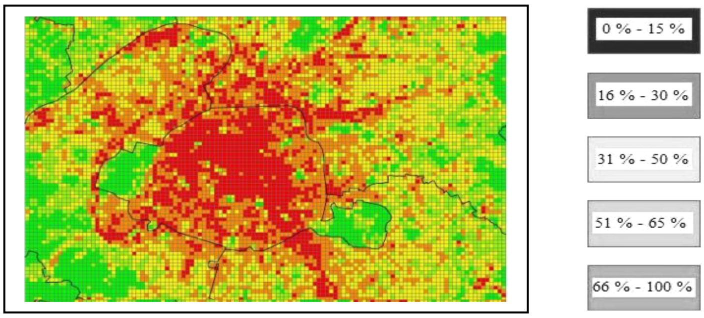

Figure 5: Illustration of the Paris urban tissue representation: percentage of green surface in each 250 m x 250 m grid cell (Source: APUR).

The third phase of the project concerns the impact on urban climate of modifications of the urban tissue. The aim is to assess the potential urban climate impact of actions on the built environment. Preliminary studies were carried out using the TEB pattern in "forced" mode during selected summer and winter days (Colombert, 2008). These results confirm the importance of radiative characteristics of material surfaces on the global energy balance. Future work will consist in evaluating the influence of urban parameters on urban climate over a 25 year period (1971-2007). Construction materials characteristics, vegetation of urban space and anthropogenic heat sources will be taken into account. The modification of the urban geometry, which is relatively stable in Paris, will not be considered. Health risks will also be considered from detailed observations of the extra-mortality during the 2003 heat-wave (InVS, 2004b). Results from climate simulation and mapping of mortality will be compared in order to identify potential links between the built environment characteristics and the mortality. This will allow reflections on the definition of vulnerability indicators such as (Fig. 6):

- mortality indicators (data from the InVS and Inserm (CépiDc))
- meteorological indicators (data from the French Met Office)
- indicators related to land use (data from the APUR) and to the built environment (data from CSTB)

The combination of such indicators is expected to contribute to the assessment of the vulnerability of a dense urban environment during a heat-wave event through the use of a GIS.

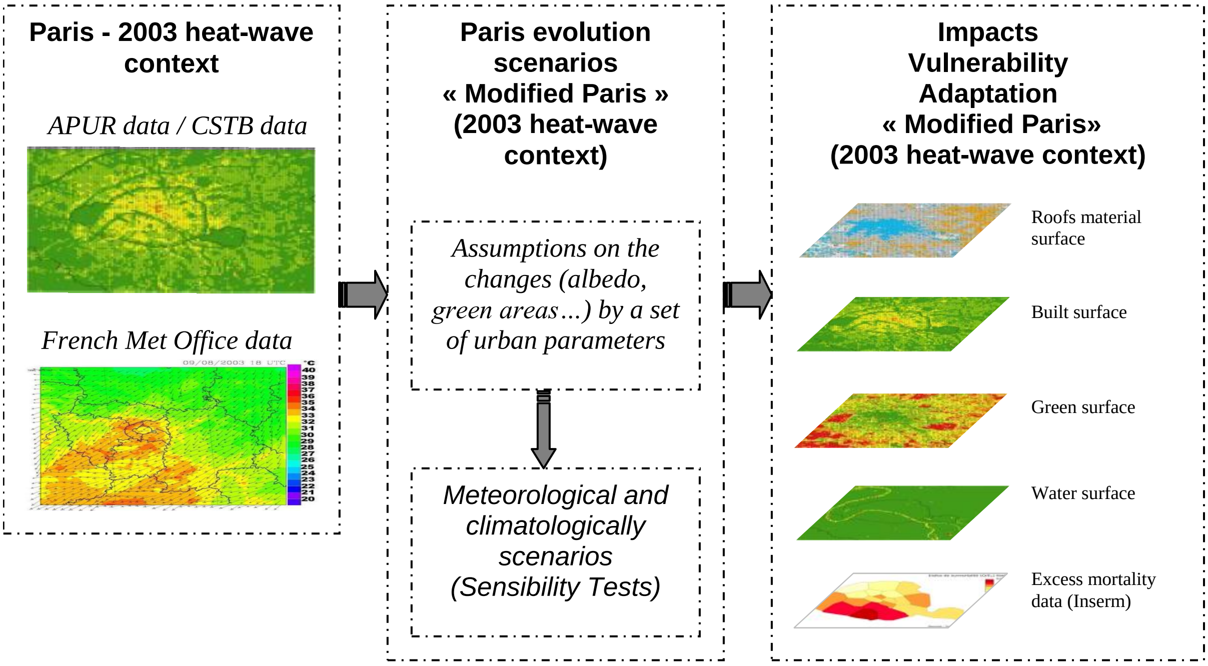

Figure 6. Schematic representation of a modeling approach of the 2003 heat-wave in Paris as well as of impact studies and vulnerability indicators.

5 CONCLUSION

The EPICEA project will contribute to assess the vulnerability of a large city like Paris to a changing urban environment in the context of global climate change and to establish quantitative relationships between the organization of a territory and its associated climate. This approach will highlight the influences of some urban built environment characteristics on local climate. By producing quantitative indicators, the project will contribute to identify potential actions to adapt the urban tissue in case of more frequent heat waves.

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Cost-effectiveness, Carbon Emissions, and Carbon Tax Implications of Energy Efficiency Measures in New Commercial Buildings

Joshua Kneifel[1] and Barbara Lippiatt[2]

T3 - Policies

ABSTRACT

Building energy efficiency has become a top priority due to the recent energy price spikes and increasing concern regarding climate change. It is easier and less costly to increase energy efficiency in new buildings than in existing buildings, making new construction a key target for efficiency improvements. This paper uses life-cycle cost analysis and environmental life-cycle assessment with extensive building cost databases, whole building energy simulations, and state-level emissions and utility rates to determine the relative cost-effectiveness, carbon emissions, and carbon tax implications of energy efficiency improvements in new commercial buildings.

The time horizon, building type and size, and local climate all impact the financial and environmental benefits from both energy efficiency improvements and hypothetical carbon taxes. Many energy efficiency measures are cost effective without climate change policy, and should be implemented regardless of carbon restrictions. The cost-effective energy efficiency improvements not only save money, but also significantly reduce a building's carbon footprint. A carbon tax results in a greater adjusted internal rate of return on these investments, and makes many otherwise cost-ineffective energy efficiency projects economically feasible.

KEYWORDS

Energy efficiency, buildings, carbon taxes

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1 INTRODUCTION

Building energy efficiency has once again come to the forefront of political debates due to high energy prices and climate change concerns. Improving energy efficiency in new commercial buildings is one of the easiest and lowest cost options to decrease energy use, owner operating costs, and greenhouse gas emissions. This paper uses life-cycle cost analysis and life-cycle assessment with extensive building cost databases, whole building energy simulations, and state level emissions and utility rates to determine the cost-effectiveness of energy efficiency improvements, the resulting carbon emissions reduction, and the impact a carbon tax would have on energy efficiency investment decisions. Energy cost savings can allow a building owner to recoup the first costs of energy efficiency measures while simulaneously decreasing greenhouse gas emissions over the building service life. A carbon tax increases the relative cost-effectiveness of energy efficiency improvements and carbon emissions reduction in new commercial buildings.

The building type and local climate impact the financial and environmental benefits from both energy efficiency improvements and a hypothetical carbon tax. Many energy efficiency measures are cost-effective without climate change policy, and should be implemented regardless of carbon restrictions. However, a carbon tax results in a greater adjusted internal rate of return on energy efficiency investments, and makes energy efficiency projects more attractive relative to alternative investments. The cost-effective energy efficiency improvements not only save money, but also reduce a building's carbon footprint.

2 COST DATA

2.1 Building construction costs

Prototypical building and component assembly costs and component maintenance, repair, and replacement costs originate from the RSMeans *CostWorks* online database. [3] The RSMeans *CostWorks* "Cost Books" are used to adapt the RS Means prototypical buildings to meet the *American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1-2007* energy efficiency standard and a higher efficiency "Low Energy Case." Component and building lifetimes are collected from *Whitestone Building Maintenance and Repair Cost Reference 2008-2009*. The building residual value—its value at the end of the study period (i.e. analysis period)—is estimated based on first costs and remaining component and building lifetimes.

2.2 Utility rates and emissions data

Utility rates for electricity and natural gas are obtained from the U.S. Energy Information Administration. The state-wide average retail price per 3.6 MJ (1 kW·h) of electricity is used as the building owner's/operator's cost of electricity consumption. The *December 2008 Natural Gas Monthly* is used for average retail natural gas prices by state for 2007. The state-level average emissions per 3.414 $MBtu_{th}$ / h (1 MW) of electricity for carbon dioxide, sulphur dioxide, and nitrogen oxides are obtained from the Environmental Protection Agency's *2007 Emissions and Generation Integrated Database* (eGRID 2007).

3 ENERGY SIMULATIONS

Whole building energy simulations were run in *EnergyPlus 3.0* through its "Example File Generator." Building characteristics, such as building type, location, size, and type of heating, ventilating, and air conditioning (HVAC) system are input to generate a representative building's annual energy use. For this paper, two alternative building designs are compared: A baseline, *ASHRAE 90.1-2007*-compliant

[3] Disclaimer: Certain trade names and company products are mentioned throughout the text. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the product is the best available for the purpose.

building design, and a "Low Energy Case" design, which increases the thermal efficiency of insulation and windows, "right sizes" the HVAC system, and adds daylighting controls and overhangs for window shading based on *EnergyPlus 3.0* recommendations.

4 ENVIRONMENTAL FLOWS

Life-cycle environmental flows from building construction, repair, and replacement are derived from U.S. Environmental Input-Output Tables included in the *SimaPro 7* software that have been adapted to the National Institute of Standards and Technology (NIST) *Building for Environmental and Economic Sustainability (BEES)* life-cycle assessment framework. The adapted Environmental Input-Output Tables quantify resource inputs and pollutant flows for 172 substances based on national average flows per dollar spent in the U.S. construction industry's commercial and industrial building sector. The environmental flows from operational energy use (electricity and natural gas) are derived from the *eGRID* and *BEES* databases based on simulated annual energy use. The *BEES* software is used to combine life-cycle costing and life-cycle assessment results from construction and operation of the building. Carbon emissions are isolated by BEES to allow for a direct comparison of carbon emissions across building types, designs, and locations.

5 RESULTS

Eight building types, representing a range of building sizes and energy intensities, were evaluated over a 40-year study period. For each building type, energy simulations were run for 16 U.S. cities located in different sub-climate zones.[4] As compared with the baseline ASHRAE design, the Low Energy Design decreases building energy use for all building types and decreases life-cycle costs for all except several three story office buildings. The savings vary by building type and location. As shown in table 1, the only increase in life-cycle costs occurs for a three-story office building (0.4 %). The highest life-cycle cost reduction occurs for a two-story high school (up to 7.7 %). Operational energy use reduction is greater than 15 % for all building types and locations with one high school approaching 40 %. As shown for a 16 story office building in table 2, cities within U.S. Climate Zones 3 to 5 generally have the highest life-cycle cost savings and greatest energy use reductions.

Building Type	No. Floors	Building Size in m^2 (ft^2)	% Δ Life-Cycle Cost ($)	AIRR	% Δ Operational Energy Use	% Δ Life-Cycle Carbon (CO_2e)
Dorm	3	2 323 (25 000)	-1.3 to -3.6	∞	-23.0 to -32.0	-4.3 to -17.9
Dorm	6	7 897 (85 000)	-0.9 to -2.5	8.8-∞	-19.6 to -27.3	-4.2 to -16.0
Hotel	15	41 806 (450 000)	-0.6 to -5.1	4.0-14.7	-26.7 to -35.1	-5.7 to -25.5
School, Elem.	1	4 181 (45 000)	-0.4 to -2.2	3.6-∞	-22.1 to -34.5	-10.6 to -19.9
School, High	2	12 077 (130 000)	-1.2 to -7.7	4.3-∞	-26.2 to -39.9	-10.9 to -29.7
Office	3	1 858 (20 000)	0.4 to -3.4	2.3-6.2	-19.4 to -29.4	-5.1 to -19.1
Office	8	7 432 (80 000)	-1.1 to -3.7	5.2-16.6	-15.7 to -31.5	-6.7 to -16.9
Office	16	24 155 (260 000)	-0.1 to -4.5	3.1-11.0	-18.6 to -34.1	-11.97 to -25.6

Table 1. Low Energy Design as Compared with ASHRAE 90.1-2007 Design over 40 Years, by Building Type

As shown in table 1, life-cycle carbon dioxide equivalent (CO_2e) emissions—from building materials production (for construction and component replacements) and energy use over 40 years—are reduced in all cases, by 4.2 % to 29.7 % depending on building type and location. Life-cycle CO_2e emissions reductions are lower than operational energy reductions due to the dampening effects of changes in materials-related CO_2e ranging from a decrease of 3 % to an increase of 6 %. The cost of reducing carbon emissions is negative for all locations with a reduction in life-cycle costs. Office buildings in climate zones 6 and 7 have a positive cost per metric ton of carbon reduction. Emissions reduction is greater for cities that consume a large percentage of electricity generated from coal-fired power plants while cities with more alternative energy consumption have lower emissions reductions.

4 Climate zones range from hot (1) to cold (8) and some have sub-zones of moist, dry, and marine.

Some building types and locations have an infinite adjusted internal rate of return (AIRR) because first costs decrease for the Low Energy Design. The cost savings from HVAC capacity reduction are greater than the costs for more insulation, daylighting controls, and overhangs. For these buildings, there is a compelling economic case for improved energy efficiency even over a one-year study period. All 44 building-location combinations with infinite returns are dormitories and schools, specifically in temperate climate zones.

For the more extreme climates and other building types, the AIRR on energy efficiency investments varies widely, from 2.3 % to 24.8 % in real terms. These investments are cost effective if the AIRR exceeds the investor's minimum acceptable rate of return (MARR). In 2008, the MARR for energy-related investments in federal buildings was 3.0 % in real terms. Of the 128 building type-location combinations analyzed, 126 have an AIRR above 3.0 % while 104 (81 %) have an AIRR above 5 %.

City	Climate Zone	% Δ LCC ($)	% Δ Energy Costs ($)	AIRR (no CO_2e tax)	AIRR ($50/t CO_2e tax)	% Δ Operational Energy (MJ)	% Δ Life-Cycle Carbon (CO_2e)
Honolulu, HI	1	-2.9	-25.5	5.4	6.0	-25.4	-18.7
Miami, FL	1	-0.3	-20.8	3.3	4.7	-21.0	-14.3
New Orleans, LA	2	-0.1	-19.5	3.1	4.0	-21.0	-14.0
Phoenix, AZ	2	-2.9	-26.3	6.9	7.6	-27.6	-17.9
Birmingham, AL	3	-1.0	-21.9	4.2	5.3	-24.4	-17.2
Los Angeles, CA	3	-3.2	-30.7	6.7	6.9	-30.7	-12.6
San Francisco, CA	3	-2.5	-30.1	6.0	6.2	-30.7	-12.4
Amarillo, TX	4	-4.5	-29.9	8.2	9.0	-31.1	-22.9
Kansas City, MO	4	-1.5	-25.8	4.9	6.2	-27.6	-21.4
New York, NY	4	-2.3	-25.8	5.3	5.7	-26.8	-17.0
Seattle, WA	4	-2.9	-32.5	11.0	11.2	-34.1	-12.0
Pittsburgh, PA	5	-2.7	-27.4	6.4	7.3	-29.6	-21.0
Salt Lake City, UT	5	-3.1	-31.0	8.2	9.6	-32.7	-25.6
Minneapolis, MN	6	-1.5	-19.8	5.6	6.7	-20.6	-15.5
Portland, ME	6	-3.1	-20.6	6.9	7.2	-21.2	-12.5
Anchorage, AK	7	-1.5	-18.4	5.2	5.6	-18.6	-12.1

Table 2. 16 Story Office Building Low Energy Design as Compared with ASHRAE 90.1-2007 Design over 40 Years, by City

Introduction of a carbon tax of $50 per metric ton CO_2e emissions from operational energy changes the cost-effectiveness calculations. The additional cost of carbon increases the AIRR range by 0.2 percentage points to 1.5 percentage points, with a median increase of 0.8 points. Although the energy efficiency measures are cost-effective without carbon restrictions, a price on carbon increases the return on investment and could make otherwise cost-ineffective measures cost effective. Locations with significant coal-based electricity, such as the central United States, see the greatest carbon tax reductions through improved energy efficiency. A carbon tax has minimal cost impacts on locations with large amounts of alternative energy, such as West Coast cities, because the marginal CO_2e reduction from energy efficiency improvements is small.

6 CONCLUSIONS

The group of energy efficiency measures recommended in the Low Energy Cases for the building types studied are cost effective without carbon restrictions for nearly all locations in the United States, with 126 of 128 building type-location combinations studied having an AIRR greater than 3 % in real terms. Life-cycle costs, energy use, and carbon footprints are all reduced over a 40-year study period. The introduction of a carbon price increases the rate of return on energy efficiency investments across all locations and building types. The results lead to several policy implications. Investments in building energy efficiency measures recommended by whole building energy simulations are often cost effective and have competitive annual investment returns in many areas of the United States, while improving efficiency and lowering a building's impact on climate change. Placing a price on carbon emissions further increases the AIRR for energy efficiency improvements, substantially improving the business case by increasing the likelihood that the energy efficiency investments will be the best investment alternative.

7 LIMITATIONS AND FUTURE DIRECTIONS

There are a number of limitations in the scope of this analysis that will be addressed in future work, including consideration of advanced HVAC systems, solar photovoltaic systems, project financing, tax incentives and rebates, alternative building types, designs, and locations, and detailed Input-Output Tables and electricity pricing schemes. NIST is in the process of incorporating these enhancements into the BEES analysis framework.

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The Specific Characteristic of the Chinese City Impact on Climate Change

Han Xiaobao[1]

T3 - Policies

ABSTRACT

Due to the fact that nowadays the urbanization of China is at a high rate of speed, the impact of Chinese cities on the climate change becomes much more significant than before. Thus, this research suits to a background that focuses on the analysis of the character of the present greenhouse gas emission of Chinese cities by the study of the relevant factors such as climatic condition, development level and economic activity type which all affect the energy consumption of cities.

KEYWORDS

Energy consumption, Climate change, Urbanization

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1 THE SPECIFIC CHARACTERISTIC OF CHINESE CITIES

To comprehend the specific characteristic of the Chinese city influence on the climate change, it is significant to know the characteristics of the Chinese cities. Today China is in the high speed urbanization process and in the meantime, due to the fact that China is of 9 600 000 sq.km^2 areas, there are several various kinds of climate, furthermore, some of them are so different that in winter time of the year, some places can have summer temperature. Therefore, analyzing the complicated characteristic of the Chinese cities becomes necessary.

1.1 The High-Speed Urbanization

Since early 1980s, with the economy developing, China has been in the high speed urbanization process, which can be recognized by three factors – city population, land area of cities and transport.

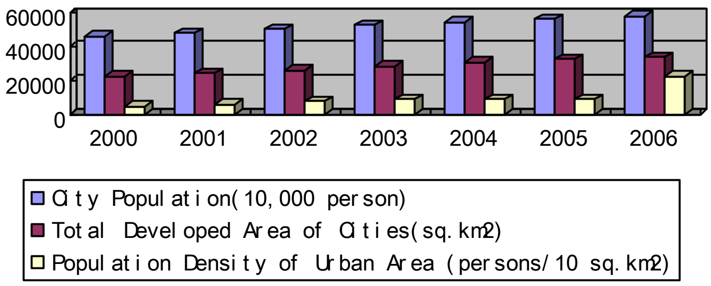

Fig.1.1.1. The growth of city population and city developing area in China

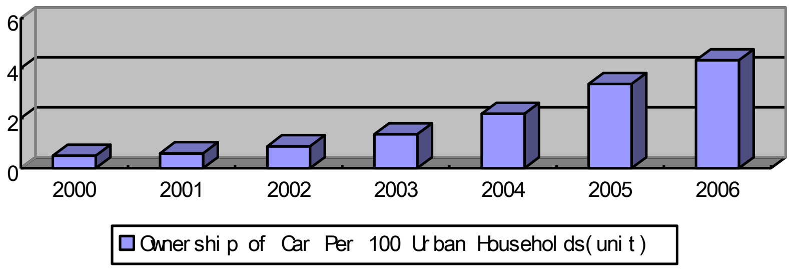

Fig.1.1.2. The growth of ownership of car per 100 urban households

1.2 Industrial Proportion

In this urbanization process, the proportion of second (manufactering) industry in Chinese cities contributes an essential part not only in the economic sector but also in the energy consumption one. This urbanization characteristic is attributable to the present level of developement and the style of the economic activity of the Chinese cities. Especially in the mega cities such as Shanghai, Guangzhou and Tianjin where the manufacturing centers are always centralized.

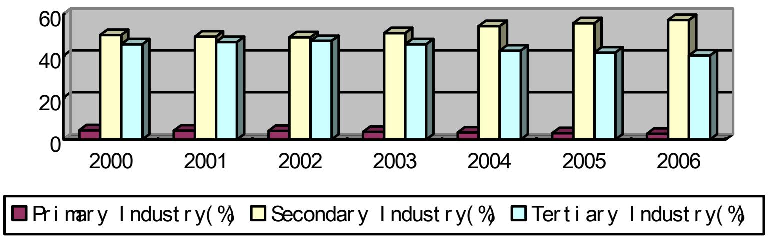

Fig.1.2.1. The GDP of Tianjin (100 million yuan)

1.3 Different Climate of Chinese Cities

According to the regulation for building energy demand and indoor comfort quality design, China can be divided into several zones: frigid zone, cold zone, cold-winter & hot-summer zone, hot zone and temperate zone which are different in average temperature and humidity from each other. Thus, the energy consumption of building sector becomes various in these zones.

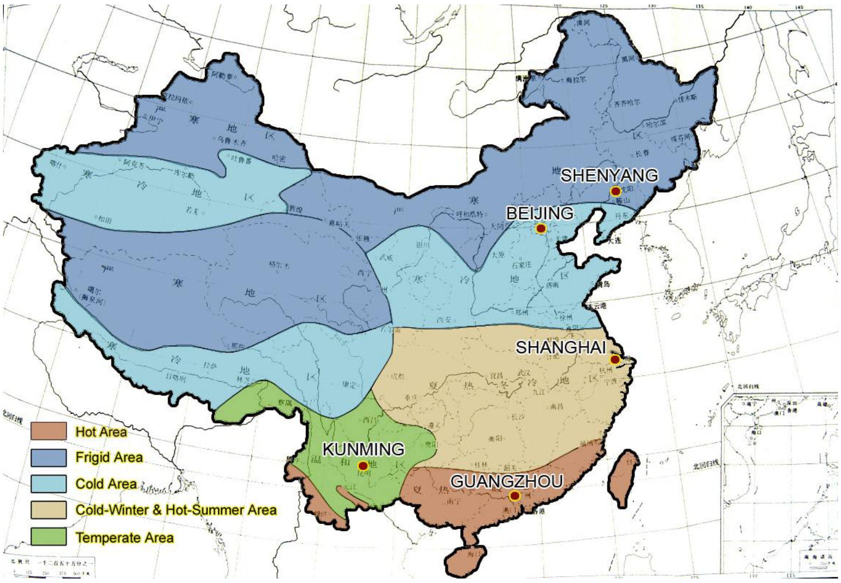

Fig.1.3.1. The climate zones in China

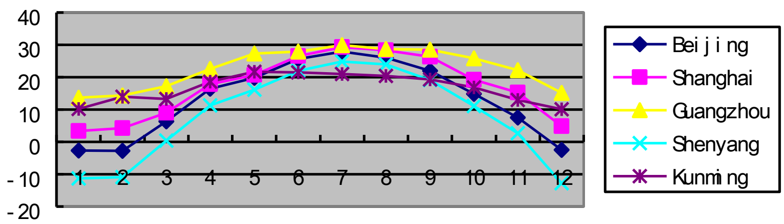

Fig.1.3.2. The monthly average temperature (°C)

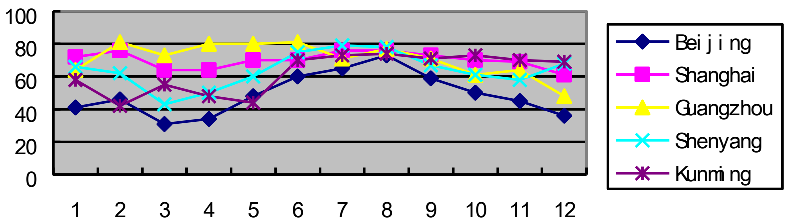

Fig.1.3.3. The monthly average relative humidity (%)

Nowadays, except the frigid and cold zones, there is limited centralized heating system in any other zone where in winter the average outdoor temperature is lower than what the comfort quality demands. Therefore, in those zones, the indoor temperature can fall below the comfort demand level in winter if there is no heating. In contrast, in summer, even in the cold zone, the weather always becomes hot and moist, which makes space cooling become neccessary. This condition indicates that the potential energy demand for improving the comfort quality can be high when the expected comfort level improves with the developing of the economy.

2 THE SPECIFIC CHARACTERISTIC OF ENERGY CONSUMPTION IN CHINESE CITIES

2.1 Industry Sector

The high economy proportion of the secondary industry results in high energy consumption in this sector. In the cities like Shanghai, Guangzhou and Tianjin, the energy consumption of the secondary industry plays the prevailing part role of total amount.

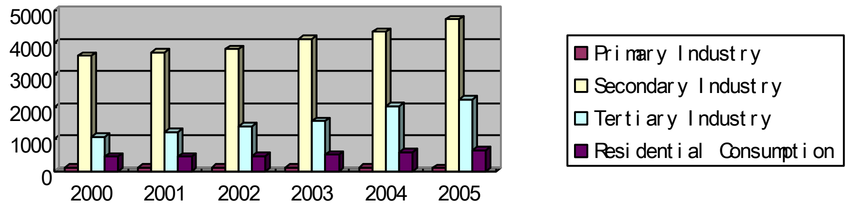

Fig.2.1. The energy consumption of Shanghai (10 000 tons of Standard Coal E) (1 ton of Standard Coal E = 29307.6 MJ)

2.2 Building Sector

The residential building energy consumption is mainly composed of space heating, space cooling, lighting, domestic appliance, water heating and cooking.

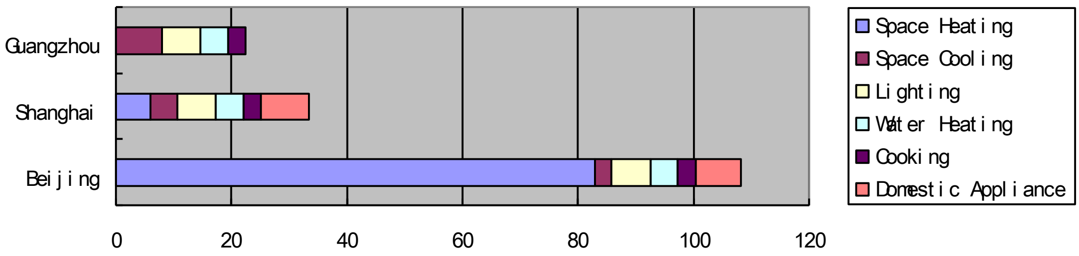

Fig.2.2.1. Energy consumption in households of Beijing, Shanghai and Guangzhou (kWh/m2·a), 2004

Very different from residential buildings, the energy consumption of commercial buildings mainly consists of space cooling, lighting and equipment sectors. Especially in the ones which are of larger than 20000 m^2 square meters, usually lighting and air conditioning energy consumption can compose of more than 50% of total amount, even in the cold zone such as in Beijing.

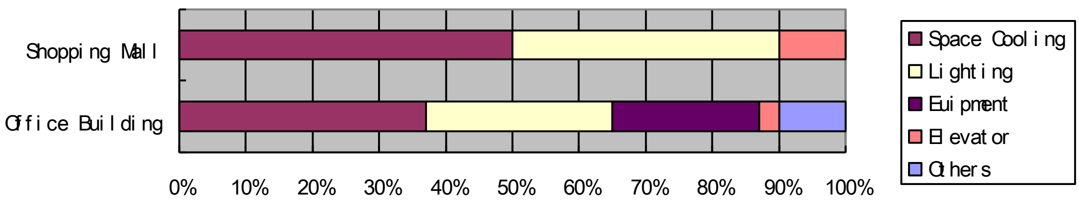

Fig.2.2.2. Energy consumption of commercial buildings in Beijing, 2004

2.3 Transport Sector

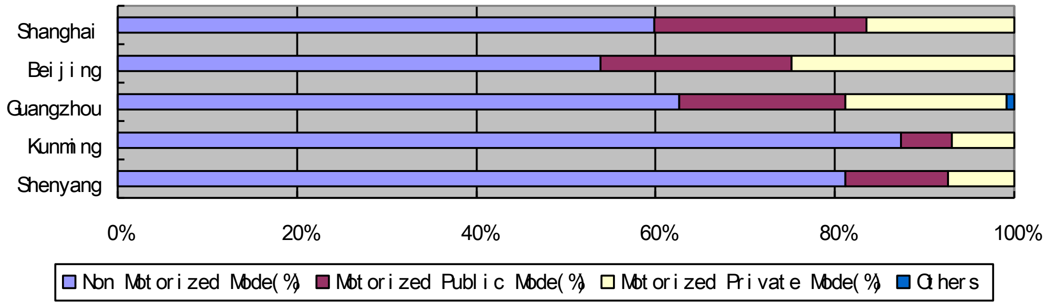

Fig.2.3. The present transport mode of Chinese cities

2.4 Fuel Mix

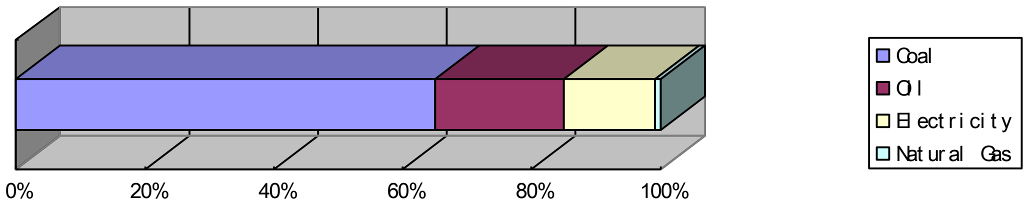

Fig.2.4. The type of the final energy consumption of Beijing in 2005

3 CONCLUSION

The characteristic of the impact of the Chinese cities on the climate change is:

- The high speed urbanization in China makes the impact of Chinese cities on climate change undoubtedly become more and more due to the fact that the energy demand of cities increases fast;
- The industrial sector in Chinese cities always has the largest proportion of total present energy consumption because of the city economic developing level and style;
- The various climates in China result in the different energy consumption characteristic of Chinese cities especially in the residential building sector;
- Even though the present energy consumption per capita in Chinese cities is low, with the improving of average income, the expected comfort quality level enhances, and the domestic household appliance amount increases as well, both of which can make the greenhouse gas emission of building sector become more;
- The prevailing resource of fuel mix of Chinese cities presently is coal, which makes the unit GDP greenhouse gas emission in China high.
- In conclusion, based on the present situation of Chinese cities, the impact of them on climate change has its own characteristic. Therefore, to mitigate the climate change, it is necessary to analyze this characteristic before making policy and practicing technology.

Energy Efficiency of Social Housing

Angela Silvia Pavesi[1], Amalia Siriana Vivian[2]

T 3 Policies

ABSTRACT

Currently, at least half of residential energy consumption is made up of wastes that could be avoided using economically mature technologies. In fact, some recent studies point out that 45% of national energy consumption is caused by inefficient residential use[1]. By reducing wastes and increasing efficiency, it is possible to obtain not only the maximum possible reduction of CO_2 emissions with the same amount of investments, but also the reduction of imports of fossil fuels in a directly proportional measure.

A good example of building redevelopment based on this assumption is given by the town of Padova that starting in 1998, through its Housing Department, has implemented initiatives to improve the quality of some urban settlements. With the collaboration of ATER (Territorial Company for the Residential Building), the APS (Padova Company Services) and the ESU (Regional Company for the University Right to Education) the Housing Department has undertaken a policy of redevelopment of degraded residential neighborhoods.

The aim was to work both on the social environment and the housing, with the purpose of redeveloping them both in terms of type and energy consumption.

The tool used to implement the redevelopment is the District Contract (Contratto di Quartiere), which, among the forms of planned and negotiated contribution, is the most advanced project tool to enhance the integration of local planning, environmental and social sustainability functions.

KEYWORDS

Environment, Energy Redevelopment, Technology Innovation

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[1] Source: Libro Bianco Energia – Ambiente - Edificio dell'Enea e della Federazione Industrie per le Costruzioni FINCO, 2004.

1 INTRODUCTION

The current environmental situation, which degrades due to the increase of pollution and the continuous consumption of energy and non-renewable fossil fuels, is an emergency that our society must inevitably face.

According to various national and international reports on CO_2 emissions and energy consumption, the construction sector, which includes construction, renovation and buildings management, accounts for more than 40% of total European consumption and represents 45% of total domestic consumption (in terms of primary energy this represents 84 MTEP per year compared to the national total of around 190 MTEP per year) and about 76% of this is due to heating.

Moreover, the construction sector involves an extreme use of land along with a high energy consumption which implies a substantial contribution to climate change.

The recovery and reuse of existing buildings will become a stronger priority because it represents a plausible solution to the environmental crisis.

In fact, according to some data by Cresme, building recovery represents approximately 60% of the total construction industry and could reach an estimated 80% in 2020, with a potential for reducing energy consumption but also one for economic growth and employment as set out by the "Libro Verde".

Recovery interventions focused on the need to contain energy consumption of buildings are in fact already taking place. These include the use of technologies and strategies of both active and passive type, with the exploitation of renewable energy sources.

Despite this, progress in the recovery of existing buildings and in finding solutions to related problems, are currently not very effective. The causes of this can be identified in weak regulation, technical difficulties of implementation and economic considerations related to the huge costs of these interventions.

> *[…] In particular, the public housing sector is a good starting point both to intervene directly on a large scale in the energy redevelopment of existing buildings (about 60% of public housing has a low level of energy efficiency),and to be towed across the whole housing sector […]*[2].

It is important to note that in the current situation where housing demand is changing in relation to the ongoing transformations of society and according to more environmentally friendly choices, it is necessary that the Government, that is facing the problem of the recovery of Public Residential Buildings (ERP), takes action not only with a deep knowledge of the starting situation, but also with an awareness of the potential that may result from solving the problems themselves.

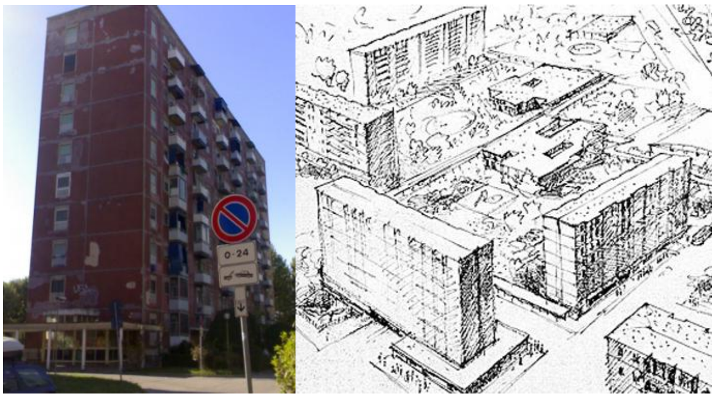
The Government should not limit the interventions to simple maintenance, but must promote interventions that develop a concrete re-qualification of the built environment, which must be renewed with climate change issues in mind.

2 SOCIAL HOUSING ASSET IN ITALY

Speaking about Social Housing today means dealing with old buildings which are deficient in several ways. Since the beginning Social Housing was developed often with low technological quality,

[2] European Conference organized by CECODHAS, "Energy and sustainable social housing - The commitment of the players against the impoverishment of families," Ancona April 2008

especially in relation to new applications for energy saving. The vast majority of buildings have been constructed with heavy prefabrication technology (e.g. “Raymond-Camus” system which relies heavily on prefabrication of elements of walls and floors of large dimension, generally based on the size of a room, which has found its extensive testing in the South Gratosoglio quarter in Milan), where the goal was the optimization of the building process to face the immediate housing need.



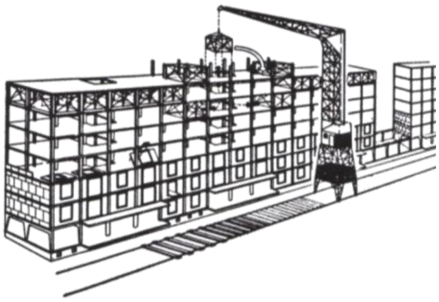


Figure 1a e 1b. District Gratosoglio (Architecs BBPR, 1962-1971), Milan: example of prefabricated building.

Figura 2. Scheme of construction of a prefabricated building. Source: *L’industria delle costruzioni*, n. 397, settembre-ottobre 2007.

Figure 3. District Via Giuffrè/Villani, Milan: example of prefabricated building.

Figure 4. A building during construction (1984).Source: Comune di Milano.

This priority has left a secondary place to the focus on the housing as an element of separation between the inner and outer space and regulating the conditions of comfort, with the consequent loss of massive and thermal properties.

It also should be noted that social housing developments also need requalification and upgrading due to changing needs of its new users. These have dramatically changed over the last thirty years, due to important social phenomena such as aging of the population, immigration and gradual impoverishment of some categories of the population.

In addition to Social Housing’s need of requalification should be added the disinterest shown in the last two decades by institutions and local authorities. These have failed to put in place specific and targeted intervention programs and policies for housing, hence leaving some social housing neighbourhoods to shift from housing deterioration to social degradation.

For all these reasons, the Social Housing asset appears as an area with the potential to provide a substantial response to the energy problem and, at the same time, be an example for other existing Italian real estate. Two-thirds of these buildings are previous to 1976, year in which the first law on energy efficiency was enacted, n. 373, with the result that such real estate has neither design nor technology to face the energy efficiency problem.

2 A GOOD EXAMPLE OF IMPLEMENTATION OF POLICIES FOR ENERGY RECOVERY: THE DISTRICT CONTRACT OF PADOVA SAVONAROLA

The District Contracts[3] represent an innovative tool provided to municipalities, in the framework of urban regeneration, for the implementation of experimental re-construction of subsidized social housing.

In the interventions of requalification and upgrading of settlements, the achievement of primary objectives is possible only if prioritized quality macro-objectives have been defined.

These are identified in the "Guide to testing programs" approved by the Executive Committee of the CER, on the 27th February 1997, in which the general goals of testing are divided into morphological quality, eco-system quality, usage quality and quality system.

In particular, in this work the issue of ecosystem quality[4] is highlighted, which covers the physical-environmental and technological dimension and their respect of the pre-existing ecosystem. The ecosystem quality is determined by the maximization of resource efficiency, such as water and energy through use of environmentally friendly components and materials.

To this regard the district contract of Savonarola Quarter emerges as the first and the only Italian example of interest in the topic of Social Housing requalification with a view to energy saving and respect for the environment, even though the implemented strategies cannot be considered of advanced technological innovation.

The key objectives of the District Contract of Savonarola quarter were focused on the sustainable recovery of ATER residences located in Piazza Toselli, of the student house managed by ESU in Via Monte Cengio, and the creation of a tele-heating network for the entire unit of San Giuseppe.

In this paper we will highlight the project for the requalification of the buildings of the "Quartiere Caduti della Resistenza" in Piazza Toselli[5], built during the nineteen twenties. The intervention took place at different levels by improving the thermal and noise performances, by upgrading the architecture and the functionality of the existing buildings and by taking into consideration the social environment.

The works on the envelope of the buildings were intended to provide better efficiency in terms of both thermal and noise performance. It included the use of materials which would satisfy the basic principles of Bio-Architecture: breathability and vapour permeability, fire resistance, insulation and thermal inertia, durability, pleasantness, the recyclability, etc..

For the coat isolation of the buildings, special panels consisting of an innovative and environmentally friendly material were chosen. This material is derived from a mixture of rock powder, protein and

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3 The District Contracts were created in 1998 by the Committee for Residential Building (CER) established by Law 865/71, to rule the distribution of funds for the execution of public programs for residential housing to the single Regions, which are responsible for the localization of interventions and their implementation through the choice of public (IACP) and private (cooperative edilizie) executors.

4 In the "Guida ai programmi di sperimentazione" ECOSYSTEM QUALITY is defined as "the set of conditions to achieve and ensure over time the welfare conditions of living in the city and particularly inside of the buildings, while respecting the existing ecosystems and providing a saving in the use of the available natural resources".

5 The "Quarter of Caduti della Resistenza" was originally an organic system of gallery houses, a typological and morphological pattern almost unique in Padova area.

mineral binders, homogeneously mineralized without fibrous formations and open to the spread (μ = 5-10), with good mechanical properties, and thermal conductivity equal to 0.043 $W·m^{-2}·K^{-1}$.

According to the final tests, thanks to this technological solution, the transmittance of the exterior walls is changed from the value of the statement of fact, 1.37 $W·m^{-2}·K^{-1}$, to 0.483 $W·m^{-2}·K^{-1}$ for walls with 43 cm width, and from 1.78 $W·m^{-2}·K^{-1}$ to the value 0.529 for walls with 30 cm width. Again, for thermal insulation of the cover, made with ventilated system, the use of special wood-fibre panels was decided. These are free from synthetic petrochemical adhesives and recyclable, with a thermal conductivity equal to 0.044 $W·m^{-1}·K^{-1}$. The calculations have shown that the values of thermal transmittance have decreased from 0.69 $W·m^{-2}·K^{-1}$ to 0.36 $W·m^{-2}·K^{-1}$.

In addition, to facilitate both circulation and quality of the air, natural breathable materials have been selected and an experimental ventilation based on humidity was implemented. The latter is able to vary the volume of air circulating in the house in relation to the needs of occupants at any specific

Over one courtyard, a glass cover was erected with steel structure and laminated wood, thus creating a Winter Garden (Fig. 5).

Figure 5. Sustainable recovery of ATER residences located in Piazza Toselli. Source: Comune di Padova.

Figure 6. Image of the winter's garden indoors. Source: Comune di Padova.

In addition to ensuring a place of aggregation protected throughout the year, this large covered area (which encloses a volume of approximately 10 600 cubic meters of air) works as a solar greenhouse, like a heat accumulator, which provides a reduction in energy consumption necessary to heat the residential units.

The aim of this implementation is to ensure a better comfort both in winter months and also in summer, ensuring adequate ventilation and a constant air supply, avoiding abrupt changes in temperature and an overheating of the environment: at this regard all these elements were considered in studying a structural and technological system that could meet these objectives.

It was hence designed as a self-supporting structure, where existing buildings only perform the role of bracing. This structure consists of steel columns and laminated wood arches, while the entire roof is made of glass with aluminium frames, "with openings in flap driven by industrial hydraulic actuators, to ensure a high level of durability and reliability" [6].

To try and improve ventilation, a raised central element (h. 50-60 cm) was created on the ridge that performs the function of a chimney, using the Venturi effect.

[6] *Relazione Progetto Esecutivo,* District Contract of Quartiere Savonarola, Municipality of Padova, Residential Housing Department, program responsible Arch. Sergio Lironi, March 2000.

In order to guarantee an adequate protection from solar beams during the summery months, inner and external shielding have been used and glasses of selective type have been adopted to allow a higher luminous flow compared with a limited energetic contribution of the solar beams.

An internal instrumental monitoring of the housing was installed (pre-intervention, upon completion of retraining and after a period) to allow the analysis of data in relation to concurrent weather conditions, because of the experimental feature of the intervention[7]. The various records[8] of all data and all monitoring have been performed by the sensors (Tiny-tag) to detect the air temperature, the surface temperature and the humidity both external and internal of some apartments, in strategic positions for an efficient sampling.

By reading the pre-intervention data it has been possible to perform a detailed design of the technical solutions for the insulation of the apartments. In particular, it was clear that comfort is closely dependent on heating system, since the thermal mass is not sufficient to effectively mitigate the variations in temperature. Hence, the decision was made to implement coat isolation on the exterior walls, leaving untouched the ones facing the winter garden.

3 CONCLUSIONS

Working on the Social Housing assets and on its upgrading in terms of energy, should be seen as a way to meet the needs of our society, both environmentally and socially.

The example of the District Contract of Quarter Savonarola is the first example in Italy and, as such, it should be the drive towards a good practice of environmental and energy requalification of the vast Italian assets.It should be recognized that the applied technologies do not represent a real innovation (greenhouse, coat insulation, solar chimney), but what makes this case unique is the willingness to undertake concrete choices to focus on climate change and energy efficiency. The District Contract is actually the appropriate instrument with which to implement these objectives.

This example will highlight not only the potential that may result from these actions on existing building, but also the corrections and weaknesses that must be bridged. In fact, the field checking has clearly shown that all aspects related to air quality and to energy efficiency have to necessarily be accompanied by proper training of the tenants, to ensure that the implemented strategies are not only a good intention but that they also represent an achievable outcome in terms of ecosystem quality.

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Relazioni Progetto Esecutivo redatti per tutti e due i Contratti di Quartiere dall'ATER e dal Comune.

Simplified Method for Modification of Weather Data File for Energy Simulations within Urban Areas

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T 4 – Climatic Data

ABSTRACT

Energy simulations for the estimation of building energy demand are in almost all cases carried out for each site with a TRY (i.e. Test Reference Year), based on data collected at airports, thus out of urban areas. Nevertheless, within urban areas, climatic and more generally environmental conditions – the aspect mostly studied, though not the only one, is the Urban Heat Island – are different from the ones in non urban zones, thus using the data collected at airports may introduce sometimes relevant errors in the final result of the energy demand estimation. Nonetheless, climate data collected within urban areas are rarely available over a long period of time necessary for building historical series (the World Meteorological Organisation recommends 30 years).

In this paper the case of Milan is studied and a simplified method is proposed for estimating the intensity of the Urban Heat Island, namely the increase in urban temperatures, which is an unsteady phenomenon, over one year. The proposed method is based on the modification of weather data file (in this case the IWEC for Milano Linate airport) with corrections linked to circulation types. Thus the energy demand for an office building type in Milano is investigated, carrying out simulations both with corrected climatic data and with the ones from airport measurements, results are then analysed and discussed.

KEYWORDS

TRY, Urban Heat Island, Climatic Data, Dynamic Energy Simulation.

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1 INTRODUCTION

The Urban Heat Island (UHI) is recognised as one of the most relevant effects of urbanisation and after Landsberg [1981] and Oke [1987] is defined as an urban area within which average temperatures are significantly higher than in non-urban areas, in the neighbourhood, especially during the night. On this definition is thus based the quantification of the Urban Heat Island Intensity (UHII): the difference of temperatures between the urban and the rural area, mostly referenced as the ΔT_{u-r} [K]. Several studies on many cities demonstrate that the UHII is not negligible at all: for certain sites, peak ΔT_{u-r} values can even exceed 12 K (e.g. see RIZWAN et al. 2008). The problem intrinsic in this definition is the selection of the site to be considered the rural reference.

Despite the relevance of the phenomenon and its influence on energy consumption, the climatic file used for energy simulations for buildings are in almost all cases based on data collected at airports out of urban areas; in addition, urban measurements are rarely available. Santamouris [2001], furthermore, reports that only few studies analysed the influence of the UHI on energy demand of buildings.

Besides, in literature there exist relations for estimating the UHII showing its dependence on simple parameters. The expression suggested by Oke [1982] connects UHII with population or population and regional wind velocity; always Oke [1988] shows the variability of UHII with the sky view factor. Other studies put into relation the ΔT_{u-r} with other climatic parameters such as wind velocity, atmospheric pressure or cloudiness, but are proposed for specific cities. In general, these simple formulas were, however, meant as a first tool for perceiving the intensity of the phenomenon and qualitatively understanding the most important parameters involved and they were not meant for modifying climatic files for energy simulation. In fact, they are very dependent on the data set with which they were built, they often give only peak values and they also disregard several important environmental variables. Moreover, the urban heat island is an unsteady phenomenon (for Milano, documented by Bacci and Maugeri 1992) over one year and non homogeneous over the urban area (for Milano, is described by Poli *et al.* 2007 and Borghi 2008).

Hence, the first objective of this paper is to propose a procedure for modifying the climatic file used for energy simulation (available for Milano Linate airport). The temperature series provided by IWEC is changed adding a ΔT related to circulation types observed in the Po Valley. The temperature series (urban and achieved with the proposed method and with relations from literature) are then compared.

The second objective of this work is to carry out a preliminary assessment of the impact of the Urban Heat Island on energy demand of buildings; more in detail, the performance of a selected tertiary building in Milano is analysed. First, the difference in energy demand using the airport climatic data for the urban context is assessed, then the same building is evaluated in urban and non-urban context and finally the influence of natural ventilation is studied.

2 METHOD FOR CLIMATIC FILE MODIFICATION

In order to take into account the Urban Heat Island effect a procedure is suggested for adjusting the temperatures given by the climatic file used for energy simulations, analysing the case study of Milano. The considered input file is the IWEC (i.e. International Weather for Energy Calculations), which is the 'typical' weather file outcome of ASHRAE Research Project 1015, commonly used for energy simulation software. The IWEC are based on up to eighteen years measurements data set and provide information about the main climatic quantities (i.e. air temperature and relative humidity, wind velocity and direction, beam and diffuse solar radiation, cloud cover, air pressure, etc.). The IWEC file considered is the one supplied for Milano Linate airport, based on measurements carried out from 1984 to 1999. Linate airport is sited on the East side of Milan, 12 km far from the centre of the city and about 2 km far from the boundary of the city.

The proposed procedure is based upon the concept of modifying the IWEC file adding the increments (positive $\Delta T_{u\text{-}r}$ [K]) related to the presence of the Urban Heat Island over the area of Milan (see Tab.1). These increments are given by a study on a data set of three years (1988 – 1990) carried out by Belloni [1993] at OMD (Osservatorio Meteorologico Milano Duomo), which relates different Urban Heat Island Intensities, for Milan, to different circulation types (firstly studied by Borghi and Giuliacci 1980). Each circulation types is characterised by wind velocity and direction, relative humidity, cloud cover, pressure and temperature; consequently, each circulation type produces a different UHII and also a different structure of the Urban Heat Island (that means a different shape over the city – for instance it could be split up in two parts – and evolution). Moreover, some circulation types do not give UHI.

Table 1. Circulation types over the Po Valley and associated UHII, after Belloni [1993].

Circulation type		*Heat Island Effect*	*Summer $\Delta T_{u\text{-}r}$ [K]*						*Winter $\Delta T_{u\text{-}r}$ [K]*					
			Day			*Night*			*Day*			*Night*		
			A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
1	*Libeccio*	*NO*	-	-	-	-	-	-	-	-	-	-	-	-
2	*Cyclo-genesis over Ligurian Sea*	*NO*	-	-	-	-	-	-	-	-	-	-	-	-
3	*Scirocco*	*NO*	-	-	-	-	-	-	-	-	-	-	-	-
4	*Split depression over Ligurian See and High Adriatic*	*NO*	-	-	-	-	-	-	-	-	-	-	-	-
5	*Anticyclone over Mediterranean Sea*	*YES*	3	2	-	3	1	-	4	3	3	3	4	4
6	*Föhn*	*NO*	-	-	-	-	-	-	-	-	-	-	-	-
7	*Stable currents from North-West*	*YES*	3	-	-	1	-	-	2	1	-	1	1	-
8	*Grecale*	*YES*	2	-	-	2	-	-	2	-	-	3	4	-
9	*Wavy West*	*YES*	2	1	-	2	-	-	1	2	-	2	1	-
10	*Bora*	*NO*	-	-	-	-	-	-	-	-	-	-	-	-

Thus, the procedure consists of three main steps:

a) The circulation types causing the UHI are recognised in the IWEC file (the circulation types not producing an UHI are not considered);
b) A filter is adopted in order to detect the most probable circulation type; this is done because the circulation types are observed at 1 500 m height AMSL, whilst the IWEC is based on measurements at 10 m height from ground level. Then, the more stable circulation structure in the considered period (within ± 12 h) is associated to each hourly step (in this way the uncertainty in recognising the circulatory structure is thus limited and was achieved the best fit with the statistics by Belloni - OMD);
c) The UHII associated to each circulation type is applied to the climatic file adding the relative $\Delta T_{u\text{-}r}$ [K].

A small difference in the frequency of the presence of the different circulation type is observed between the statistical analysis carried out by Belloni [1993] and the occurrence of the circulation structures recognised in the IWEC file (see Tab.2). This is due to the fact that the extension of the data set is not the same (1988 – 1990 and 1984 – 1999) and due to simplification in the procedure adopted for recognising the circulation type in the climatic file.

However, the modified data show a good accord with the statistical analysis, in particular in the evaluation that in most of the cases (see Tab.2) the UHI appears not in its maximum intensity, but at a value lower than 3 K. Moreover, it can be noticed that the Urban Heat Island is present all over the year, but, for Milan urban area, it has a higher intensity, mainly in winter condition (see Fig. 1 and Bacci and Maugeri 1992); this is due to the protection against wind provided by the other constructions and to the high thermal dispersion of buildings.

Table 2. Comparison between the frequency of the observed circulation types in the original data set and the circulation types recognised in the IWEC file.

ΔT MILANO CENTRE – LINATE [K]	*Belloni - OMD*	*IWEC Modified*
ΔT < 1	40%	43%
1< ΔT <2	24%	25%
2< ΔT <3	15%	17%
3< ΔT <4	8%	8%
4< ΔT <5	6%	5%
5< ΔT <6	6%	3%
6< ΔT <7	1%	0%

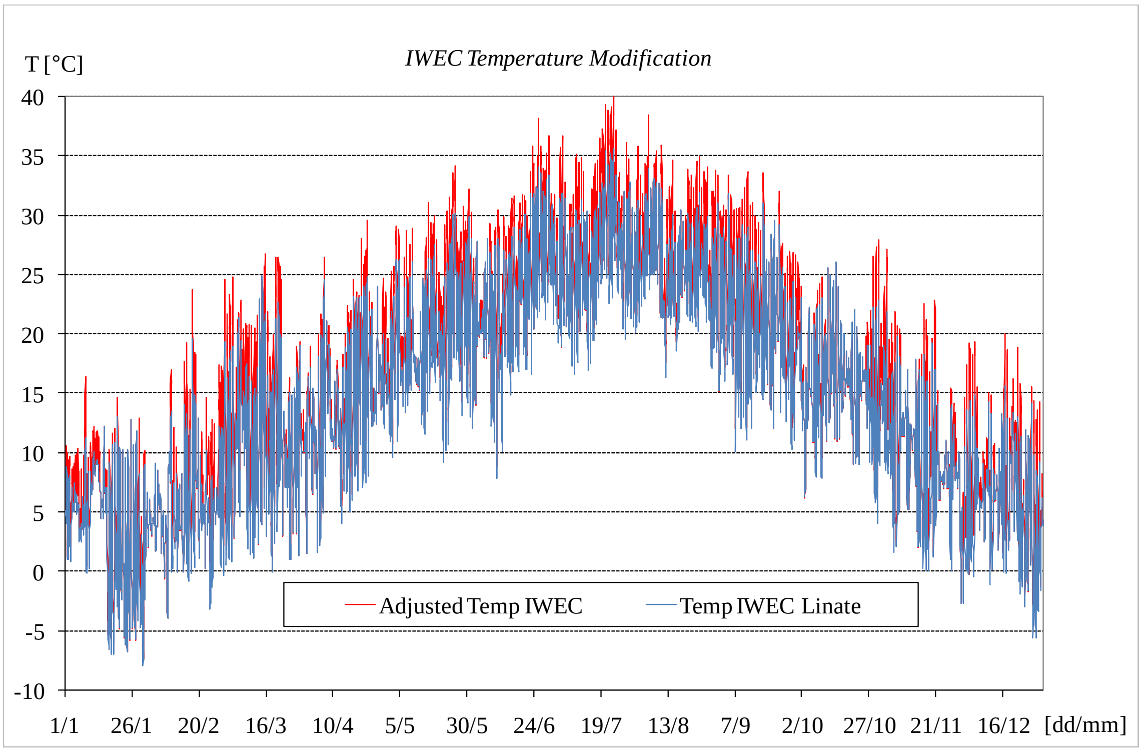

Figure 1. Comparison between the air temperature provided in the IWEC file given for Milano Linate and the air temperature achieved by adopting the proposed method.

3 INFLUENCE OF UHI ON BUILDING ENERGY DEMAND: A CASE STUDY

Once the climatic file had been adjusted, according to the above described procedure, energy simulations (synthesised in Tab. 3), by means of EnergyPlus, have been carried out in order to assess the influence of the UHI on building energy demand for heating and for cooling. The variables considered are: the presence of the UHI, the wind velocity (non-urban values modified for considering protection given by other buildings within urban sites, according to EnergyPlus Calculation Reference 2008), the shading effect due to the presence of other buildings and the natural ventilation.

The subject of this analysis is a large office building of 5 floors with the major axis S-W oriented. His S/V ratio is equal to 0.26 m^{-1} (external surface of 8 501 m^2 and occupied volume of 32 706 m^3) and the value of the ratio between window area and total façade area is 40%.

For simulations, the standard floor has been divided into five main thermal zones: south-east zone (20 offices, 710 m^2), north-west zone (21 offices, 514 m^2), north-east zone (3 offices, 66 m^2), south-west zone (3 offices, 33 m^2) and internal zone (corridors, WC zones and stair-lift zones, 935 m^2). The building has specific capacity of 50 $W·h·m^{-2}·K^{-1}$ and insulation levels typical for Italian existing buildings (U-value of external wall, roof and basement respectively equal to 0.8, 1.4 and 2 $W·m^{-2}·K^{-1}$).

The window components are characterized by standard double glass, internal blinds and aluminum frames without thermal break. Typical office schedules and high internal gains were considered: 16.2 $W·m^{-2}$ for lighting and 15 $W·m^{-2}$ for electric equipments.

The first set of simulations, referred in Table 3 as S-1cnv and S-2cnv, aims to compare the energy demand of the studied building adopting the non-urban weather data and the modified data set, within the city, considering the presence of other buildings, reduced wind velocity and not considering natural ventilation. Hence, it portrays the error made in adopting non-urban weather data for buildings within the urban area of Milan. As a result, taking into account the UHI with the suggested method the heating energy demand is almost halved (from 45.4 to 25.4 $kW·h·m^{-2}·y^{-1}$), whilst the cooling energy demand is increased by more than 70% (from 19.9 to 34.5 $kW·h·m^{-2}·y^{-1}$).

Table 3. Energy simulation results for an office building type in Milano.

Simulation	*Heat island*	*Wind velocity*	*Other buildings*	*Natural ventilation*	*Heating energy demand* $kW·h·m^{-2}·y^{-1}$	*Cooling energy demand* $kW·h·m^{-2}·y^{-1}$
S-1unv	no	city	yes	no	45.4	19.9
S-2unv	yes	city	yes	no	25.4	34.5
S-3rnv	no	country	no	no	42.1	24.8
S-4uv	yes	city	yes	yes	25.4	24.4
S-5rv	no	country	no	yes	42.1	14.1

Comparing simulation S-2unv and S-3rnv, it can be been noticed that the same building positioned in a non-urban context has a higher demand for heating and lower for cooling then in urban area. Finally, comparing simulation S-2unv and S-4uv, the strong influence of natural ventilation on cooling energy demand (reduced by about 30%) is evident, even for a building located in an urban context (whilst out of the city the influence of stronger).

4 CONCLUDING REMARKS

A method for modifying the climatic data for taking into account the urban heat island effect has been proposed. This procedure can be used in case of lack of updated and complete temperature series for an urban site, in presence of information regarding relation between circulation types and ΔT for the considered city. These relations could be achieved by comparison of urban and non-urban data for observation periods even shorter than the ones required, for instance, by ISO 15924 for TRY and even if the temperature data could not be considered a series (not continuous and complete). This method is based on the hypothesis that each year can be seen as a different combination of circulation types and that only one ΔT can be associated to a specific circulation type (distinguished in ΔT given in summer or in winter conditions). The application of this method could be also extended to the modification of non-urban weather file for cities with similar structure and dimension, within the same climatic zone.

A first step has been carried out in the analysis of the energy demand considering a case study which shows that the Urban Heat Island does affect the energy demand of the building: taking it into account or not can lead to different design strategies for both the building envelope and the building services.

Future development of the research will include the comparison between the measured complete urban series for Milan and the one achieved with the proposed method. Then, the possibility of application of the method to other urban contexts will be assessed. Besides, simulations for more building types will be performed, building services will be taken into account and the influence of the Urban Heat Island on the COP of HVAC systems will be studied too.

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Illuminance Measurements related to Global Radiation in Milan

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T 4 – Climatic data

ABSTRACT

Within urban settlements significant modifications of climate occur, hence there is properly urban climatology. The most studied phenomenon is the Urban Heat Island, but also other variations take place such as changes in horizontal rain distribution, wind velocity or air relative humidity. One more aspect that must be taken into account in order to describe the urban environment is the illuminance distribution, which affects the energy demand of buildings also and not only indoor visual comfort. Nevertheless, often data about natural light are not available within urban areas and hence the input for the daylighting design may be affected by noticeable inaccuracy. The aim of this contribution is hence to search for a correlation between illuminance and global short-wave radiation, more often recorded, thus define the real sky conditions for Milan over one year and not only standard reference cloudy conditions, such as for Daylight Factor. This could allow considering critical conditions for glare. Data have been collected for five years by a station positioned over the rooftop of the tallest building in Politecnico di Milano (no shadows from other buildings). Finally the possible advantages and outcomes in building design are addressed, in order to achieve not only Climate Sensitive Buildings, but directly "Environment Sensitive Buildings".

KEYWORDS

Daylight, real sky, illuminance.

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1 INTRODUCTION

The aim of this contribution is to look for correlations between global short-wave radiation and illuminance. Data have been collected in Politecnico di Milano since 2005, with a station called MeteoLAB, which is placed on a rooftop of the tallest building in the campus, without shading from other buildings. The climatological station measures the following data:

- global horizontal illuminance;
- diffuse horizontal illuminance;
- global vertical illuminance in the four cardinal directions (North, East, South and West);
- global horizontal irradiance;
- diffuse horizontal irradiance;
- air temperature;
- relative humidity;
- wind speed, direction and frequency.


Figure 1 and 2. MeteoLAB. Instruments for global radiation and photometric measurement.

Both for radiation and illuminance measurements, data are recorded each 10 minutes (i.e. average of the values masured each 10 ms during the former 10 minutes).

2 LUMINOUS EFFICACY AND RADIATION

Luminous efficacy of the global radiation K_G [lm·W^{-1}] is defined as the ratio of the global illuminance on the horizontal surface E_G [lux] to the global irradiance G_0 [W·m^{-2}] on the same surface.

From MeteoLAB data it is possible to calculate this parameter having simultaneous measurements of illuminance and irradiation. The correlation of daylight luminous efficacy with other parameter is a chance for the evaluation of the quality of MeteoLAB data since no other measurements are available for Milan. In detail correlation of luminous efficacy K_G with Clearness index (K_t) and solar zenith angle (ϑ_z) are respectively showed in Figure 3 and Figure 4.

Clearness index (K_t) is the ratio between the global irradiance on horizontal surface (G_0) and normal direct extraterrestrial irradiance (I_E). It is representative of the sky conditions ranging ideally from 0 (cloudy sky) to 1 (clear sky). Figure 4 shows a predominance of cloudy sky and a shape typical for these conditions. This result is also confirmed by another sky clarity index: the sky clearness (ε). In Figure 3 the percentages of hour of the year having an assigned sky clearness are presented: it's evident the large fraction of the year with cloudy skies.

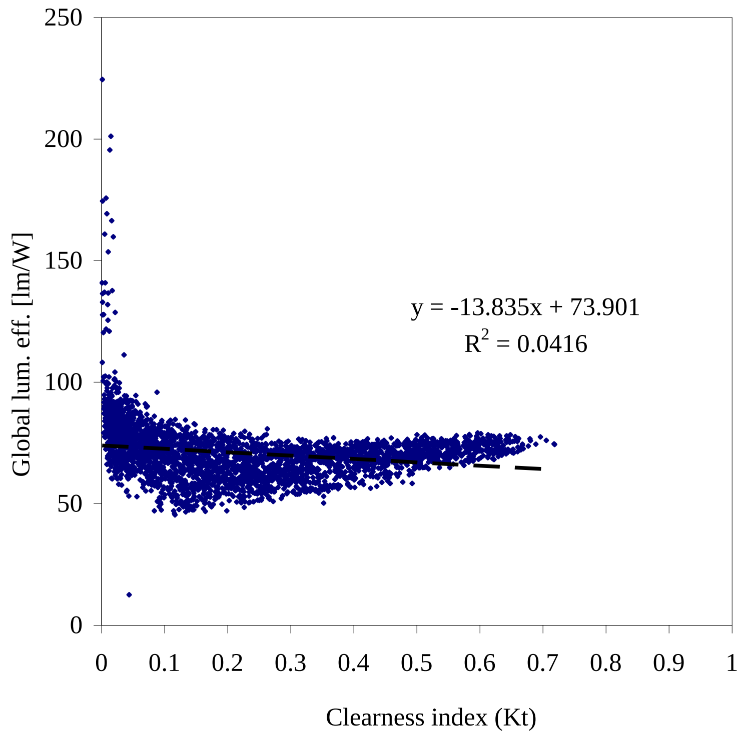

Figure 3. Clearness index vs. Global luminous efficacy - Data from MetoLAB 2008

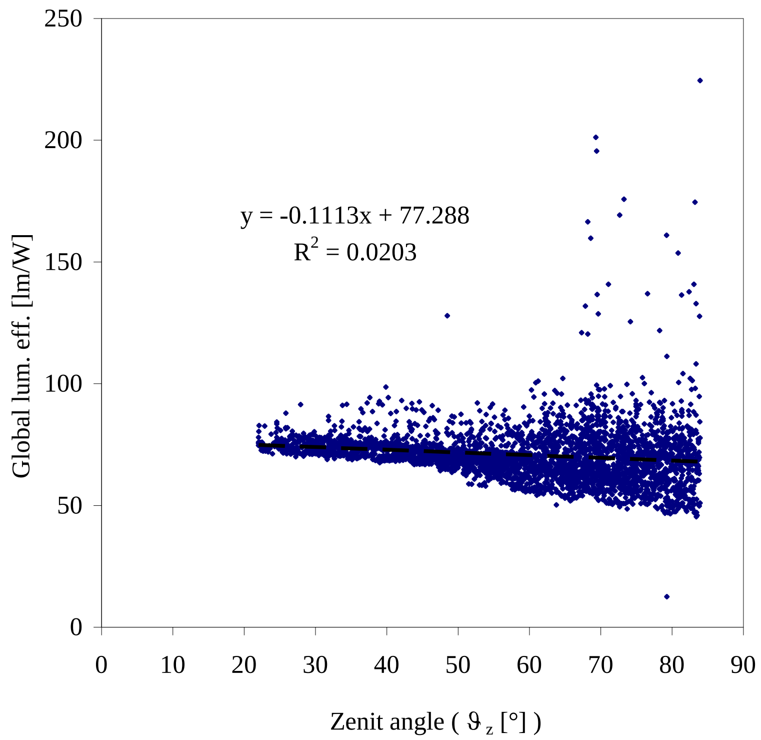

Figure 4. Zenith angle vs. Global luminous efficacy - Data from MetoLAB 2008

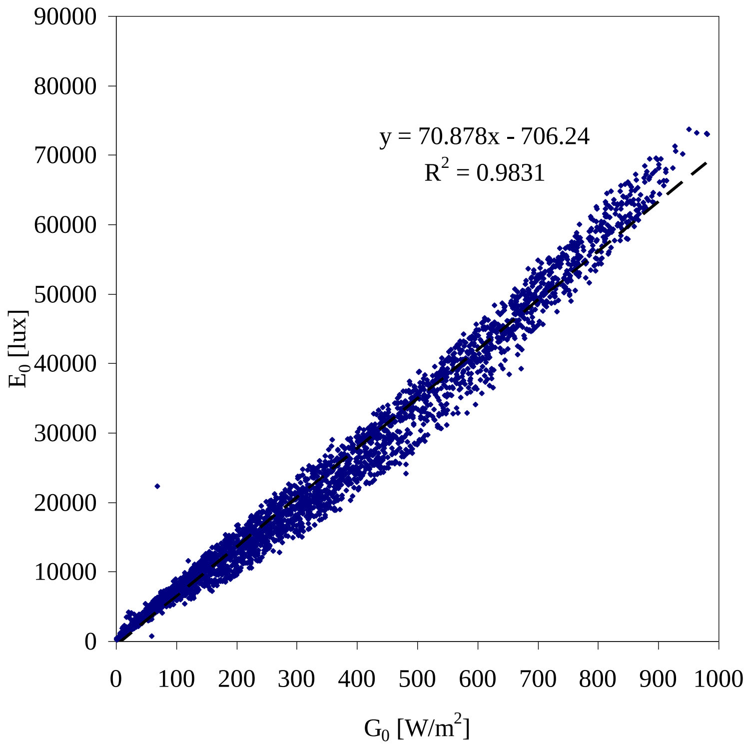

Figure 1. Global irradiance G_0 vs. Horizontal Illuminance E_G - Data 2008

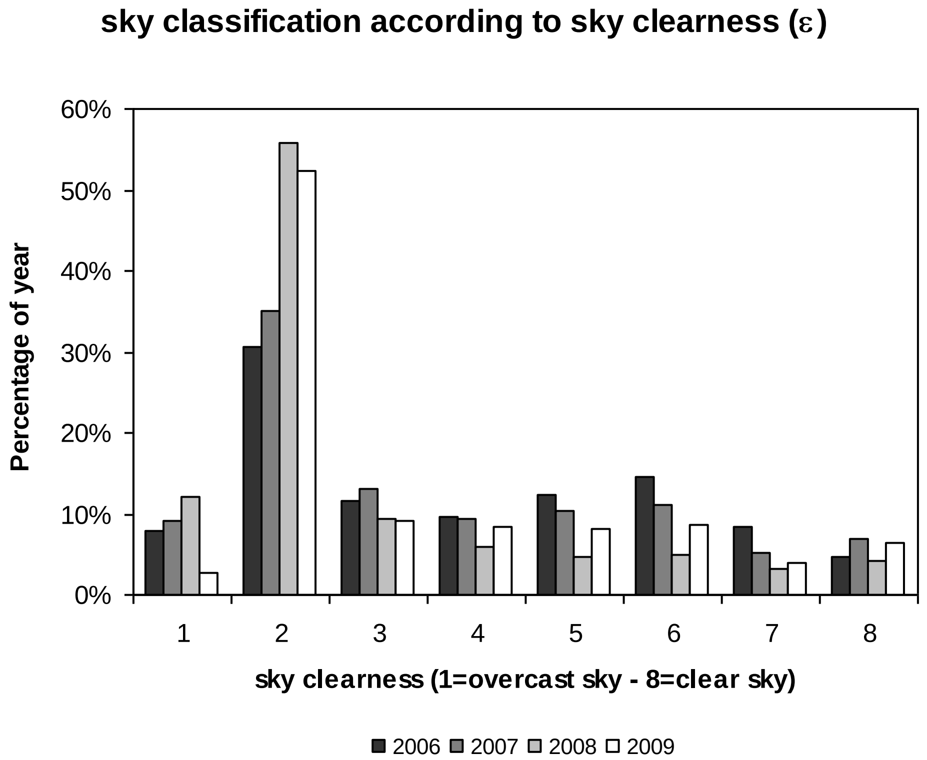

Figure 2 - Sky classification according to sky clearness - Data from MetoLAB 2008

The data of MeteoLAB station were also compared with the Perez model of luminous efficacy in order to realize the plot in figure 6 (the source of data is the year 2008: similar plots are available for previous years) and to have an idea of the quality of data in respect to one of the most common model.

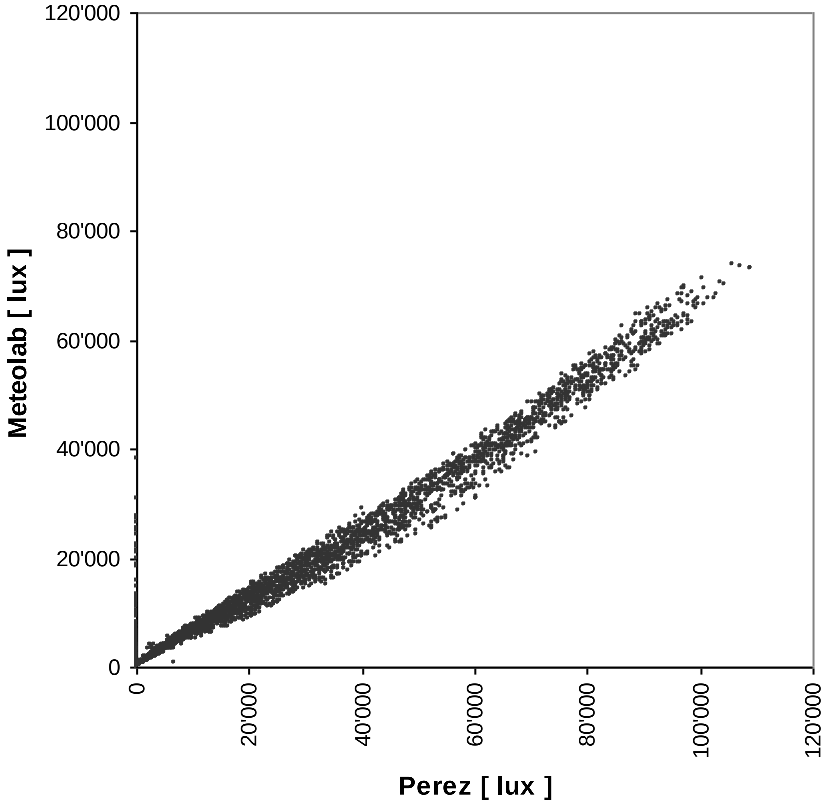

Figure 6. Horizontal Illuminance E_G [Perez derived from MeteoLAB vs. MeteoLAB] – Data 2008.

3 CONCLUDING REMARKS

Starting from ordinary meteorological data it is possible by the mean of Perez model to receive values of illuminance (i.e. from radiometric data you can estimate photometric data). Since radiometric data are far more available than photometric ones it's important to check the quality of measured data before to use it for engineering purposes. In the case of Milan two needs emerge clearly. First of all a long term data set, issued from urban environment, and carefully recorded for engineering utilization (at least data for global and diffuse irradiation on the horizontal plane) is needed: the Meteolab station aims in futures years to fill this gap (eventually with the support of data recoded from other station even with a worse location or with partial and low quality data set). Secondly, right now, the earliest evaluation of measured data from Meteolab station shows a probable general underestimation of value of illuminance on the horizontal plane. In this case the support from other urban stations is missing (Meteolab is the only one in Milan measuring photometric data) and we can rely only on literature data from similar situations. Nevertheless the causes of this outcome are now under investigation in order to be corrected.

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TG68	Construction Mediation
TG69	Green Buildings and the Law
TG71	Research and Innovation Transfer
TG72	Public Private Partnership
TG73	R&D Programs in Construction
TG74	New Production and Business Models in Construction
TG75	Engineering Studies on Traditional Constructions
TG76	Recognising Innovation in Construction
W014	Fire
W018	Timber Structures
W023	Wall Structures
W040	Heat and Moisture Transfer in Buildings
W051	Acoustics
W055	Building Economics
W056	Sandwich Panels
W062	Water Supply and Drainage
W065	Organisation and Management of Construction
W069	Housing Sociology
W070	Facilities Management and Maintenance
W077	Indoor Climate
W078	Information Technology for Construction
W080	Prediction of Service Life of Building Materials and Components
W083	Roofing Materials and Systems
W084	Building Comfortable Environments for All
W086	Building Pathology
W089	Building Research and Education
W092	Procurement Systems
W096	Architectural Management
W098	Intelligent & Responsive Buildings
W099	Safety and Health on Construction Sites
W101	Spatial Planning and infrastructure Development
W102	Information and Knowledge Management in Building
W104	Open Building Implementation
W107	Construction in Developing Countries
W108	Climate Change and the Built Environment
W110	Informal Settlements and Affordable Housing
W111	Usability of Workplaces
W112	Culture in Construction
W113	Law and Dispute Resolution
W114	Earthquake Engineering and Buildings
W115	Construction Materials Stewardship
W116	Smart and Sustainable Built Environments
W117	Performance Measurement in Construction

International Council for Research and Innovation in Building and Construction

Publications: The CIB produces a wide range of special publications, conference proceedings, etc., most of which are available to CIB Members via the CIB home pages. The CIB network also provides access to the publications of its more than 400 Members.

Recent CIB publications include:
- Guide and Bibliography to Service Life and Durability Research for Buildings and Components (CIB 295)
- Performance Based Methods for Service Life Prediction (CIB 294)
- Performance Criteria of Buildings for Health and Comfort (CIB 292)
- Performance Based Building 1st International State-of-the-Art Report (CIB 291)
- Proceedings of the CIB-CTBUH Conference on Tall Buildings: Strategies for Performance in the Aftermath of the World Trade Centre (CIB 290)
- Condition Assessment of Roofs (CIB 289)
- Proceedings from the 3rd International Postgraduate Research Conference in the Built and Human Environment
- Proceedings of the 5th International Conference on Performance-Based Codes and Fire Safety Design Methods
- Proceedings of the 29th International Symposium on Water Supply and Drainage for Buildings
- Agenda 21 for Sustainable Development in Developing Countries

R&D Collaboration: The CIB provides an active platform for international collaborative R&D between academia, R&D organisations and industry.

Publications arising from recent collaborative R&D activities include:
- Agenda 21 for Sustainable Construction
- Agenda 21 for Sustainable Construction in Developing Countries
- The Construction Sector System Approach: An International Framework (CIB 293)
- Red Man, Green Man: A Review of the Use of Performance Indicators for Urban Sustainability (CIB 286a)
- Benchmarking of Labour-Intensive Construction Activities: Lean Construction and Fundamental Principles of Working Management (CIB 276)
- Guide and Bibliography to Service Life and Durability Research for Buildings and Components (CIB 295)
- Performance-Based Building Regulatory Systems (CIB 299)
- Design for Deconstruction and Materials Reuse (CIB 272)
- Value Through Design (CIB 280)

PeBBu

An example of a recent major CIB collaborative activity is the Thematic Network PeBBu Performance Based Building: a four-year programme that included 50 member organisations, that was co-ordinated by CIB and that was funded through the European Commission Fifth Framework Programme.

Themes: The main thrust of CIB activities takes place through a network of around 50 Working Commissions and Task Groups, organised around four CIB Priority Themes:
- Sustainable Construction
- Clients and Users
- Revaluing Construction
- Integrated Design Solutions

CIB Annual Membership Fee 2007 – 2010

Fee Category		2007	2008	2009	2010
FM1	Fee level	10526	11052	11605	11837
FM2	Fee level	7018	7369	7738	7892
FM3	Fee level	2413	2534	2661	2715
AM1	Fee level	1213	1274	1338	1364
AM2	Fee level	851	936	1030	1133
IM	Fee level	241	253	266	271

All amounts in EURO

The lowest Fee Category an organisation can be in depends on the organisation's profile:

FM1 Full Member Fee Category **1** | Multi disciplinary building research institutes of national standing having a broad field of research

FM2 Full Member Fee Category **2** | Medium size research Institutes; Public agencies with major research interest; Companies with major research interest

FM3 Full Member Fee Category **3** | Information centres of national standing; Organisations normally in Category 4 or 5 which prefer to be a Full Member

AM1 Associate Member Fee Category **4** | Sectoral research & documentation institutes; Institutes for standardisation; Companies, consultants, contractors etc.; Professional associations

AM2 Associate Member Fee Category **5** | Departments, faculties, schools or colleges of universities or technical Institutes of higher education (Universities only)

IM Individual Member Fee Category **6** | Individuals having an interest in the activities of CIB (not representing an organisation)

Fee Reduction:
A reduction is offered to all fee levels in the magnitude of 50% for Members in countries with a GNIpc less than USD 1000 and a reduction to all fee levels in the magnitude of 25% for Members in countries with a GNIpc between USD 1000 – 7000, as defined by the Worldbank. (see http://siteresources.worldbank.org/DATASTATISTICS/Resources/GNIPC.pdf)

Reward for Prompt Payment:
All above indicated fee amounts will be increased by 10%. Members will subsequently be rewarded a 10% reduction in case of actual payment received within 3 months after the invoice date.

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CIB Publication