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Assessing the solar potential of low-density urban environments in Andean cities with desert climates: The case of the city of Mendoza, in Argentina

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Abstract

Energy use in the built environment is globally recognized as a key issue for sustainable urban development. In tempered-cold arid regions with a generous solar resource, adequate design and technology can substantially reduce the energy demand for space and water heating in urban buildings. This study assessed the solar potential of low-density urban environments in the city of Mendoza, Argentina. The results of the study will be used to develop technical guidelines for urban and energy planning agencies and professionals involved in the production of habitat. The study included the following successive steps: (i) selection of a representative sample of analysis units (city blocks); (ii) selection of a series of urban and building variables; (iii) definition of indicators accounting for solar masking, building's potential use of the solar radiation on the whole urban area, and availability of adequate collecting areas to satisfy high percentages of the energy demand in low-density urban environments; and (iv) insolation of potential collectors simulated by a graphic-computational model developed in the R + D unit. Only the results for solar space heating are presented in this paper. The results, direct and statistical, indicate that it is technically feasible to meet the target solar fractions. At the same time, by means of the solar recycling of existing building stocks, it is possible to considerably reduce the environmental impacts due to the extraction of materials from, and the disposal of solid wastes into, the ecosystem.

Keywords: Sustainable urban development; Building morphology; Solar access; Energy efficiency

1. Introduction

Scientists and informed leaders of the more progressive societies agree about the necessity of attaining environmental sustainability in the mid-terms [1–3]. On the path towards such an ambitious, yet elusive goal, urban and energy planners and building designers must undoubtedly address the key issue of energy use in the built environment.

Many studies have evaluated the interrelationship between urban form and energy use [4–7]. Energy consumption in urban environments can roughly be divided in two main sectors: transportation and buildings. Energy consumption related to transportation is influenced by the urban form at the macro-scale, such as the city's inner functions and regional links. In contrast, energy consumption related to buildings is mainly dependent on the conditions of the urban climate and the micro-scale of the city's inner structure, mainly the configuration of neighborhoods, urban spaces, and building morphology (design) and materials (technology).

While constant advances in energy-efficient building technology have provided significant and well-known contributions to energy conservation, advances in urban morphology have been more limited and complex. Physically, economically, and legally feasible alternatives are required to minimize energy waste and maximize the

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potential use of renewable energies, namely solar radiation in urban buildings. Passive and active space heating, domestic water heating, and, eventually, "on site" PV generation need to be considered.

In 2002, the R + D group initiated a comprehensive research project to assess the energy savings potential of urban environments in the region [8,9]. The relevant relationship between urban morphology and solar access was addressed, and the solar potential of existing low-density urban environments was assessed. Morphological and technological proposals for effectively recovering a large portion of the solar potential will be developed. These proposals will be transferred to local agencies, mainly municipalities, to update, develop, and implement them in municipal building codes (MBCs). They will contribute to the attainment of the "most sustainable" energy future for existing urban buildings in the temperate-cold, mid-latitude arid regions of Latin America. The metropolitan area of the city of Mendoza (MMA), in the Sub-Andean region of western Argentina, was selected as a case study.

As it is well known, the common outstanding morphological feature of cities of Spanish foundation in South America is the "gridiron" plan. In the case of the MMA, five smaller municipalities have surrounded the main capital city through a conurbation process. The six municipalities are presently integrated into a single urban conglomerate. Initiating from similar foundational cores, these urban areas have extended in processes that are specific to each city's culture, inner features, and natural contexts. In most cases, however, gridiron layouts have prevailed and today continue to be the predominant physical configuration.

While city-center areas have developed high building densities [10], the foundational cores are surrounded by low building densities, which are now a large portion of the urbanized area. These low-density urban environments, which are mostly residential, have a rectangular shape as a common pattern, and their areas, proportions, and orientations are variable. These variations required a thorough analysis to assess the present and future solar potential of these areas. The urban city block was considered as the basic analysis unit, with the shape, proportions, and orientation of city blocks as the fundamental variables of the urban area that determine the main features of the built environment. The street width was also an important variable, particularly for areas with streets running in an approximately east–west (E–W) direction.

Urban trees in the public and private open space were also an important variable [11], particularly in the MMA, where there is an exceptionally dense and tall urban forest among low-rise residential structures, usually no taller than two stories (Figs. 1 and 2). Several features of this urban forest were taken into account: tree species, size and shape of typical urban trees, deciduous or permanent foliage, solar permeability of the crowns during the different seasons, and the degree of completion of the tree stock around each city block.

Fig. 1. Mendoza from the air.

Fig. 2. Typical downtown forested street.

The MMA's present energy system depends, predominantly, on the intensive use of fossil fuels. Because of the progressive depletion of this resource and the deleterious effects of conventional energy consumption on local and global environments, reducing consumption and substituting the use of renewable energy sources is imperative.

Official figures regarding the energy consumed by the urban domestic sector in the province of Mendoza, provide sufficient justification for this study. The residential sector, mostly urban, consumes 30.97% of the total energy, with an efficiency (useful consumption/total consumption) of 55.6%. This means that almost half of the energy consumed is lost due to deficient building design and technology. Of the energy consumed by the domestic sector, 37.8% is used for space heating, 30.8% for domestic water heating, 9.3% for cooking, 9.5% for food conservation, 0.2% for lighting, 0.7% for space cooling and ventilation, and 11.7% for other appliances. In most cases, the energy source is natural gas, with a national