Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 143 (2017) 277–282

Energy Procedia

www.elsevier.com/locate/procedia

World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference, WES-CUE 2017, 19–21 July 2017, Singapore

The effect of urban density on energy consumption and solar gains: the study of Abu Dhabi's neighborhood

Milos Mirkovic[a]*, Khaled Alawadi[a]

[a]*Masdar Institute of Science and Technology, Masdar City, Abu Dhabi 54224, United Arab Emirates*

Abstract

The study shows that native-born neighbourhoods occupy a large portion of Abu Dhabi's landscape, with 55.2% of the total land designated for development. Even though 18% of the total Abu Dhabi's population lives in these neighbourhoods, they consume 47.8% of total domestic electricity demand in 2014, or almost six times more than the average per capita electricity consumption. This paper explores potential building energy reduction and solar heat gains by focusing on urban density of one typical Emirati neighbourhood in Abu Dhabi. Results show that building energy demand can be reduced by up to 10.5%, while solar heat gains can be reduced by more than 50%, depending on the urban density. Results in general reveal how urban density can affect solar heat gains and reduce building cooling demand for low-rise Emirati neighbourhoods.

Peer-review under responsibility of the scientific committee of the World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference.

Keywords: building energy; urban form; cooling load, solar gains, passive cooling design, energy consumption.

1. Introduction

The increasing number of the world's population who lives in cities and their activities led to an increase in building energy demand, especially during summer months. The reduction of cooling load is one of the main factors for making buildings more sustainable, especially when these buildings are located in hot and arid climate regions. (Wargocki, 2000). In these climate regions, it is important to passively reduce solar gains and passively decrease the total energy demand of the building. This study is analysing the energy consumption of native-born neighbourhoods in Abu Dhabi and potential passive reduction rate through urban form.

* Corresponding author. Tel.: +971-56-123-1781.
E-mail address: mmirkovic@masdar.ac.ae

Peer-review under responsibility of the scientific committee of the World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference.
10.1016/j.egypro.2017.12.684

Energy consumption of the buildings in the UAE represents more than 80% of total energy demand of Abu Dhabi (Mahboob, Tsaia, Bacaa, & Afshari, 2014). The spatial analysis shows that native-born neighbourhoods, even though they make around 18% of total Abu Dhabi's population, occupy a large portion of Abu Dhabi's landscape, with 55.2% of the total land designated for development. These neighbourhoods are characterized by a low-rise, detached, low-density, single family housing units. Information provided by ADWEC (2015) shows that, in 2014, native-born neighbourhoods consumed 47.8% of total electricity demand for domestic sector in Abu Dhabi (9,895,963MWh), or 18,073KWh per capita. Compared to the world per capita electricity consumption (3,104KWh), it is larger by almost six times (IEA Statistics, 2014). These are the reasons why the study of these neighbourhoods is very important; even though less than 1/5 of the population lives in these neighbourhoods, they consume almost 50% of total domestic electricity demand and almost six times more than the world's average consumption.

The literature study shows different strategies which improve the energy demand of the building. O'Malley, Piroozfarb, Farr, and Gates (2014) argue that one of the most effective passive strategies are building form, orientation and layout. In addition, the size of the building (Ewing & Rong, 2008; Ko, 2013; Min, Hausfather, & Lin, 2010) and the size of the plot (Brian Jr & Rodgers, 2001; Ko, 2013; Stone & Rodgers, 2001) are crucial factors influencing energy consumption since residential energy use greatly depends on the building volume, which needs to be heated or cooled, and its surrounding plot size. The effect of cool paints and building albedo shows important results too (Bouyer, Musy, Huang, & Athamena, 2011; Gros, Bozonnet, & Inard, 2014). Moreover, measures applied to buildings to reduce energy demand depend on natural and controlled ventilation, solar shading and glazing (Florides, Tassou, Kalogirou, & Wrobel, 2002; Hirano, Kato, Murakami, Ikaga, & Shiraishi, 2006). Furthermore, the right building orientation on the site (Bouyer et al., 2011; Cheng, Steemers, Montavon, & Compagnon, 2006; Florides et al., 2002; Ko, 2013; Steemers, 2003) and its clustering on a wider scale (Golany, 1996; O'Malley et al., 2014) are crucial for a building to receive a right amount of sunlight and natural winds, which can passively cool the building. Similarly, proper shading strategies can reduce building cooling load by up to 30% (Balaras, Droutsa, Argiriou, & Asimakopoulos, 2000). Finally, landscape elements and surrounding vegetation are a successive way of mitigating UHI and reducing the surrounding temperature through evaporative transpiration (Akbari, 2002; Bouyer et al., 2011; Brian Jr & Rodgers, 2001; Heisler, 1986; Huang, Akbari, Taha, & Rosenfeld, 1987; Ko, 2013; McPherson, Simpson, & Livingston, 1989; Wong et al., 2003).

Most of analysed literature covers the topics of energy efficiency and design strategies and their possible reduction rate. However, either they are not completely related to this climate or even more specifically, this region and Abu Dhabi. Besides, most of the literature explains different strategies for reducing energy consumption, but without quantitative results and percentage of reduction. Furthermore, the literature study does not describe the relationship between urban density and energy consumption, moreover for low-rise buildings, which is the case of this study. This research is trying to contribute to the body of literature by addressing stated gaps in the literature, focusing on Abu Dhabi's region and investigating the relationship between urban density and building energy.

2. Methodology

To better understand architectural design and building service strategies, an understanding of the climate is essential before the design phase. This helps to respond to the external environment and to understand potential energy savings which could be achieved through passive design and renewable energy sources. The climate data was obtained from Abu Dhabi airport, where it was collected for a period of more than 18 years, making this source reliable and representative of the macroclimatic conditions of the Emirate.

The United Arab Emirates have a hot desert climate due to its location within the northern desert belt, as classified under Köppen-Geiger climate classification. The temperature varies significantly during the day and year and it represents the most critical metrics to be considered in the passive cooling design. As it can be seen in Figure 1, mostly during summer months external temperatures reach over 40°C, which makes the outdoor life uncomfortable, indicating the need for shading, protection of building envelope openings and other passive cooling strategies which enhance occupant thermal comfort and reduce building energy consumption.