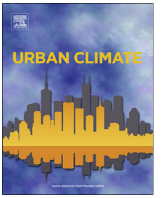
Urban Climate 10 (2014) 42–55

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim



Response of office building electricity consumption to urban weather in Adelaide, South Australia

Huade Guan [a,b,*], Veronica Soebarto [c], John Bennett [a], Roger Clay [d], Robert Andrew [a], Yunhui Guo [a,b], Saeedeh Gharib [a], Kathryn Bellette [a]

[a] School of the Environment, Flinders University, Australia
[b] National Centre for Groundwater Research and Training, Australia
[c] School of Architecture and Built Environment, University of Adelaide, Australia
[d] School of Chemistry and Physics, University of Adelaide, Australia

ARTICLE INFO

Article history:
Received 11 January 2014
Revised 25 July 2014
Accepted 7 September 2014

Keywords:
Office building
Electricity consumption
Climate dependency
Greenhouse gas emission
Multiple linear regression
South Australia

ABSTRACT

Knowledge of climate dependency of building energy consumption is useful for predicting the impacts of climate change and urban heat island on energy demand and associated carbon emissions, and to evaluate and improve building energy performance. Climate dependent electricity consumption is examined in this study for four office buildings in Adelaide, the capital city of South Australia with a warm-summer Mediterranean climate. Influences of both outdoor temperature and specific humidity on building electricity consumption are analyzed using the multiple linear regression, based on both sub-daily and monthly electricity consumption data. The results indicate that there is a daytime mean temperature threshold of around 17 °C, above which, electricity consumption increases with air temperature. Specific humidity also contributes to interpreting the temporal variability of office hour electricity consumption. Daytime temperature and specific humidity together determine 80–90% of office hour electricity consumption variation for days with mean daytime temperature above the threshold temperature. Office building daily electricity consumption can be examined with monthly electricity consumption data of a period of three years. The results also suggest that heatwaves may increase office building electricity demand by up to 50%, and that one degree warming can increase annual office electricity consumption by 2% in Adelaide.

* Corresponding author at: School of the Environment, Flinders University, Bedford Park, Australia. Tel.: +61 8 82012319.
E-mail address: huade.guan@flinders.edu.au (H. Guan).

http://dx.doi.org/10.1016/j.uclim.2014.09.005
2212-0955/

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), in the last three decades, the average global land temperature has increased by 0.24 °C per decade. In Australia, the average temperature has increased by 0.7 °C since the 1950s (Braganza and Church, 2011). Increasing greenhouse gases (GHG) are considered to be the most likely factor contributing to this observed global warming. In 2005, CO_2 concentration in the atmosphere was 379 ppm, contributing to 63% GHG radiative forcing for global temperatures. Global warming increases energy demand in many areas in the world, leading to pressure to decrease the global GHG emission. This issue is also reflected in the economy. In Europe, the CO_2 emission price is suggested to be connected with climate conditions (Mansanet-Bataller et al., 2007). In urban areas, local climate is modified by built environments, leading to a commonly known urban heat island (UHI) phenomenon (Oke, 1973). Thus, UHI can potentially influence building energy consumption in cities (Hirano and Fujita, 2012; Kolokotroni et al., 2012; Mavrogianni et al., 2011). Knowledge of how building energy consumption responds to air temperature provides a basis to evaluate economic and environmental benefits of UHI counter measures (Ihara et al., 2008b).

Climate dependent energy consumption and its response to climate change has been increasingly studied (Ahmed et al., 2012; Amato et al., 2005; Eskeland and Mideksa, 2010; Franco and Sanstad, 2008; Hekkenberg et al., 2009; Lecomte and Warren, 1981; Psiloglou et al., 2009; Sailor, 2001; Sailor and Pavlova, 2003; Valor et al., 2001). Energy consumption from different functional types of buildings (e.g., office, commercial, public, industrial, and residential) is often lumped in these studies, partly because of limited availability of data. As a result, they do not provide details of the energy consumption and its climate dependency for each type of buildings. However, this is important for policy makers in order to take more specific measures (Moral-Carcedo and Vicens-Otero, 2005).

According to Ren et al. (2011), buildings account for 40% of the world energy consumption, and are responsible for one third of global GHG emission. Building energy consumption is sensitive to weather conditions, primarily in its use for air conditioning (cooling on hot days, and heating on cold days, though the latter can be achieved with electricity but also natural gas and oil), which can be a large component of total building energy consumption (Saidur, 2009). It is commonly known that building energy consumption often varies with air temperature (Ihara et al., 2008a). For cooling with air-conditioners, condensation often occurs in the air conditioner's coil, which reduces the cooling efficiency (Ihara et al., 2008a). This impact becomes more significant at times when specific humidity of the air is high. Sometimes, dehumidification only is performed to achieve a good indoor comfort level. Thus, besides temperature, it is also found that building energy consumption is sometimes sensitive to humidity in the air (Ihara et al., 2008a).

The level of energy use within buildings, and its variation with environmental temperature, is clearly important for energy efficiency and broader environmental perspectives. The level of energy use depends in part on how thermally effective the building's external walls are in isolating the building from the environment. It also depends on the heat loads generated by the occupants and their activities in the buildings, and the requirements for cooling and heating by the occupants of the building, as well as on energy management protocols for the building. The building energy use is thus dependent on outside temperature when the temperature is beyond a "human comfort level".

If this weather-dependent energy consumption is quantified, in the macroscale, it can be used to predict climate change impacts on electricity load demand and associated carbon emissions, and the economic consequences. Such quantification would also be useful for forecasting energy demand for an area a few days in advance (Cancelo et al., 2008) and planning for electricity allocation during heat waves when reliable weather forecasts are available. In the microscale, knowledge of the weather dependence of energy consumption will be useful to evaluate and improve building energy performance.

Due to different climates, socio-economical conditions, cultural background, building function and structure, and many other factors, the relationship between building energy consumption and climate varies between regions and across different building functional types (Eskeland and Mideksa, 2010;