Improving the resilience in urban environment by applied research for the development of a simple equation-based Energy Conservation Building Code for India

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Abstract. This contribution presents the approach and methodology followed by the Building Energy Efficiency Project (BEEP) [1] to contribute to the improvement of energy efficiency and climate change resilience for multi-story residential buildings in the rapidly growing urban construction in India. As a consequence, the urban resilience will be improved at two levels: 1) the improved thermal comfort in non-air-conditioned apartments will reduce the health-related heat wave impact, 2) the cooling energy demand in air-conditioned apartment will be reduced by 20–40%. The impact of the Energy Conservation Building Code for Residential (ECO Niwas Samhita) was launched in December 2018 by the Indian Government. It has been estimated to reach a cumulative 100 Million tons of CO2 emission reduction by 2030. The Code was developed with the main objective to reduce heat gains between 20 to 40% through the building envelope by passive measures at no or marginal additional costs of construction.

1. Introduction
India is in the hot climates region which will suffer the most of climate change. In emerging economies with hot climates, most residential occupants do not yet have access to active cooling. The occurrences of extreme heat waves are increasing and are likely to become deadly during days or even weeks in hot climates. Poorly designed residential buildings contribute to health risks in relation to heat waves, due to overheating in these buildings. Among these countries, many do not yet have a simple building code designed to control the heat ingress through the building envelope of residential buildings. This was also the case of India, which had launched earlier an Energy Conservation Building Code only for commercial buildings. The urban population in India is growing at a fast pace; the Government of India’s scenario for urban growth indicates an increase of the urban population by 220 Million between 2011 and 2031[2]. In the Tier I (‘metro’) and Tier II (large) cities, the urban density is very high with a rapid construction of high-rise residential buildings.

The Indo-Swiss Building Energy Efficiency Project (BEEP) is a bilateral cooperation project between the Ministry of Power (MoP), Government of India and the Federal Department of Foreign Affairs (FDFA) of the Swiss Confederation. The Bureau of Energy Efficiency (BEE) is the
implementing agency on behalf of the MoP while the Swiss Agency for Development and Cooperation (SDC) is the agency in charge on behalf of the FDFA [3].

2. Background and long-term approach for a successful collaboration developing passive building design guidelines and building codes for the residential sector with the Bureau of Energy Efficiency, Ministry of Power, India

Until recently, in India, energy efficiency in residential buildings focused principally on appliances and room air conditioner performance (star labelling for room air conditioners introduced in 2001, revised in 2009 [4] and 2017 [5]). The building envelope performance was not included in construction permit procedures, even though the potential for reduction of cooling loads is between 20-40% by sound passive design.

The residential sector in India did not have a building code. Only commercial buildings had been targeted by an Energy Conservation Building Code for commercial buildings [6] introduced in 2007 and revised in 2017 [7].

The BEEP project, which was designed in close collaboration with the Bureau of Energy Efficiency, has been operating since 2011 and has been extended in 2016 until end 2021. BEEP has conducted more than 20 design ‘charrettes’ (integrated design workshops) for large projects (total area of 1.6 million m²). The methodology for design charrettes was presented in a contribution to the UNESCO Conference on Technologies for Development 2012 at EPFL (Tech4Dev 2012) and published in a book [8].

These design charrettes helped building the credibility of BEEP vis-a-vis the stakeholders. As an example, one early building in operation following a BEEP design support charrette was the first building to comply with the ECBC-commercial code in Rajasthan [9]. It has reached very high performances as per Indian performance classification (Energy Performance Index (EPI) of 43 kWh/m²-yr) [10] which rates a building as 5 stars for an EPI of 90 kWh/m²-yr (more than 50% air-conditioned category) [11]. It was also identified as the only published detailed energy monitoring of ECBC-Commercial code compliant building in operation [12].

In 2014, BEEP developed Design Guidelines for Energy-Efficient Multi-Story Residential Buildings: Composite and Hot-Dry Climate [13]. These guidelines were mentioned by the Indian Government in their COP 21 Intended Nationally Determined Contribution [14] at Paris. In 2015, at IBPSA 2015 at Hyderabad, the methodology used to develop these guidelines was presented in an oral presentation [15]. Later in 2016, new Design Guidelines for Energy-Efficient Multi-Storey Residential Buildings: Warm and Humid Climate were issued by BEEP [16].

In 2017, the Indian Government (Ministry of Power) decided to develop quickly a first Energy Conservation Building Code for Residential buildings. BEEP provided the technical assistance to conceive and develop the technical part of this Building Code between the second part of 2017 and early 2018. The Code was developed with the main aim to reduce heat gains through the building envelope by passive measures at no or marginal additional costs of construction. At India level, the penetration of air conditioning remains low (less than 10% [17]), but there is a very rapid increase especially in urban areas.

3. Preparatory studies and methodology for the development of the of BEEP Energy Conservation Building Code for Residential buildings

The basis of the concept of the code was developed in early 2017 with a comprehensive literature search about warm climate residential building codes. One of the early applications of the concept of energy efficient building envelope in residential sector was found in Singapore [18] and discussions happened in early 2017 with the Building Construction Authority of Singapore and with Prof. Chou of National University of Singapore.

4. Concept and development of the Energy Conservation Building Code for Residential

The development of the Energy Conservation Building Code for Residential Buildings (named for its launch Eco Niwas 2018) by the Indian Government was initiated in July 2017. BEEP with its Indo-Swiss team was mandated for the technical development of the Code. The Bureau of Energy Efficiency (BEE, under Ministry of Power, India) established a Steering and a Technical Committee to accompany the development of the new Code. The technical development of the code by the BEEP team was
accompanied by numerous meetings with each of the two Committees. The openness to dialogue and rapid progress of the BEEP team helped in developing a mutual confidence with the two Committees. The intention was to develop a code which would require as little effort for the project stakeholders as possible and be easy for compliance checking for the government authorities. The steering and the technical committee agreed with this approach. The first research work was to define if multi-linear regressions would be applicable in hot climates. In Singapore, where a similar approach had been followed, the daily temperature difference between day and night does not usually exceed 5°C. One of the main questions which remained unanswered was the application of the concept they used for warm humid climates to the hot climates of India with the night/day difference reaching as much as 20 °C. Based on multi-parametric variation studies leading to initiate hundreds of EnergyPlus simulations of a typical flat of multi-story building, one could demonstrate that it was possible to apply the multi-linear technique to the hot climates of India.

BEEP contributed to the development of the new Code by driving the technical development, the writing of its various versions and the tool for its application. The Code was officially launched on 14th of December 2018 [19] by the Ministry of Power. The printed version of the Code was released in spring 2019 [20].

5. Summary of the theoretical frame and approach followed for the Code Development

5.1 The concept of the Residential Envelope Transmittance Value

In cooling dominated climates like in India, the main heat gains in residential buildings are across the building envelope. In residential buildings, which have relatively shallow floor plates (unlike office buildings), the heat entering across the building envelope is the main contributor of heat gains in the apartments. The heat load is then directly related to the following main parameters:

- the heat transmission by conduction and convection of opaque and non-opaque areas
- the solar radiation passing through the windows as a function of the solar heat gain coefficient of the window system.
- the orientation of each façade,

The main objective was to come up with a simple equation model based on few variables and obtain the Residential Envelope Transmittance Value (RETV) in W/m². The RETV (W/m²) is the value of the potential heat gains averaged over the cooling period. The code specifies a maximum of value of 15 W/m² to be compliant. Green building associations like USGBC homes, GRIHA, IGBC homes are likely to apply a more stringent value or 12 W/m².

5.2 Methodology for the development of the Energy conservation building code for residential

The parameters which were varied are:

- the Window to Wall ratio, i.e. the portion of glazed area on the exposed façade of one typical intermediate floor: (WWR: 10% step of 5% up to 35%)
- the U-value of the opaque walls (Uwall: 0.48 to 3.27 W/m².K)
- the U-values of the glazing (Uwin: 5.78 to 2.65 W/m².K)
- static shading parameters: no shading, 300 mm overhang, 600 mm overhangs as used in low- and mid-income housing and effective Solar Heat Gain Coefficient (SHGC which is equivalent to g-value)
- natural ventilation parameters, the openable area of the window as either 50% (typical two panes sliding windows) or 90% for casement windows.
- the orientation of the façades

The development consisted in running these multi-parametric studies for each of the climate zones. For each of the climate zones, 4560 multi-parametric simulation cases were conducted, for a total of 27360 simulation cases. The simulation results were expressed in the form of multi-linear regressions developed for the following combination of variables:

\[ \text{RETV} \ (\text{W/m}^2) = a(1-\text{WWR})\text{Uwall} + b\text{WWR}\text{Uwin}+c\text{WWR}\text{SHGC} \text{ effective} \]

(later-on the orientation factor was also added), a, b and c are the coefficient resulting from the multi-linear regressions and are used for the RETV calculation in each of the 3 climates zones selected for India (only three sets of coefficients a, b, and c, the composite and Hot-Dry climates have the same coefficients as they were very similar in value obtained by simulation and multi-linear regression).
Figure 1: Table of the coefficient a, b, c (K) for the RETV equation taken from the final ECO NIWAS

In order to check the validity of the statistical approach, a multilinear collinearity test was performed, confirming the statistical validity of the approach (it was performed with inputs from LBNL and CARBSE [21]). The test confirmed the validity of the statistical method. The RETV calculated was compared with RETV in a linear correlation, the result was good with regression coefficient of $R^2=0.963$

![Figure 2](source)

![Figure 3](source)

The RETV averaged value over the cooling season (8 months for hot climates, 10 months for warm and humid climates) was correlated to the sensible cooling demand over the same period. The result was very satisfactory.

The RETV (W/m²) being the value of heat gains averaged over the cooling period, there is a very good correlation with the sensible cooling load during the same period.

The final form of the RETV equation in the Building Code is presented below:
The factor $\omega_i$ is defined as a correction factor function of the orientation of each façade. The summation of the RETV is performed on each façade orientation.

$$ RETV_{\text{formula}} = \frac{1}{A_{\text{envelope}}} \times \left[ \alpha \sum_{i=1}^{n} (A_{\text{opaque}_i} \times U_{\text{opaque}_i} \times \omega_i) + b \sum_{i=1}^{n} (A_{\text{non-opaque}_i} \times U_{\text{non-opaque}_i} \times \omega_i) + c \sum_{i=1}^{n} (A_{\text{non-opaque}_i} \times SHGC_{eq_i} \times \omega_i) \right] $$

Figure 4: general form of the RETV equation applicable for each façade orientation (a freely available tool has been developed to allow the users of the Code to perform these calculations in simple manner), taken from the ECO-NIWAS SAMHITA 2018 code
6. Discussion and potential impact

The potential cumulative reduction of CO2 emissions by the application of the ECBC-R in India until 2030 has been estimated to be of the order of 100 Million tons of CO2. This also improves the power grid system resilience by reducing peak loads and energy demand in large cities of India.

The expected impact in terms of health should also reduce the overheating burden by 2-4 °C inside the dwellings for dozens of millions of occupants improving significantly their resilience during and after hot waves.

The deliberated choice of the Indian Government to develop and get applied an Energy Conservation Building Code for Residential is likely to succeed in its application quickly enough to influence the design of dozens of millions of new residential multi-story buildings in the next 10 years. BEEP is mandated to support the policy dialogue with the States of Gujarat, Rajasthan, and Andhra Pradesh. With the rapid penetration of room air conditioners, the cooling load of new residential buildings should also be reduced in the range of 20-40 % as compared to business-as-usual designs.

Lexicon:
Tier I: Classification of Mega Cities of India (Delhi, Mumbai, Calcutta, Chennai, Bangalore, Hyderabad), Tier II: Capital States and other large cities (about 70 cities in India)
Design charrette: A 4-day intensive integrated design workshop bringing the important stakeholders of a project together with BEEP support
BEE: Bureau of Energy Efficiency, Ministry of Power, India
RETV: Residential Envelope Transmittance Value: averaged specific net heat gain through the exposed façade areas (W/m²)

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