Energy for Sustainable Development 34 (2016) 1–9

Contents lists available at ScienceDirect

Energy for Sustainable Development

Towards daylight inclusive bye-law: Daylight as an energy saving route for affordable housing in India

Ronita Bardhan *, Ramit Debnath

Centre for Urban Science and Engineering, Indian Institute of Technology Bombay, Mumbai 400076, India

ARTICLE INFO

Article history:
Received 9 March 2016
Revised 2 June 2016
Accepted 17 June 2016
Available online xxxx

Keywords:
Daylighting
Energy saving
Useful Daylight Illuminance
Building bye-laws
Affordable housing

ABSTRACT

Building sector in India consumes about 33% of total electrical energy use, out of which 25% is accounted by the residential sector. This can be effectively reduced by utilizing daylighting as an essential component of building design strategy. Indian building codes lack specific daylight-inclusive design guidelines, which can provide policy support in reducing the energy consumption. In this study, energy sustainability through daylighting is studied with respect to daylight performance of a middle income, residential apartment in the city of Mumbai. Useful Daylight Illuminance (UDI) is used as the performance metric. The effect of built components like window-to-wall ratio (WWR) and orientation on the UDI ranges was studied. Occupancy behavior was modelled using an UDI threshold of 500 lx, and an energy management matrix (EMM) was derived. It has been found that at south-east orientation and at 20% WWR, the base-case building would save up to 26% lighting energy. Finally, a methodological framework for developing a policy toolbox using EMM was proposed as a route towards designing daylight inclusive building bye-law.

Introduction

Rapid urbanization in India, is pushing the energy demand at an unpreceded rate of 8% per annum (Yu et al., 2014). The sprawling of compact multi-storied high rise buildings, currently an archetype to meet urbanization demands, is increasingly putting pressure on urban energy needs. Moreover, non-stringent building bye-laws and lack of solar legislation add to the burden. While such development is better from the point of minimizing energy usage for transportation, the close proximity of the high-rises limits the sky-component and daylight penetration (Bardhan et al., 2015a). This in turn affects the quality and the quantity of daylight received, especially at the lower floors, and puts pressure on artificial lighting needs. Especially, in a country like India which has prolonged sunlight hours it seems imperative to have regulatory norms that integrate daylighting into the housing sector. The building bye-laws of Indian cities prescribe that every habitable room should have one or more apertures like windows, opening to external environment such that in no case the glazing to floor ratio be less than 10% of all habitable spaces (Kolkata, Gazzette. Orders and Notifications by the Governor of West Bengal, the High Court, Government Treasury, 2007) and the prescribed minimum distance between buildings is based on the "sustained vertical angle requirements" as per NBC-2005 Part 8 Sec 1 (BIS, 2005). These laws were first developed in the UK, primarily for low rise terraced houses, which assume that all windows receive a fairly good amount of "sky component" and that there is a constant angle of obstruction among the buildings. Given that Indian cities are growing taller and the windows have varying skyline obstruction, these laws become less effective. The building design itself suffers with no guarantee on daylight availability and performance. This situation calls for remedial measures in building bye laws that can meet with the contemporary demands in the growing residential sector.

One of the critical characteristic of India is its low socio-economic class driven urbanization (Bardhan et al., 2015b). This has led to a huge deficit of affordable housing in India. As a remedial measure, the Government of India has formulated the scheme of "Housing for All-2022", which aims to build 20 million affordable houses in the next seven years (MHUPA, 2015). Under this pretext it would be judicious to propose daylight inclusive building bye-laws for this upcoming housing stock.

Hence, this study intends to propose a route towards daylight inclusive building bye-law and policy formulation. First, the study describes the gaps in current bye-laws and then estimates the daylight performance of an existing building. It then suggests the metric of Usable Daylight Illuminance (UDI) for evaluating the energy saving capability of residential buildings. Finally, an energy management matrix is designed as a method for formulating daylight inclusive building bye-laws.

* Corresponding author at: Centre for Urban Science and Engineering (CUSE), Indian Institute of Technology Bombay, Mumbai 400076, Maharashtra, India. Tel.: +22 2576 9332.

E-mail address: ronita.bardhan@iitb.ac.in (R. Bardhan).

http://dx.doi.org/10.1016/j.esd.2016.06.005
0973-0826/

The specific objectives of this study are

- To understand the current lacuna in the current building bye laws with respect to daylight legislation for naturally ventilated residential houses.
- To examine and establish applicability and suitability of existing metrics as a way of energy saving in the affordable housing stock in India.
- To determine the energy saving potentials by varying the window to wall ratio (WWR) and orientation.
- To develop a method for design guidelines for including daylighting at early design stages of affordable housing.

Indian context

Building sector in India consumes 33% of total energy, out of which 25% accounts for residential sector whereas 8% is consumed by the commercial sector (Kumar et al., 2009). In the residential sector, there is a growing trend of single person households, especially in the metropolitan cities, which is more likely to push this energy consumption and demand upwards. Thus the energy consumption in the building sector might become a challenge, if not arrested at this stage. India needs to orchestrate design guidelines especially for the residential sector to make it energy efficient and climate resilient.

Energy Conservation Building Code-2011 (ECBC), which defines norms and standards for the energy performance of the buildings and their components based on the climate zone in which they are located, states that 80% of the energy in commercial building is due to lighting and air conditioners (ACs), whereas the major energy use in the residential buildings is due to lighting and fans (Kumar et al., 2009). The energy consumption break up in the residential sector for 2011 was as follows: 28% of energy use is in lighting, 34% in fans, and 13% in refrigeration (Centre for Science and Environment (CSE), 2014). In 2010, the room air conditioner saturation among Indian urban households was only 3% which is likely to grow to 60% by 2030 (NSSO, 2012). However, given the current status of India's building stock it is only one-fourth of the total estimated building stock of 2030 i.e. 70% of the houses are yet to be constructed (Centre for Science and Environment (CSE), 2014; The World Bank, 2008). Therefore, it is evident that one way for energy saving for Indian residential conditions is by harnessing while assessing the residential energy consumption in India; it was reported that in 2030, about 45% of the energy savings can alone be achieved by optimizing the lighting technology (Planning Commission Government of India, 2014).

Hence, for a country like India where the majority of the population lives in the middle or low income group, estimating energy savings from lighting becomes more practical than focusing on reducing cooling loads from ACs in the residential sector. Moreover, according to Roychoudhury (as seen in Burke, 2015) “Indian buildings do not need air conditioning for 365 days, 24 h a day” and although architects are resorting to means for ensuring better lighting, air movement, and shading, but to realize it as an energy saving option needs policy support. The peak summer months of June and July demands the highest cooling needs through ACs (Rawal and Shukla, 2014). Therefore, Rawal and Shukla (2014) recommend building energy efficiency in India which can be achieved by using smart devices to acquire energy data from buildings, energy efficient household appliances, policy road map for implementing energy efficiency measures for residential buildings and by developing a climate based residential building energy code. Moreover, much of the building energy is wasted because of “poor design, inadequate technology and inappropriate behaviors” and that government intervention in design is required to transform the building energy scenario especially in developing countries like India (WBCSD, 2009). It is suggested that the building energy use decision making should be “bottom-up” approach to identify the barriers for energy-efficiency and the means to overcome them. One of the essential means identified is the building design.

Currently in India two such building codes exist which are a national instrument for providing guidelines for building construction activities and aim to create sustainable practices. These are namely the National Building Code of India (NBC) — 2005 (BIS, 2005) and the Energy Conservation Building Code (ECBC) —2011 (Kumar et al., 2009). However, these are more of a blanket recommendation than regulatory norms. They are mostly used to adjudge the performance of a completed building and are seldom used as guideline for designing the house at the early stages of design.

NBC-2005 and ECBC-2011 do not explicitly specify any building byelaw that can foster the usage of natural lighting in place of artificial lighting. For instance: Section 5.2 (e) of NBC-2005 which deals with the planning, design and development, mentions “*Emphasis on daylight utilization, natural ventilation, shielding, and window area and its disposition; daylighting to be supplemented with an integrated design of artificial lighting*”, similarly Section 5.2 (f) mentions, “*Optimum utilization of renewable energy sources duly integrated in the overall energy system design; with consideration of active and passive aspects in building design including thermal performance of building envelope*”. Part-8 Section 1 of NBC-2005 (also IS 3646-Part I 1992) covers the requirement for lighting and ventilation in buildings which deals with daylight thresholds required for various indoor functions. However, these are yet to become building legislation. The building permission authorities, which give sanctioning for construction of buildings, also lack any standard metric to adjudge the daylight performance of a building design, with respect to energy saving potential.

Similarly, Chapter-4 of ECBC-2011 which primarily sets the guidelines for building envelop, fails to specify any essential code or guideline for integrating the daylighting component in the building envelope. It only ‘prescribes’ skylight and a cool roof as alternative methods of energy efficient building. Moreover, for a warm and humid climate zone ECBC recommends use of wind towers, courtyard-type construction, ventilated roof construction and cross-ventilated openings as the key cooling strategies through natural ventilation (see ECBC-4.3.1.1). However, in order to improve thermal comfort levels in the residential buildings ECBC recommends use of de-humidifiers and desiccant cooling (Kumar et al., 2009). Section 5.2.1 of ECBC-2011 and Part 8, 5.4.3 and 5.7.1 of NBC-2005, specify the usage of natural ventilation for cooling purposes either by wind action or through stack effects. The fans are inherently integrated in these guidelines. Chapter-7 of the ECBC guidelines deals with the lighting controls for mostly commercial buildings. It fails to integrate daylight compliance guidelines or building byelaws for the residential sector.

Hence, the housing sector in India needs passive solar building byelaws that can integrate daylight as a key strategy for the creation of sustainable built environment. Moreover, in India, where the annual sunshine hour ranges between 2300 and 3200 h, well day-lit buildings can boost the energy efficacy of sustainable housing to a greater extent and perhaps it becomes imperative to consider utilization of daylighting as an integral part of building industry both in policy and practice (Harinarayana and Kashyap, 2014).

Under this purview, this study aims to analyze the energy saving potential in a naturally ventilated house using daylight and propose a policy toolbox that can enable daylight inclusive building bye-laws to ascertain a sustained energy saving in the context of growing urbanization. The novelty of this work lies in the methodological framework for incorporating daylight metric as an energy saving indicator in a naturally ventilated residential house and formulation of policy toolbox to frame daylight inclusive building bye-laws.

Study area and base-case scenario

A typical residential building for a middle income household within the city of Mumbai is chosen as a base-case model for the study. This building is built as per existing building bye-laws. Mumbai is one of the densest cities in the world, which has a diverse mix of culture and