Chapter 9

Urban Morphology and Energy Consumption:
Simplified Tools for the Estimation of Energy Needs and Solar Income at the Urban and District Level

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ABSTRACT

Urban form matters in assessing the energy consumption of buildings. This chapter introduces three useful tools to assess the environmental impact of the urban form and to define possible energy scenarios. These outcomes can be used to inform the redevelopment or the new design of urban districts, or simply to evaluate the overall energy performance of different urban fabrics. The tools presented comprise: (a) simplified indicators of energy-dependent variables based on morphological information of the urban form; (b) algorithms for the estimation of the heating energy needs of the urban fabric, based on the implementation of European Standards; (c) algorithms for the assessment of the solar potential of the urban form, computing the solar irradiance impacting on different sloped urban surfaces. The techniques introduced are based on an innovative approach that makes use of Digital Urban Surface Models (DUSMs) and Digital Image Processing (DIP) techniques.

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PART 1: ESSENTIAL CONCEPTS AND KNOWLEDGE

1. Introduction

We argue that site layout planning and the arrangement of buildings are crucial in assessing the energy consumption of the urban form. For instance, both the relationship between buildings (e.g., solar access and reciprocal overshadowing) and the geometry of the single buildings (e.g., compactness and heat loss) affect the overall energy performance of the urban fabric. The energy performance of buildings – and consequently its computation – is directly related to manifold factors that cannot disregard from the morphological and climatic context where the building is located. If correctly considered in the design phase, an energy-conscious morphological layout can lead to huge savings, thus anticipating the benefits of implementing eco-technologies at the building level.

In recent years, most of the research on energy efficiency has been devoted to building technology, aiming at increasing the performance of buildings through a series of technical solutions derived from the dictates of passive architecture (e.g., improving thermal insulation, thermal inertia, orientation of facades, natural ventilation).

“Learning from the past” is a common paradigm in architecture and urbanism, and it refers to pre-modern times when the city was not dependent on mechanical facilities. In fact, during the centuries, buildings had been skilfully adapted to places by using different materials and typological solutions depending on the locations. As a matter of fact, traditional northern Europe constructions – where the climate is very cold and rigid for the major part of the year – are characterized by materials (such as wood, straw, stone) with a good thermal inertia and high insulation properties. Furthermore, numerous solutions capable to capture and store solar gains were developed. In addition, buildings are generally box-shaped to minimize heat losses (i.e. low surface-to-volume ratio). Conversely, places where the climate is very hot and dry are traditionally characterized by solutions that favour internal heat losses. Buildings’ plaster and wall paint are very bright and the materials used (such as wattles, terracotta bricks) tend to delay the thermal wave. The openings are tiny and oriented such to create internal air flows or to tap the natural ones that are already present. Not only building design but also traditional city design relied upon the optimization of local natural resources, and the form of the city as a whole was the major clue of a wise understanding of modalities for rational use and energy saving, through a series of rules derived from “passive urbanism” principles. Street orientation on coastal areas allowed to invite pleasant breezes to penetrate or to stop cold winds; the tight disposal of buildings made it possible for heat and mass transfer control, as opposed to porous environments with detached housing that enabled to cool down building surfaces and interiors. In short, sun, wind and soil (geothermic energy) assumed the role of urban-form generators.

The majority of traditional knowledge has been abandoned during the 20th century. Modern technologies have enabled to overcome local hurdles due to the specific climatic context, thus contributing to the wide spread of the International Style architecture, which could be replicated everywhere in the world. During the second half of the last century, the necessity of a rapid reconstruction after World War II and the increasing availability of standardized technologies lead to the diffusion of new building typologies, obviously divergent from the traditional ones. That trend was justified by the necessity of providing affordable housing for everyone, speeding up the building process and containing the expenditure, frequently at the expense of quality (i.e. rapid obsolescence, scarce thermal performance). In fact, starting from the Fifties, the new building technologies tended more and more to decrease the thermal inertia properties of the building envelope, by reducing the amount of...