Mitigating Urban Heat Island Effect by Urban Design: Forms and Materials

Julien Bouyer,* Marjorie Musy, Yuan Huang, Khaled Athamena

Summary

This paper provides a synthesis of three complementary research works that contribute to the same objective: proposing solutions to reduce building energy consumption by modifying local climate. The first work explores urban forms: it proposes methods to describe them and analyze the climatic performances of classified urban forms. The second one focuses on one parameter of direct relevance to urban heat island phenomenon: the surface albedo. The albedo of a city or a district depends on surfaces’ arrangement, materials used for roofs, paving, coatings, etc., and solar position. The third one proposes a simulation tool that permits to evaluate the impact outdoor urban environment on buildings’ energy consumption. This analysis permits us to propose morphology indicators to compare the relative efficiencies of different typologies. The conclusion discusses the relevance of using indicators (based on physics or morphology, related to site or to built form) in urban design process and proposes a methodology to produce indicators.

*Corresponding author: julien.bouyer@developpement-durable.gouv.fr
1. INTRODUCTION

In most countries, thermal regulations may enable to control building energy consumption. However, we sometimes dispose of efficient techniques adapted to climate and to architectural culture. For example, buildings’ envelopes are designed to better insulate indoor climate from outdoor climate by controlling heat and mass transfers between them, yet these practices sometimes omit to consider the indirect effect that envelopes have on building energy consumption. Indeed, the radiative characteristics of the buildings’ envelope and the geometrical arrangement of them in the city play an important role in the urban heat island phenomenon. This one factor may impact building energy consumption, because of the increase of air and surface temperatures. In addition, this may lead to uncomfortable and unhealthy situations for inhabitants in summer. The causes and effects of urban climates and heat islands are diverse (Akbari 2001; Oke 1987; Santamouris 2001):

- less evapotranspiration because of mineralization of cities,
- more solar energy absorption due to lower albedo,
- less nocturnal infrared radiative loss due to the building density,
- less convection because of reduced air velocity caused by higher urban surface roughness,
- higher anthropogenic loads partly due to air conditioner rejects.

Their interactions are complex and the effect of the different design parameters that play a role in these phenomena, in particular urban form, can be contradictory.

This paper gives a synthesis of three complementary research works in progress that are contributing to the same objective: proposing solutions to reduce building energy consumption by corrective actions that modify the local climate.

The first work explores classified urban forms. It proposes methods to describe urban forms and then analyze the climatic performances of those classified forms. Based on this study, it is possible to propose morphology indicators that compare the relative efficiencies of different typologies. The urban form typologies described and the climatic performance indicators developed can become beneficial tools and references to assist urban design. As such, research results are translated into design guidelines in order to express optimal urban form guidelines based on typology and morphology indicators. This is an important process that allows for designers to more-easily understand research results and applications of the research.

The second one focuses on solar energy absorption and surface albedo. The albedo of a city or a district depends on the surfaces’ arrangement, materials used for
roofs, paving, coatings, and solar position. We study these dependencies through the
calculation of the albedo for different urban blocks in the case of a real urban project
located in Lyon, France. This study can be used to increase the awareness of urban
planners, designers and decision makers on the importance of the choice of coating,
paving and roof materials not only for their aesthetics but also for their function - i.e.
their effect on local climate and indirectly on building energy consumption.

For these urban blocks, several morphology parameters have been evaluated
and correlations drawn between them through calculated albedos. From these
correlations, we propose a simple indicator that can be used to characterize the
radiative contribution of a district to urban heat island effect. This indicator, due
to its simplified formulation, could be classified as a decision-support tool for
early stages of the project. The tool allows to compare different projects with an
objective criterion, eventually integrated in a multi-criteria approach.

The third work proposes a complete simulation tool that permits to evaluate
the impact of outdoor urban environment on buildings’ energy consumption. The
simulation tool is a physics based code that includes models for thermal and hydrous
behavior of walls, grounds, trees and water ponds. The model permits simulation
of airflows, including thermal and hydrous effects and evaluates the energy balance
in buildings taking into account the local climate contrary to what is usually done
when using climate data from weather stations (often located near airports). This
tool, dedicated to research, allows to study the complex interactions between the
phenomena implied in Urban Heat Island (UHI), the buildings’ construction and
use, and their related impact on the energy demand and consumption.

The conclusion integrates the three study results to discuss the cumulative
intake of the used methods and indicators, which deal with different degrees of
knowledge (based on physics or morphology, related to site or to built form) in the
urban design process.

2. URBAN FORM AND ENERGY PERFORMANCE

It has been proved that urban forms affect urban microclimate (Givoni 1989),
and that these changes in the urban environment result in modified building
energy consumption (Santamouris 2001). As Oke (1984) argued, urban clima-
tology can become a more predictive science in which findings can be of direct
value in urban planning and design. Mills (1999) proposed that by examining
the relationship between urban forms and climate, one could employ the results
of urban climatology into urban design guidelines. Therefore, for mitigating
urban heat island effect by urban design, our primary work on the research of
urban forms is to systematically collect and comb all urban form factors that may
impact building energy consumption through microclimate.
2.1 Method
Based on literature review, we collect studies that have proved the impact of urban forms on climatic parameters and on building energy consumption. Then we extract the part of urban form analysis from these studies, and classify the urban form factors with different scales. This is followed by analysis and introduction through two methods: 1) urban form typology and 2) morphological indicators. Then we study and explore the derivative urban form patterns and compare/quantify these urban forms patterns with the corresponding morphological indicators.

2.2 Results
The framework established for the urban form factors covers the scales from single building to urban block. We establish an elementary framework (Table 1) that is

<table>
<thead>
<tr>
<th>SCALE</th>
<th>FORM PATTERN</th>
<th>RELATED INDICATORS</th>
</tr>
</thead>
</table>
| Single building | ![Single building diagram](image) | • shape ratio (S/V)  
• main façade orientation  
• glazing ratio  
• ratio of side (Lx/Ly) |
| Generic built form | Pavilion, Slab, Terrace | • plot ratio  
• site coverage  
• shape ratio (S/V)  
• total surface area  
• sky view factor (SVF) |
| Street | ![Street diagram](image) | • aspect ratio (HW)  
• street orientation |
| Urban block/district | ![Urban block/district diagram](image) | • floor space index (FSI)  
• grid azimuth (θ)  
• number of floors (n)  
• base block dimension (Ly)  
• building depth ratio (=Lx/Ly)  
• directional aspect ratio (HWx : HWy)  
• directional street width ratio (swx/swy) |

TABLE 1
Basic Frame of the Proposed Urban Form Factors

(Razzi et al. 2003)

(Pavani et al. 2008)
composed of basic urban form patterns and morphological indicators at different scales. Data is then cited and analyzed to accurately represent derivative urban form patterns and morphological indicators as a result of this basic framework.

2.2.1 Single Building

Taking rectangular shape as the basic form pattern, we proposed shape ratio (S/V), main façade orientation and glazing ratio as the basic morphological indicators. They have been proved their importance for building energy consumption impact (Fu 2002).

2.2.2 Generic Built Form

Generic built form is a basic single building on a little plot for an urban block arrangement. The study of Ratti (2003) presented that the generic built forms are from simplified synthetic urban fabric. Under the same plot ratio, he proposed six archetypal forms linking with several basic indicators (Table 1); especially the ratio of passive to non-passive floor area that indicated the impact on building energy consumption. Brown (2001) defined directional space ratio (H_1/W_1, H_2/W_2 etc.) for court space to analyze the relation between directional H/W and court wind, incident solar radiation. Ratti (2003) set up three generic built forms (Fig.1) for the research in an arid climate based on the six archetypal forms.

2.2.3 Street

Arnfield (1990) studied the solar access index of street canyon in the form of H/W in variable value with E-W and N-S street orientations. They are the basic street form pattern and morphological indicators. After that, Ali-Toudert (2006) used these two basic indicators to set up the systematic case studied with H/W=0.5, 1, 2, 4, and orientation= E-W, N-S, NE-SW, NW-SE. There are three typical street form patterns that presented by Shashua-Bar (2006): separated form, continuous form and colonnaded form (Fig.2). He then introduced the “spacing ratio” (buildings’ distance parallel to street/building length parallel to street orientation) to quantify the separated form.

Many studies that deal with urban wind effects are also using aspect ratio as the main canopy layer morphological indicator. Oke's basic patterns, highlighting three main situations (isolated roughness, wake interference and skimming flow), is an initiatory example (Oke 1987).
2.2.4 Urban Block/Urban District

In our research, we take the grid aligned arrangement (Panão 2008) as the basic form pattern. Although the morphological indicators presented by Panão are not exhaustive (Table 1), he combines variable values of each indicator to explore the optimum urban building efficiency potential. The study usually focuses on the exploration of horizontal arrangement. Fu (2002) concluded that the residential blocks in general follow five patterns: 1) Parallel columns and rows, 2) staggered rows, 3) staggered columns, 4) oblique rows, 5) surrounding-style and free-style (Fig.3). It is a simplified method to represent a diffuse urban morphology with straight elements.

One parameter of direct relevance to the UHI phenomenon is albedo of an urban surface. Urban surface albedo is evaluated by the ratio of reflected and incident solar energies. The greater the albedo, the smaller the solar energy stored by the urban surface. The albedo of a city or a district (scale more pertinent at design process) depends on the surface arrangements (e.g. density, orientation, homogeneity, etc.), on the materials used for roofs, paving, coatings, etc., and on the solar position (e.g. site latitude, date and hour). The prediction of the urban energy budget and mesoscale climate involves the study of radiative exchanges within the urban canopy (Miguet 1996). Because these calculations cannot be carried in detail at mesoscale, taking into account real materials and urban forms data, the equivalent surface albedo is used in mesoscale models. This is the main application of the urban surface albedo. However, it is difficult to use this kind of model to calculate albedo of real urban fabrics that are not like checked frames. Starting from prior results obtained (Groleau 2003), this study proposes to calculate albedo for every kind of urban form, including street, single building, and urban block.

FIGURES 1, 2 and 3

![Figure 1: RSB, Slab and Pavilion-Court](Source: Patti, 2003)

![Figure 2: Three Archetype Street Forms](Source: Shachar-Bir 2006)

![Figure 3: The General Five Block Form Patterns](Source: Fu 2002)
3.1 Albedo Calculation: Application to Lyon Confluence

3.1.1 Method

We study surface albedo for different urban blocks in the case of a real urban project that takes place in France: the Lyon Confluence project. After having grouped the radiative characteristics of materials used in this project, we have performed simulations with SOLENE. This simulation tool is able to compute a comprehensive solar and thermoradiative balance of the urban surfaces, thanks to detailed sky vault model and radiosity algorithm (Miguet et al. 1996). Post-processing facilities allow users to analyze accurately the physical variables and fluxes. The first stage relies on 3D modelling of the district as a set of polygonal planar facets of the external surfaces constituting the urban site: roofs, facades, courtyards and streets. A triangular mesh is applied to these facets and calculations take place at the center of each mesh element. The second stage is to assign radiative properties to surfaces.

The first calculation stage, based on geometric procedures, determines the visibility between mesh elements or between a mesh element and a sun location or a sky patch of the geodesic sky model, considering masks. It results in form factors. The second calculation stage examines the solar energy received by each mesh element. The sun and sky irradiation are computed separately; the direct component is evaluated over time (for each sunlit element); and the sky contribution is calculated according to a type of sky (clear, overcast or other) and location of the sun at the considered time. The time-dependent global solar energy received on each mesh element is the first result to be used.

Then, the inter-reflections between surfaces are calculated by a radiosity method that leads to knowledge of net flux received by each facet and the parts that are absorbed or reflected.

At the end, we sum the fluxes absorbed by all the surfaces and the fluxes received directly (not including flux received after reflection) and the albedo is:

\[
\rho = \frac{\Phi_s(\text{absorbed})}{\Phi_s(\text{incoming})} \quad (\text{eq. 1})
\]

Absorbed and global incident fluxes are calculated for three different days: the winter and summer solstices and the equinox so that we can measure the impact of solar azimuth on the albedo.
3.1.2 Results

We studied different blocks of the first stage of the Lyon Confluence project. They are compared to an existing district the « cité jardin » (Fig. 4). In table 2, the characteristics of the blocks and the simulation results have been grouped.

The analysis of results shows that:

- In summer, the horizontal surfaces, including roofs participate fully in the reflection of sunlight. According to materials, there are keys to decrease the UHI effect.

- In order to better exploit the benefits of the UHI effect during the winter period and in particular in reducing energy consumption, it is advisable to use low reflective coatings for the facades of buildings.

- Albedo impact has to be considered carefully when photovoltaic arrays are used. In these cases, heat is not stored in the materials but converted into electricity, so the low albedo property does not really participate in the UHI causes.

A limitation of these results is that the specular reflection of metallic materials could not be taken into account. However, attention must be paid to this high albedo surface because they reflect energy to ground surfaces which are often made with low albedo materials.

FIGURE 4
Aerial view of Lyon Confluence District: Location of the Studied Blocks

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Number of concerned Buildings / Façade Materials (Mean Albedo) / Roof Materials (mean albedo)</th>
<th>Simulation date</th>
<th>Global Energy incident (KWh)</th>
<th>Solar Energy Absorbed (KWh)</th>
<th>Albedo</th>
</tr>
</thead>
<tbody>
<tr>
<td>A North</td>
<td>3 / Glazing + metallic frame (0.16) / Photovoltaic arrays (0.05) 1 / concrete + glazing (0.26) / Green roof (0.33)</td>
<td>21-6</td>
<td>1834</td>
<td>1570</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-3</td>
<td>1192</td>
<td>1024</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-12</td>
<td>446</td>
<td>380</td>
<td>0.15</td>
</tr>
<tr>
<td>A South</td>
<td>2 / Concrete + glazing (0.22) / Green roof (0.33)</td>
<td>21-6</td>
<td>1947</td>
<td>1341</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-3</td>
<td>1259</td>
<td>922</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-12</td>
<td>475</td>
<td>374</td>
<td>0.19</td>
</tr>
<tr>
<td>B North</td>
<td>2 / Aluminum + glazing (0.69) / Green roof (0.33)</td>
<td>21-6</td>
<td>3563</td>
<td>2574</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>2 / Aluminum + glazing (0.67) / Photovoltaic arrays (0.05) 1 / Polycarbonate + glazing, (0.18) / Photovoltaic arrays (0.05) 1 / Stainless-steel + glazing (0.67) / Photovoltaic arrays (0.05) 1 / Concrete + glazing (0.24) / Green Roof (0.33)</td>
<td>21-3</td>
<td>2083</td>
<td>1501</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-12</td>
<td>562</td>
<td>389</td>
<td>0.30</td>
</tr>
<tr>
<td>B South</td>
<td>1 / Stainless-steel + glazing (0.77) / Green Roof (0.33)</td>
<td>21-6</td>
<td>2894</td>
<td>1675</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>2 / Aluminum + glazing (0.67) / Green roof (0.33)</td>
<td>21-3</td>
<td>1785</td>
<td>1011</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>1 / Copper + wood + glazing (0.65) / Green roof (0.33)</td>
<td>21-12</td>
<td>668</td>
<td>355</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>1 / Copper + wood + glazing (0.65) / Photovoltaic arrays (0.05) 1 / Stainless-steel + glazing (0.75) / Photovoltaic arrays (0.05)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Part 1 / Wood + glazing (0.24) / Wood (0.4)</td>
<td>21-6</td>
<td>4589</td>
<td>3561</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Part 2 &amp; 4 / Concrete + glazing (0.22) / Concrete (0.22)</td>
<td>21-3</td>
<td>2822</td>
<td>2181</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Part 3 / Stainless steel + glazing (0.45) / Stainless steel (0.95)</td>
<td>21-12</td>
<td>871</td>
<td>671</td>
<td>0.23</td>
</tr>
<tr>
<td>Lyon confluence</td>
<td>A + B + C</td>
<td>21-6</td>
<td>11101</td>
<td>8656</td>
<td>0.22</td>
</tr>
<tr>
<td>Lyon confluence</td>
<td></td>
<td>21-3</td>
<td>6202</td>
<td>4713</td>
<td>0.24</td>
</tr>
<tr>
<td>Lyon confluence</td>
<td></td>
<td>21-12</td>
<td>2001</td>
<td>1524</td>
<td>0.24</td>
</tr>
<tr>
<td>Cité Jardin</td>
<td>6 / Concrete + glazing (0.35) / Asphalt (0.2)</td>
<td>21-6</td>
<td>6356</td>
<td>4943</td>
<td>0.22</td>
</tr>
<tr>
<td>Cité Jardin</td>
<td></td>
<td>21-3</td>
<td>3770</td>
<td>2914</td>
<td>0.24</td>
</tr>
<tr>
<td>Cité Jardin</td>
<td></td>
<td>21-12</td>
<td>1146</td>
<td>871</td>
<td>0.26</td>
</tr>
</tbody>
</table>
3.2 Albedo Indicator

For these urban blocks, several morphology parameters have been evaluated and correlations examined between them and calculated albedos. The most interesting correlated parameter is the sky view factor (SVF) that corresponds to the percentage (0% to 100%) of the sky vault surface visible from a point in the urban scene. It helps to identify the preferred exchange areas between the considered surfaces and the sky. This indicator is evaluated for each facet of the meshing and a weighted value is calculated for each block. We conducted the analysis separately for horizontal and vertical surfaces.

The histogram analysis (Fig. 5) shows that the horizontal surfaces and particularly roofs have a large SVF. A geometry that presents a large ratio of horizontal surface, including a large proportion of roof shows quite large SVF. We also remark that the vertical surfaces have almost similar SVF than the whole blocks, except for A north and C blocks. This is probably due to the size of their roofs compared to other blocks. Therefore we conclude that the vertical geometry ratio greatly affects the SVF: the greater this ratio, the lower the SVF is.

SVF is a relevant indicator because if we consider a diffuse radiative behavior for any urban facet, the flux reflected out from the city (to the sky) is directly dependent of it's SVF.

![FIGURE 5](image)

Mean Sky View Factor of Each Studied Block

The initial objective was to propose a simple indicator estimate the radiative contribution of a district (real or at design stage) to the UHI effect. Contrary to the strict computation of the albedo that involves important time cost and physical models (sky irradiance model, radiosity algorithm for urban inter-
reflexions), the indicator computation has to be straightforward in order to be dedicated to retroactive decision process at the early stage of projects. The results of the crossing analysis between the surface albedo, geometry and morphology indicators showed that the factors that most impact the value of the district albedo were the average reflection coefficient of the urban fabric and the SVF. We defined the “Albedo index” denoted $A$, is defined as follows:

$$A = \frac{\sum_{i=1}^{\text{nbFacets}} \rho_i S_i SVF_i}{\sum_{i=1}^{\text{nbFacets}} S_i}$$  \hspace{1cm} (eq. 2)

with $\rho$, $SVF_i$ and $S_i$ the albedo, SVF and area of the facet number $i$, respectively.

In Fig. 6, we have represented for each part of the district both calculated district albedo ($\rho_{\text{district}}$) and the albedo index ($A$). We can see that the indicator reflects the general trend in the albedo, although there is a little bit of bias. The indicator that we propose widens the role of solar material characteristics and the urban form in the evaluation of the phenomenon of the UHI. Nonetheless it will operate as a kind of pre-diagnosis of the quality of the elements of urban form that will be complemented by computer simulations of physical phenomenon.

FIGURE 6
Albedo Index ($A$) versus Theoretical Albedo Computation ($\rho$) on x-Axis
This study can be used to increase the awareness of urban planners, designers and decision makers on the importance of the choice of coating, paving and roof materials not only for their aesthetics, but also their function, specifically in terms of their effect on local climate and indirectly on energy consumption of buildings. It is worth noting this study could be enhanced by site experiments, in addition to computer simulations, especially as albedo indicator values are all quite far from the real albedo values.

4. MICROCLIMATE — ENERGY CONSUMPTION SIMULATION

The previous approach points out the role the urban surface based on a single phenomenon: the solar radiation. This is important to measure the impact of materials on urban form and on the UHI, but at lower scales, it is necessary to evaluate the impact of local urban design on outdoor thermal comfort and buildings’ energy consumption. Currently, there is a lack of efficient tool appropriate to the designer needs. The approach is to develop a research tool that allows to test configurations and learning about the physical phenomenon taking place in an urban space and their impact on building energy consumption.

4.1 Method

Our tool has to take into account the different energy transfer processes:

- evapotranspiration from the vegetation and soil;
- solar radiation from sun and sky vault and reflection between surfaces;
- infra-red exchanges between urban surfaces and sky;
- convective transfer between surfaces and air with an explicit computation of wind flow;
- conductive transfer of heat stored in buildings and ground.

It relies on a dynamic computation integrating three coupled modules:

- An industrial computation fluid dynamics (CFD) tool, FLUENT, customized by specific functions, allows the model to obtain precisely the outdoor aerodynamic, thermal and hydrous conditions near the building;
- The thermoradiative model, named SOLENE (see Part 3.1.1.), which computes the solar and infra red balance and gives the temperature of the surfaces according to the urban layout and the material characteristics; and
A thermal model of the building specially developed for this study and integrated to, which is able to compute indoor thermal conditions according to the physical environment given by the two previous models.

The first two modules evaluate the time-dependant spatial distribution of the climatic variables according to a fine 3D mesh (Fig. 7), while the third module computes the mean thermal variables of the different building floors.

**FIGURE 7**
Simulation 3D Model and Surface Meshing Generation
4.2 Results

An application in the real urban context of Lyon Confluence presented above was carried out aiming to compare two kinds of urban design: a mineralized one (Case A) and natural one (Case B) (Fig. 8). Four target office buildings have been studied. Geometry, occupancy and building envelope materials were the same, but compactness, glazing and orientation were different. Note that shading devices are integrated for building 1 and 2.

FIGURE 8
The Two Studied Surroundings, Mineralized (Case A) and Green (Case B)
The winter results show that buildings 1, 2 and 3 have almost the same energy consumption during the simulation week. Only building 4, which is more exposed to the solar radiation, does not have the same heating needs. The vegetated design of outdoor space do not strongly modify the consumptions except for building 4, where there remain a residual mask effect due to the branches (deciduous trees), taken equivalent to 70% transmissivity of the virtual modeled 3D tree crown.
The summer results show that buildings 1 and 2 confirmed the advantage of integrated shading to save cooling needs. The impact of the green design can be observed for building 3 and 4, for which the savings reach respectively 8.7% and 11.6%.

5. CONCLUSION AND FUTURE WORK

We have shown how urban forms can be classified and how proposed morphology indicators can help to characterize them with regard to their energy performance.

The use of morphology indicators needs to be validated. In this paper, we have illustrated how a new indicator, the albedo indicator, is built starting from urban form considerations. We have thus applied to a real project in terms of the stages of albedo indicator validation. For this purpose, we have compared the values of the albedo indicator to the values obtained when proceeding to complete albedo calculation using computer intensive calculations. The results show, in the studied case a bias between the two coefficients but a similar general trend.
So the proposed indicator can be used as a first approach for contribution to a project regarding UHI by evaluating its surface albedo and comparing different strategies of materials and buildings’ forms and arrangements.

However, for fine material arrangement decisions, we propose to use the complete albedo calculation because in the indicator, the effect of geometry is incomplete. Indeed, the effect of geometry is taken into account by the SVF that permits to render the exchanges that the surfaces are liable to have with the sky, but not their orientation with regard to the sun course. We will soon propose a new simplified indicator better adapted for this kind of studies.

We have also presented a set of tools developed that allows for examination of thermal phenomena that occur in a complex urban scene and analyzing of the effect of different urban designs on microclimate (comfort purposes) and on buildings’ energy consumption. We are able to simulate an urban scene taking into account the presence of grass, trees, and water ponds, and obtain the wind velocity, air temperature and humidity, surfaces temperatures and evaluate the energy balance of a building. Results obtained with this tool have been presented. Their consistency has been verified, but results still need to be validated with regard to experimental data, which will be the next stage of the work.

Tools being almost mature, our aim is to use them in a methodical way in order to produce guidelines for designers. The parameters concerned with urban design that affect microclimate and energy consumption are numerous: urban forms, surface materials, vegetation and water presence, and buildings’ use. Moreover, as we pointed out in the introduction, their effect on different phenomena can be antagonist. The first step is to analyze, for one particular urban project, the effect of form, studying the different classes of the typology and varying the morphology indicators, as illustrated in this paper. This is followed by study of the surface design strategies, for buildings’ envelope and for public space between buildings.

References


