



# ITRUVIO

International Journal of  
Architectural Technology and Sustainability

2016





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## CONTACT

### Luis Palmero Iglesias

Phone: +34 963879451

Fax: +34 963879129

Email: [lpalmero@csa.upv.es](mailto:lpalmero@csa.upv.es)

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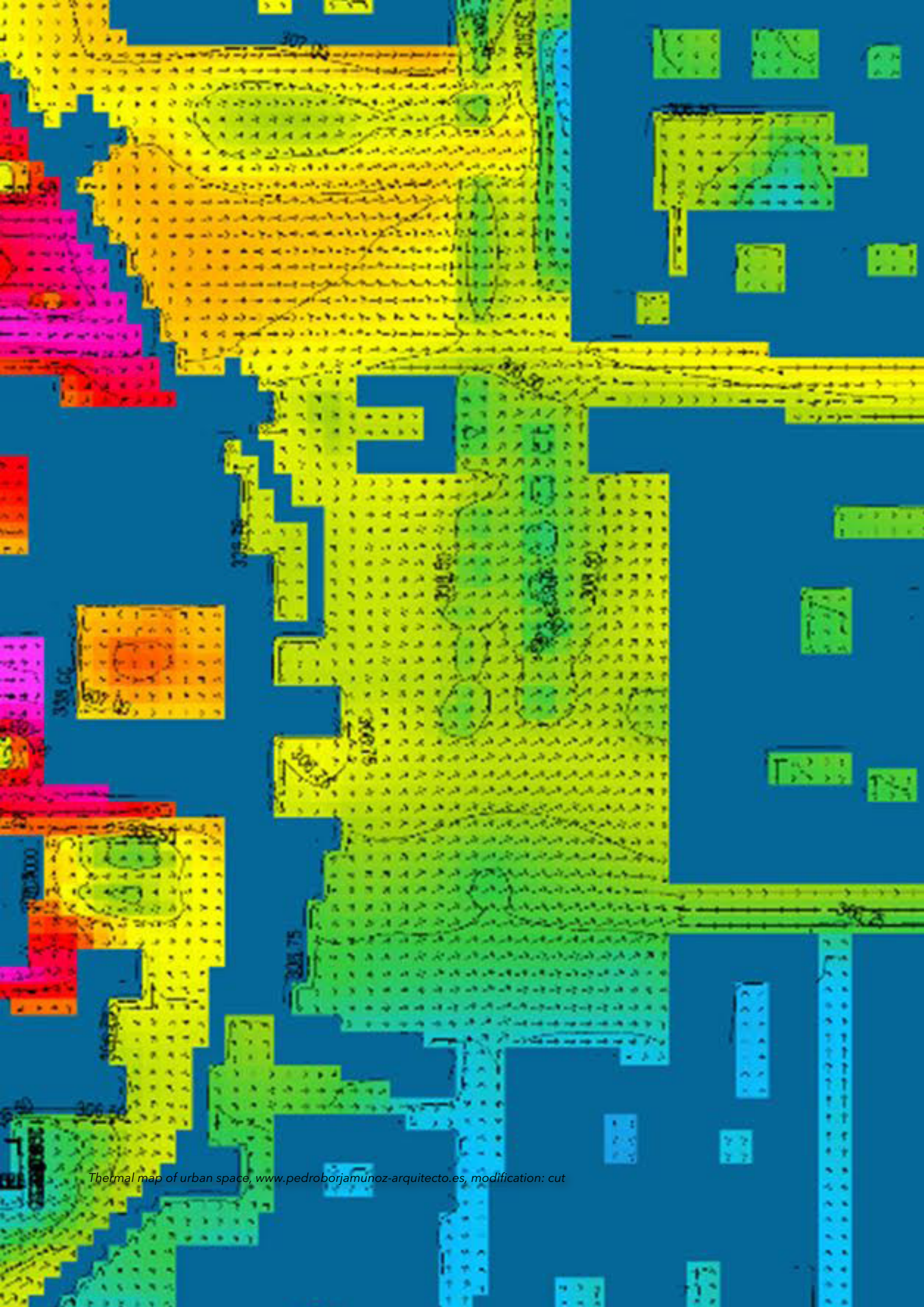
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Thermal map of urban space, [www.pedroborjamunoz-arquitecto.es](http://www.pedroborjamunoz-arquitecto.es), modification: cut

## Urban microclimate parameters for buildings energy strategies

Michele Lepore<sup>1</sup>

<sup>1</sup> Università degli Studi "G. d'Annunzio" di Chieti-Pescara, Dipartimento di Architettura

### ABSTRACT

---

Today, the cities need to increase energy efficiency, reduce polluting emissions and achieve a sufficient level of sustainability. The urban microclimate plays an important role on the buildings energy consumption and the feeling of comfort in the spaces. The microclimate parameters are of central importance for the activities that are carried out in the open spaces and to a large extent determine the use. The responses to the microclimate may be unconscious but very often result in a differentiated use of open spaces just as function of the different climatic conditions. For this reason, the aim of this work is focused on the environmental parameters and on the methodology of analysis aiming at the establishment of bioclimatic strategies for buildings on the basis of morpho-type of the components of the geometries and surface quality of the materials used in urban spaces and in function of the consequent microclimatic conditions obtained.

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### KEYWORDS

*urban microclimate, comfort, energy efficiency, bioclimatic design*



## 1. ENVIRONMENTAL DESIGN IN URBAN CONTEXT

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The environmental parameters that affect the outside comfort thermal conditions, although similar to those relating to the interior spaces, are characterized by a greater and more complex variability. Therefore, because of this variability and the broad diversification of activities in which people are involved, there have been so far few attempts to understand the comfort conditions on the outside but especially as the climatic effects outside could have an impact on the technologies of the building envelop and consequently on the conditions of comfort within the confined spaces.

One of the objectives of environmental design in urban contexts is the creation of districts with comfortable open spaces. The microclimate parameters are therefore of central importance for the activities that are carried out in the open and to a large extent determine the use. For this reason, understand the richness of the microclimatic features into urban spaces outside, and the implications in terms of comfort for the people who use them, opens up new possibilities for the design of these spaces both in terms of new interventions, both in the retraining of existing agglomerations.

The study of the districts must be configured through a series of analysis developed in successive stages of deepening the spatial characteristics, technological and environmental concerns both the settlements scale, is a typological both technological.

In particular:

- analysis of geographical context and climate;
- analysis of the morphological characteristics to the building scale;
- analysis of the conditions of comfort outside in the residential settlements;
- analysis of the technological characteristics of the building envelop;
- the system building-plant.

### 1.1 METHODOLOGY

---

The methodology is based on an evaluation of the climatic conditions and the thermal comfort in different conditions. The climatic parameters are obtained by parametric evaluations and computer simulations based on fluid dynamics, thermodynamics and irradiation in an urban environment using numeric approach. The great advantage in the use of computing systems is the ability to evaluate different scenarios.

From a careful analysis on the external climate conditions and thermal comfort in the immediate neighborhood of the residential settlements, you want to locate the appropriate technologies to the redevelopment of the individual units by improving the parameters of thermal comfort inside of the dwellings themselves.

Primary objective, therefore, is the search for a methodology to assess the quality of the microclimatic public space, that is repeatable in cases and different places with verifying the possible influences of the external climate on the overall energy efficiency of the settlement and the consequent identification of appropriate technologies that are not based only on climate class referring to the locality.

Specific objectives:

- Analyze urban spaces according to the physical aspects environmental, through a system of indicators that characterize study areas.
- Define indicators for analysis of the aspects of microclimatic space, able to put in relation the environmental conditions to the comfort of users in order to define certain minimum quality requirements.
- The identification of a methodology for the calculation capable of assessing the quality microclimates of public space in an objective manner and replicable in other cases in other places, evaluating specific software for the simulation of the phenomena that occur in the urban space outside.

## 2. URBAN MICROCLIMATE

Urban areas have particular climatic condition as results of complex urban microclimates, where many factors come into play. It is important to describe how and why the urban climate differs from the climatic condition of the surrounding rural areas.

Urban and industrial growth has caused significant changes in the radiant balance of the urban spaces, the convective heat exchange between the ground and its buildings, the air flowing above the urban area and the heat generation within the city.

The main consequence is differences in value of air temperature and in wind conditions between urban and rural areas.

Air temperature in dense urban areas are higher then temperatures in the surrounding countryside.

This different is known as the "urban heat-island effect and characterised almost every city or town in the world. The heat that is absorbed during the day by all urban constructions (buildings, roads, etc.) is re-emitted after sunset, and the greatest temperature differences are observed during the night.

Furthermore, additional heat is given by all human heat sources.

Urban space creates unique climatic conditions called the urban microclimate.

The first consideration is that it is possible associate the urban morphology to microclimatic behaviour,

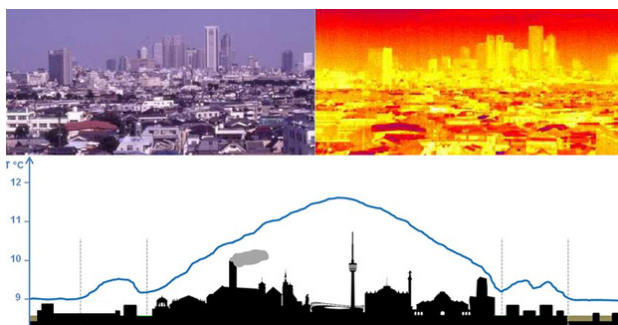


Figure 1.

*Heat island effect*

or in other words, to define a microclimatic patterns characteristic for each urban typology. The second one, as mentioned before, is based on the observation that the environmental conditions influence the use of urban outdoors spaces. If it is possible to quantify the thermal comfort through the study of climatic parameters, the modification of the urban microclimate will affects the thermal comfort of people.

The confirmation of the two assumptions leads to the definition of the third hypothesis: it is possible to mitigate the impact of the microclimate through the modification of the constructed urban space, and consequently, improve citizens thermal comfort conditions.

The specific objectives to achieve this aims are:

1. Define a system of indicators to characterize and describe the physical and environmental aspects of study areas. These indicators should be able to describe the current situation and guide refurbishment project.
2. Define indicators for the analysis of microclimatic aspects of outdoor spaces, able to establish a relationship with environment conditions and comfort sensation, in order to find a minimum quality target.
3. Establish a calculation methodology able to evaluate the microclimatic quality and comfort of public space in an objective way and suitable for the application on other cases and other locations.
4. Elaborate the guidelines for the refurbishment of built spaces from the perspective of microclimatic and environmental improvement of urban areas.
5. Evaluate specific software for the simulation of climatic phenomena which occur in outdoor urban space.

## 2.1 ANALYSIS OF THERMAL COMFORT

The environmental performance relative to the urban space in its entirety is the description of the thermohygro-metric behavior mixed as a result of the combination of morphological parameters, matter and microclimate in relation to a specific use. This type of description it is useful to make it through the use of the indicator of comfort, because the indicator contains in itself the mixer of the parameters in the game. It is important to use for comfort indicators in relation to environmental requirements, whether they are expressed by users or that are unaware.

To assess the environmental performance of an urban space as a whole there can be no limit to the analysis of the microclimatic conditions in point, as it cannot be limited to evaluate the various parameters individually. A good result is obtained by providing the areal distribution of the comfort conditions throughout the area. The maps of comfort represent an evaluation of the existing conditions or a check of the design choices.

From the observation of these maps you can get further information on the project, which relate in particular to the placement of the urban equipment that allow the carrying out of activities compatible with the environmental performance in the given time interval.

From the evaluation of the performance in the moment in which they were not congruent with the environmental requirements of users, we derive guidance on specific requirements that define the project and characterize it.

## 2.2 THE ANALYTIC INDICATORS

The analytic indicators are calculated by following the path of the heat flow from the human metabolism to the environment vice versa whereas the variations of this flow in relation to the variation of environmental factors. They derive from the equation of energy balance based on models which consider all the climatic parameters significant.

These models use a balance equation of heat with a

models more or less simplified to evaluate the mean radiant temperature.

The thermal comfort can be described with the use of certain indices:

- WBGT takes only climatic data into account such as air temperature, radiant heat, solar radiation, air movement.
- PMV has solid base in the indoor environment but takes into account relevant factors and the affect thermal sensation.
- PET and out SET are for outdoor environments.

PET does not calculate individual parameters and out SET takes personal parameters for one standard type of person.

The ISO 7730 defines thermal conditions of outdoor environment in which the probability of negative vote is minimised.

The index "Predicted Mean Vote - PMV" and the index "Predicted Percentage Dissatisfied - PPD" are based on ISO 7730 and are taking into account the climatic parameters in conjunction with the relevant factors affecting the thermal sensation of each respondent (clothing, metabolic rate, eating or drinking).

The PMV-index describes the comfort levels with the prediction of the possible votes taking into account meteorological factor in combination with human biometeorology values. The value of the index is between -7 which means too cold and +7 with means hot and the value of zero represent the comfort vote. With this scale the closets the value of the PMV index is to 0 the better are the comfort levels for the human. Still this index cannot take into account the psychological factors described and that is the why there are certain differences of the value of the PMV and the real votes on the field surveys (Fanger, 1992). Common microclimatic data with the PMV (Predicted Mean Vote) require two other indexes: PET (Physiologically Equivalent Temperature) and out SET (Standard Effective Temperature). All those thermal indices are well documented and include important meteorological and thermo-physiological parameters so as to define the total comfort.

The scale that are measured is in °C but the

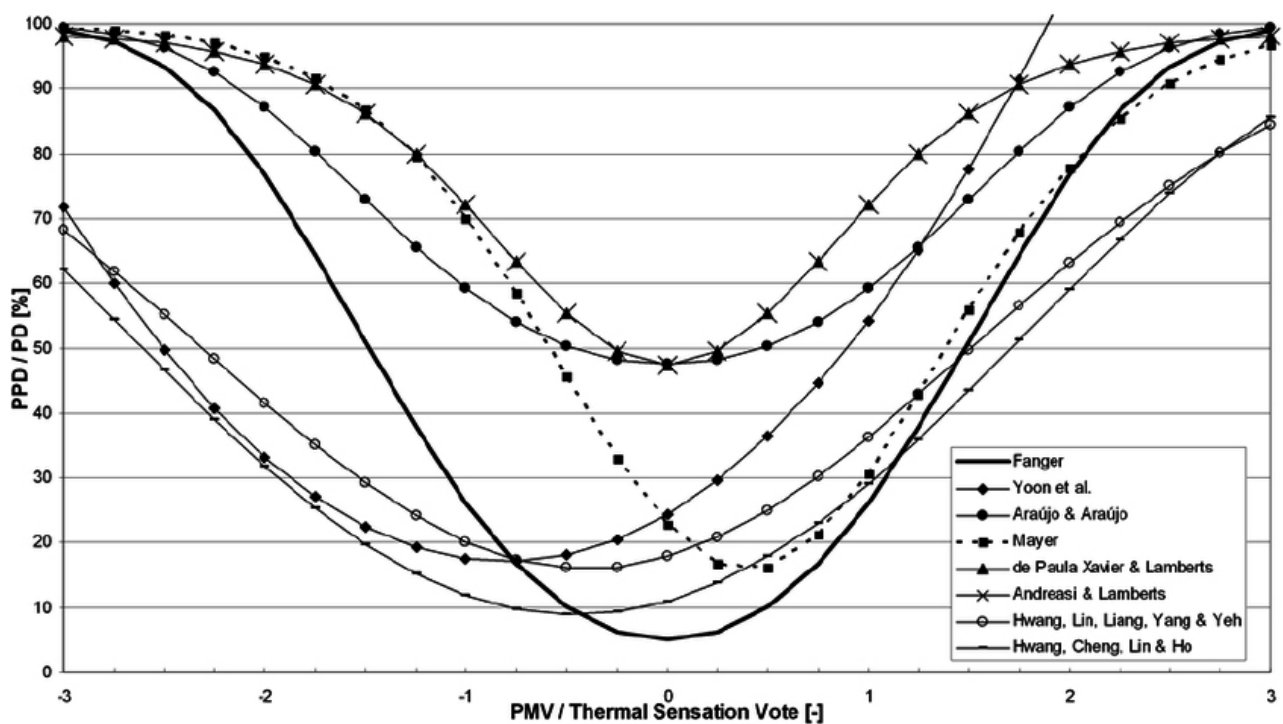


Figure 2.

*Relation between PMV and PPD, and other sensation thermal indices, as found by Fanger*

parameters required in the model are both climatic (air temperature, humidity, radiation environment, wind speed and direction) but also physical characteristics of every interviewee (age, sex, weight, height, clothes, metabolism rate).

A full application of these thermal indices on the energy balance of the human body gives detailed information about the effect of the thermal environment on every human (Van Hoof, 2010).

In the case of areas with a great variety of spaces, ranging from dense vegetation and extensive shading, to areas completely exposed to the sun and wind, the data from the meteorological station cannot adequately represent the microclimatic conditions in the site. Comfort models should be able to approach the microscale for design purposes, distinguishing

between sunny and shaded areas, or areas protected and exposed to the wind, which ultimately directly affects thermal comfort conditions in a given space. It is therefore of value to devise a way to include design related parameters into environmental data.

Identifying simplified correction factors between locally measured conditions and those of the nearby meteorological station, during the field surveys, can reflect the modification of the microclimate.

Such correction factors can be used as modification parameters for design oriented comfort models, reflecting the microscale, thus of value to designers. In this context, vegetation can affect the microclimate in a number of ways, reducing air temperature compared to hard surfaces, shading and providing wind protection (Cres, 2014).

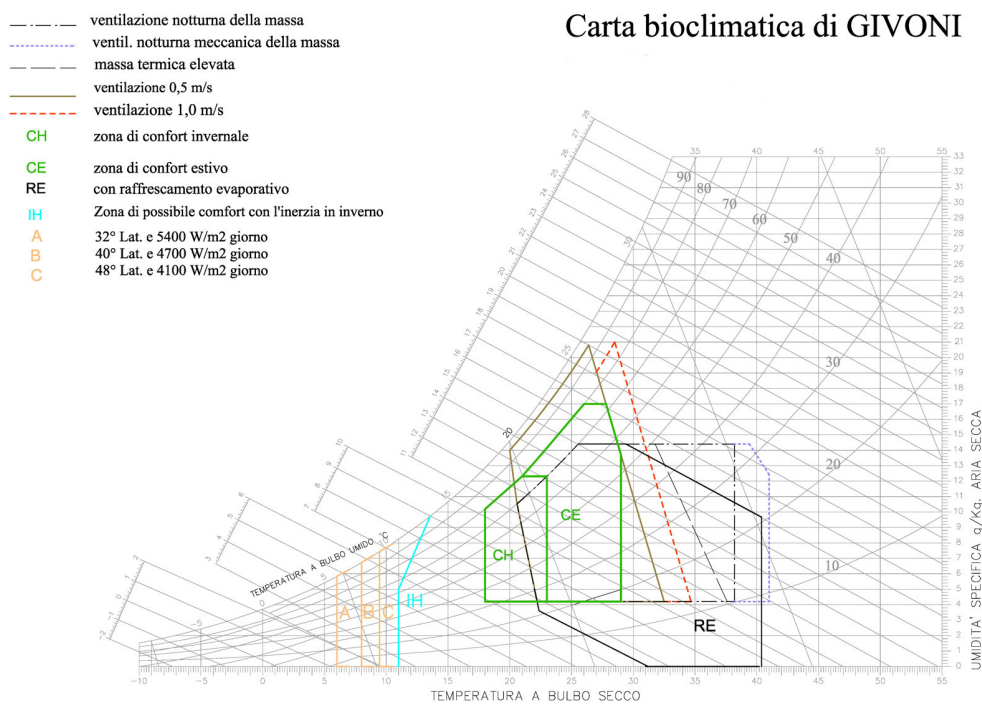


Figure 3.

*Givoni bioclimatic chart for comfort evaluation*

### 2.3 WIND

One of the most important factors influencing pedestrian comfort conditions in outdoor open spaces is the wind. Wind environment is difficult to foresee and control because it is influenced by a number of global, regional and local factors. On a global scale wind comes from air moving from high-pressure areas to low-pressure areas. The wind velocity and direction produced by the global weather systems are subsequently influenced by the regional and local landscape typology. It is therefore important to understand that there can be large differences in the wind environment from one part of a city to another or even on micro scale from one part of a space to another. Wind is not a constant phenomenon. It varies momentarily in direction and strength (wind

gusts) and variations can be seasonal or annual. The direct effects of the wind can be divided into two main categories, mechanical and thermal effects:

- mechanical effects of wind can be felt with wind velocities above 4-5 m.s-1. Above 10m.s-1 it will be unpleasant to walk and above 15m.s-1 there is a direct risk of accidents;
- for thermal effects the 5 m.s-1 comfort criteria used presumed that people will adapt their behaviour and clothing level to the season.

It should be noted that depending on climate a certain level of wind could be regarded as undesirable or desirable. In cold climates wind will almost always decrease outdoor comfort conditions, whereas the opposite is the case in hot climates (Ghiaus, 2007).

## 2.4 THE IMPACT OF MATERIALS

In order to reduce the heat island intensity, the first method is to design the external environment in order to minimise solar heat gains. In general, this can be achieved by increasing the solar reflectivity of construction material surfaces and reducing the insulation of susceptible structures. During this procedure, the albedo of the various materials and surface is a crucial factor (Santamouris, 2006).

The albedo of a surface is defined as the reflected solar radiation divided by the incident solar radiation. Urban areas and cities are characterized, in general, by a relatively reduced effective albedo. This is due to the greater absorption of solar radiation by urban construction materials and multiple reflection inside urban canyons. Thus, the optical characteristics of used materials have an important impact - their albedo-to-solar radiation and emissivity of long-wave radiation being the key parameters. High albedo material reduce the amount of solar radiation absorbed through building envelopes and urban structures, and in this way keep their surfaces cooler. Respectively, materials with high emissivity are good emitters of long-wave energy and release the energy that has been absorbed as short-wave radiation. In this way their surface temperature is lower and contributes to the reduction of ambient temperatures through the mechanism of heat convection (Santamouris, 2001).

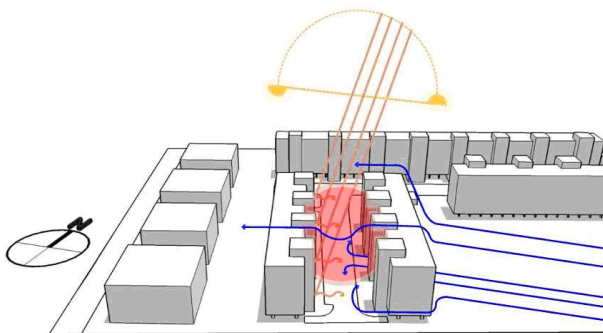


Figure 4.

*Interaction between the wind and buildings*

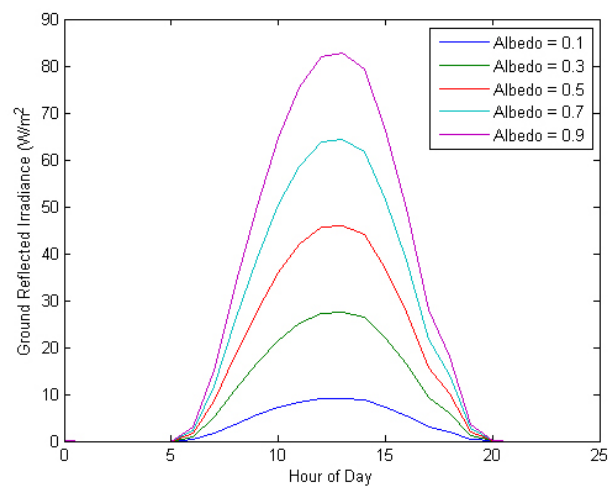


Figure 5.

*Ground reflected irradiance with varying Albedo*

## 3. ENERGY AUDITS TO SCALE SETTLEMENTS

The first action is constituted by the stripping "thermal" of the isolate to assess separately the environmental quality of the context both under the profile of thermo-hygrometric (temperatures, levels of relative humidity) and is reported to the climate wellness, evaluating the levels of both thermal sensation that the index of feeling on the part of the inhabitants of the settlement building. These parameters were evaluated by comparing two calculation methods: the ASV (Guidelines Rurors) and PMV (Fanger). The main critical points found to scale settlements are of type "physiological", linked to the levels of thermal sensation on the part of the inhabitants of the district refers to the outdoor spaces. In the case of study (Monticchio in the province of L'Aquila) to which has been applied this methodology, comparing the two methods of calculating the ASV and PMV show, both coincidence of results both while negotiating on climatic conditions in winter have highlighted deficiencies in the summer period, giving as a result a feeling of "hot", abnormal done in a mountain resort.

### 3.1 VERIFICATION OF THE SUN-AIR IMPACT

---

A careful analysis of the impact the sun-air has highlighted the objective relationship between settlement and environmental context and climate. In the preliminary stages, the quality checks have the aim to assess the relationship between climate and the morphology of the settlement with respect to the orientation to the compactness of the intervention, in addition to the climatic parameters specific to the site. In detail dismantling "thermal" of settlements and identification of external surfaces deemed more burdensome from the point of view of energy consumption and comfort of the occupants. For verification of environmental performance related to the state of fact, the first step was the "thermal decomposition" of the agglomerate, associating to each element a thermal role as for example:

- buildings = thermal mass;
- green spaces private loggias, etc. = microclimatic niches;
- spaces paved impermeable, paved, etc. = thermal amplifiers;
- garages, garages, box, cellars, etc. = buffer space.

### 3.2 ANALYSIS OF THE CONDITIONS EXTERNAL COMFORT IN RESIDENTIAL SETTLEMENTS.

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The microclimate parameters are of central importance for the activities that are carried out in the open and to a large extent determine the use.

The responses to the microclimate may be unconscious but very often result in a differentiated use of open spaces according to the different climatic conditions. The typological dimension, diagnosis has focused on performance verification residual thermal building system-installations of buildings, highlighting the poor quality of the thermal insulation and energy management in period both winter and summer in addition to an overall inefficiency of the system engineering. All homes are in class G.

Also, verification of environmental quality inner is consistent with that carried out the urban scale or, in

summer levels are obtained significant discomfort. The first results show that a pure physiological approach is inadequate in characterizing the conditions of comfort outdoors and an understanding of the dynamics of the human parameter is required in the design of spaces for public use. The thermal environment is of fundamental importance because they influence the persons to use these spaces, but the psychological adaptation (choice available, environmental stimulation, thermal history, expectations) is equally important. The responses induced by microclimate may be unaware, but they often translate into a different use of the urban space as the climatic conditions vary. Best microclimatic conditions in turn have important implications for the development of the city. Through the control of the sources of discomfort, are favored sedentary activities, as well as the use of public transport, movement on foot and the use of the bicycle. The same image of the city can benefit from the quality of the external spaces.

In San Francisco, the planning laws stipulate that new buildings must be placed in such a way as not to promote air motions over 5 m/s, 90% of the hours of light, in areas where people can sit. The shading of whole streets is achievable with the shafts with the advantage to obtain a cooling through evapotranspiration through the leaves. - always in the case of Monticchio, diagnosis has focused on performance verification residual thermal building system-installations of buildings, highlighting the poor quality to the thermal insulation and to energy management in the winter period in addition to an overall inefficiency of the system engineering. All homes are in class G.

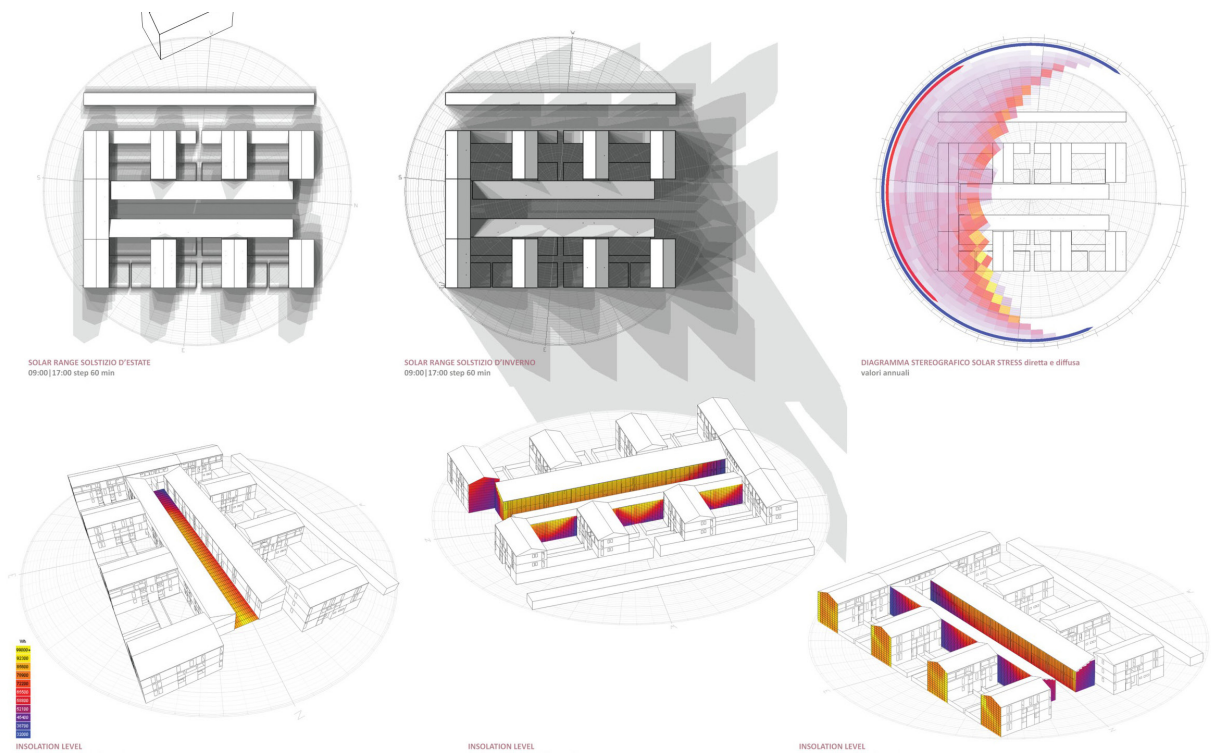


Figure 6.

Case Study of Monticchio  
(AQ), study of the impact of  
solar radiation on the external  
surfaces of buildings



## 4. CONCLUSIONS

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This study is conducted in several different steps. The final goal was to define the basic parameters that affect the comfort levels on open urban spaces and to implement a design strategies for building refurbishment project. The basic hypothesis is that the comfort condition in outdoor spaces comes as a result of the interaction of all the microclimate parameters together. For the effectiveness of this methodology, further analysis are needed for full representation of climatic behaviour of each seasonal period. This would assist the choice of buildings energy strategies through the design of outdoor spaces and eventually the use of these spaces, by allowing for different activities to be carried out by inhabitants.

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