DEPLOYMENT OF ENERGY SIMULATION FOR DESIGN OF VOLUNTARY WINDOW LABELING PROGRAM IN INDIA

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ABSTRACT

India has experienced an average economic growth of 10% since 1991 leading to the establishment of new commercial buildings. Amongst other initiatives, Indian government enacted the Energy Conservation Act in 2001 (EC Act 2001), predominantly for commercial buildings. Government of India is relying on mandatory building energy code and voluntary standards and labeling (S&L) program to foster energy efficiency in commercial buildings. Learning from S&L home appliances program the government has initiated the formation of building component labelling programs for windows, walls and roof. This paper is part of a research that aims to map the state of current affairs in Indian fenestration industry and fenestration labelling programs from across the world. The research involves evaluation of thermal and optical performance of windows available in Indian market and compares them against those prescribed in the energy code. Further it suggests mechanisms for the formation, implementation and administration of window labelling program in India. This paper also focuses on estimation of energy saving potential of high performance window systems, their payback period by using a combination of window simulation programs such as WINDOW, THERM and Optics and whole building energy simulation program such as EnergyPlus.

INTRODUCTION

As a result of sustained economic growth, India has experienced a surge in new construction of buildings across the country. High skill services sector employing educated Indian youth has fuelled construction of new commercial offices. It is estimated that approximately 67% of total building stock of 2030 will be added over the next 17 years.

Energy Conservation Building Code (ECBC) prepared by the Bureau of Energy Efficiency (BEE) – a central agency responsible for implementation of EC Act 2001 - prescribes minimum performance requirements for building envelope components, HVAC, lighting, motors and pumps. The socio-cultural-economic conditions in India are determined by agency called Planning Commission of India, who is also responsible for execution and monitoring of Indian economy. Implementation and enforcement of ECBC is one of the key focus areas under the 12th Five Year Plan (2012-17), mandatory implementation and enforcement of ECBC will be a key activity. BEE will work with state designated agencies and urban local bodies to do this.

State governments will be responsible for ECBC enforcement through local urban authorities, who are responsible for enforcement of building regulations. Inclusion of ECBC in existing regulations and within National Building Code will be crucial in achieving energy efficiency in buildings across the country.

Learning from the success of S&L program as well as to increase code compliance at local level, BEE has initiated a labeling program for windows. Fenestration is one of the most critical design components affecting energy usage in buildings. With India receiving an average solar radiation in the range of 4 to 7 kWh/m^2-day, it becomes important to focus on the performance of fenestration, especially windows, to reduce solar heat gain and optimize daylight without inviting glare inside the building. . . Advancements in frame design and glass manufacturing have led to the flooding of Indian markets with high performance glazing products to respond to the ever growing demand. These improvements have fostered the potential of India’s windows market to meet the ECBC requirements and energy efficiency demands of building sector. Presently, ECBC prescribes four parameters to evaluate window performance - U value, solar heat gain coefficient (SHGC), visual light transmittance (VLT) and air leakage. ECBC prescribes different performance standards for different climate zones in India, namely hot & dry, warm & humid, composite, moderate and cold. It also recognizes the impact of external shading on windows and allows for the modification of minimum SHGC for compliance. .

The numerous high performance options available for window systems have complicated the task of determining how a window should be labeled and verified on the basis of performance for different environmental conditions and various buildings types to meet ECBC compliance requirements. The proposed labeling program relies on the minimum performance values prescribed by the code for labeling of windows and aims to address the aforementioned variability to provide reliable information to consumers and, simultaneously, drive the market towards high performance windows.

IMPORTANCE OF WINDOW LABELLING PROGRAM IN INDIA

Traditionally window and door manufacturing in India has remained an 'on-site' activity, where window shutter and frame materials, predominantly wood, were brought and fabricated on site, with sized glass or panel material to be fitted inside. With rapid urbanization and speedy construction practices, aluminum has made inroads as one of the most widely used framing materials. That said, most of the small and medium scale projects still get local contractors to do most of the wok on site where extruded aluminum sections are brought on site for fabrication. A multitude of large projects, that fall under the ECBC scope and will be required by law to show compliance also rely on local contractors to supply and install windows. Window manufacturing industry in India, hence, has been a large unorganized sector in building construction. In the last couple of years, however, its workings changed. It has become an important enterprise and the manufacturers are now better organized.

In last three years, few industrial organizations have been set up to bring congruity to the industry production practices, achieve fair trade practices, formulate policy and work with government in a coherent manner. Such initiatives will help to achieve the performance standards being targeted under the labeling program. To develop the energy efficiency building regime, the industry will need window manufacturing units, suppliers and consumers who recognize the importance of energy efficient fenestration.

The Glazing Society of India, the Fenestration Council of India and the UPVC Material Manufacturing Association are some of the organizations that have attempted to bring awareness in the market. These efforts are, however, sporadic in nature and therefore, it is vital to bring all stakeholders to a platform. The window labeling program will create market demand for these products and will also help enforcement agencies at the urban local body (ULB) level to check code compliance in case of the use of BEE endorsed and labeled products.

METHODOLOGY

The exercise was divided into three parts. First was to understand international window rating and labeling programs. This part helped in isolating the energy performance evaluation criteria for windows, performance standards and testing protocols used in the process, as well as the administrative systems and tools used to implement such programs in various parts of the world.

The second part was aimed at understanding the current status of the Indian fenestration market in terms of a comparative assessment of the of existing windows with the minimum requirements prescribed by ECBC. The last part was to make a business case for ECBC compliant windows through component and whole building simulation and simple payback analysis for investments.

Overview of Window rating and labelling program in various countries

United States of America: National Fenestration Rating Council (NFRC) developed the rating standards followed in the USA. The three committees formed under NFRC are Certification Policy Committee, Technical Interpretations Policy Committee, and Accreditation Policy Committee. The parameters and standards used at NFRC are as listed in Table 1.

Table 1: Parameters and Standards for USA

PARAMETERS	STANDARDS
U - factor	ASTM C1199-00
SHGC	ISO 15099 in NFRC 200, NFRC 201
VLT	ISO – 15099
Air Leakage	ASTM E 283 [1]
CR	ASTM C1199, ASTM E1423

Australia: Australian Fenestration Rating Council (AFRC) developed the rating system for Australia. The AFRC board is responsible for enforcement of AFRC protocols, accreditation for simulators, test labs and auditors, certification, dispute resolution and NFRC liaison. The parameters and standards followed are as tabulated in Table 2.

Table 2: Parameters and Standards for Australia

PARAMETERS	STANDARDS
U - value	ASTM C1199-00
SHGC	ISO 15099 in NFRC 200, NFRC 201
VLT	ISO – 15099
Air infiltration	AS 2047
Fabric fading transmittance	AS 2047 – 1999 & AS 1288 – 1994

United Kingdom: British Fenestration Rating Council (BFRC) is the organization responsible for window labeling in the UK. The parameters and standards used are as listed in Table 3.

Table 3: Parameters and Standards for UK

PARAMETERS	STANDARDS
U - Value	BS EN ISO 10077-2
Solar heat gain 'G' value	EN – 832
Air leakage 'l'	BS 6375, Part 1 (EN 42)

China: Window labeling task in China is performed under the guidance of China Fenestration Energy Efficiency Performance labeling. The parameters used are heat transfer coefficient, shading coefficient, air permeability, visible transmittance, and energy saving performance objection description.

South Africa: South African Fenestration Insulation Energy Rating Association (SAFIERA) is the regulatory authority for labeling windows in South Africa. It has adopted all the NFRC parameters and standards.

Ireland: National Standards Authority of Ireland (NSAI) is the regulatory body for fenestration rating in Ireland. The parameters and standards used are as listed in Table 4.

Table 4: Parameters and Standards for Ireland

PARAMETERS	STANDARDS
U-factor	I.S. EN ISO 12567 – 1: 2001
Solar factor	I.S. EN 410
Air leakage	I.S. EN 12207: 1999

Performance evaluation of windows available in India

Market survey and simulation: This part of the study was aimed at documenting the window frame materials and glazing options available to consumers, commonly used window operation methods and window sizes used in commercial buildings. A survey was conducted by the post graduation students for a time span of about two months coverings the northern and western parts of India which almost included all the national level manufacturers and service providers. A list of manufacturers for UPVC and Aluminium frames was created and their product line was studied. Similarly, the CPWD tenders were examined for wooden frame usage. Architects and Engineers were also approached to get an understanding of the present glazing practices. This fairly gave the idea of the most frequently used frame materials, their types, sections and operations. The survey revealed the following conclusions (refer Figure 1):

a) Wood, aluminum and UPVC are the most commonly used framing materials.
b) Casement, sliding and fixed are the most prevalent window operation options available in the market.
c) Most single pane windows are fitted with clear, tinted or reflective glass whereas most double glazed units use clear glass with low-emissivity (Low-e) or solar reflective glass.

From the survey, 180 frame and glazing combinations were selected for the study. Two types of window frame sections were chosen in three materials (aluminum, wood and UPVC) for three operations (fixed, sliding and casement). These were further extended to include ten single and double pane options: clear, tinted-blue, tinted-green, coated-blue coated, coated-green, clear + clear, clear + low-e, low-e + clear, coated + low-e, low-e + low-e.

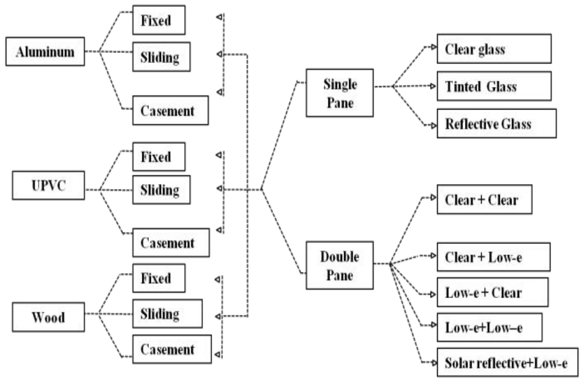

Figure 1 Run chart for one type of window, showing three window frame materials with three kinds of operation for ten type of glazing panes.

Each glass was tested using ISO 9050 method meant to determine the visual light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors. Each frame material was tested for its emissivity, thermal conductivity, specific heat and density. Energy performance properties of window components in terms of U-factor, SHGC and VLT were determined using component simulation programs (WINDOW version 6, THERM version 6 and OPTICS version 5.2). The boundary conditions considered for simulation as per ISO15099 are mentioned in Table 5.

Table 5: Boundary Conditions as per ISO15099

FOR U-FACTOR CALCULATION	
Interior Temperature	24 ºC (75.2 ºF)
Exterior Temperature	32 ºC (89.6 ºF)
Exterior Wind Velocity	3.3 m/s (7.5 mph)
Radiant mean temperature exterior	$T_{exterior}$
Radiant mean temperature interior	$T_{interior}$
FOR SHGC CALCULATION	
Interior Temperature	24 ºC (75.2 ºF)
Exterior Temperature	32 ºC (89.6 ºF)
Exterior Wind Velocity	2.8 m/s (6.3 mph)
Radiant mean temperature exterior	$T_{exterior}$
Radiant mean temperature interior	$T_{interior}$
Incident solar flux	783 W/m^2
Solar Spectrum	ISO 9050/ 9845

The performance of all 180 combinations was compared against ECBC prescribed numbers for U-actor, SHGC and VLT in order to assess the number of existing window assemblies in the market that are compliant with ECBC. ECBC prescribed values for U-Value, SHGC and VLT have been tabulated in Table 6 and 7.

Table 6: ECBC Prescribed U-Value and SHGC

CLIMATE ZONE	MAX U-VALUE	MAX SHGC	
		WWR < 40%	40% < WWR < 60%
Composite	3.30	0.25	0.20
Hot & Dry	3.30	0.25	0.20
Warm & Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51

Table 7: ECBC Prescribed VLT

WINDOW WALL RATIO	MINIMUM VLT
0.00 – 0.3	0.27
0.31 – 0.4	0.24
0.41 – 0.5	0.16
0.51 – 0.6	0.13

During the course of this study, center of glass values (without frame) were also plotted to understand the impact of window frame and operation on the performance of windows.

Results

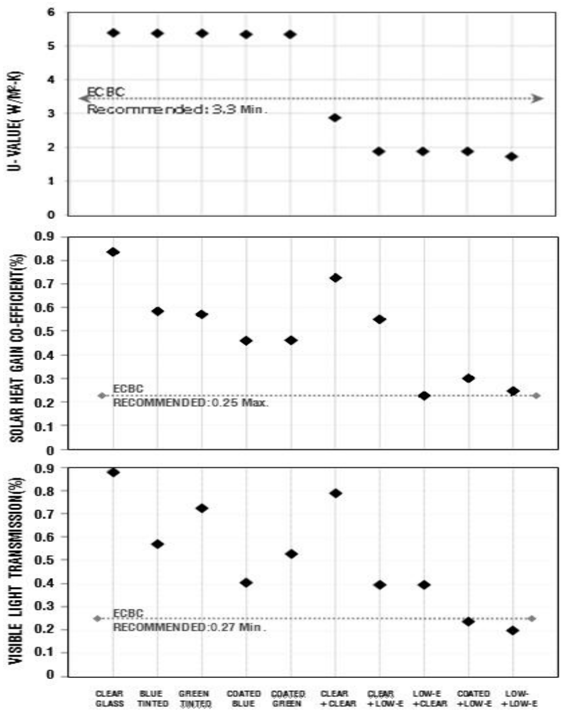

Figure 2 U-Value, SHGC and VLT at centre of the glass (without frame) for10 glazing panels.

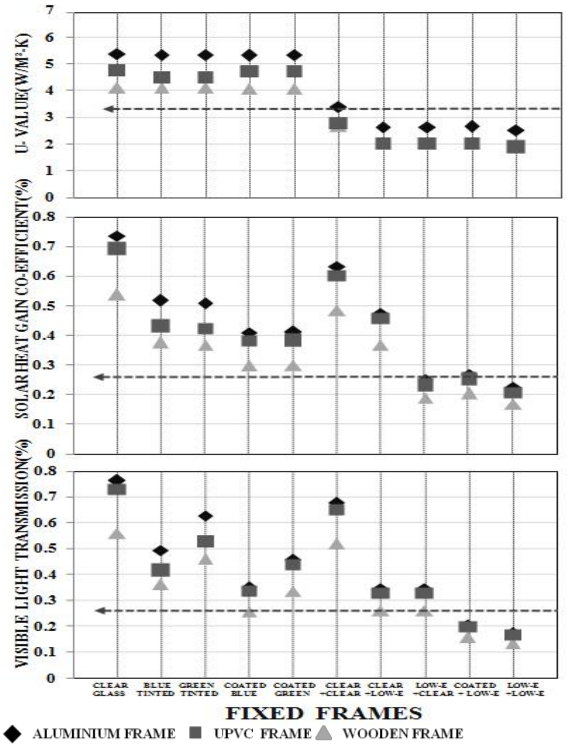

Figure 3: 30 cases of fixed frame using three window frame material and 10 types of glazing panes.

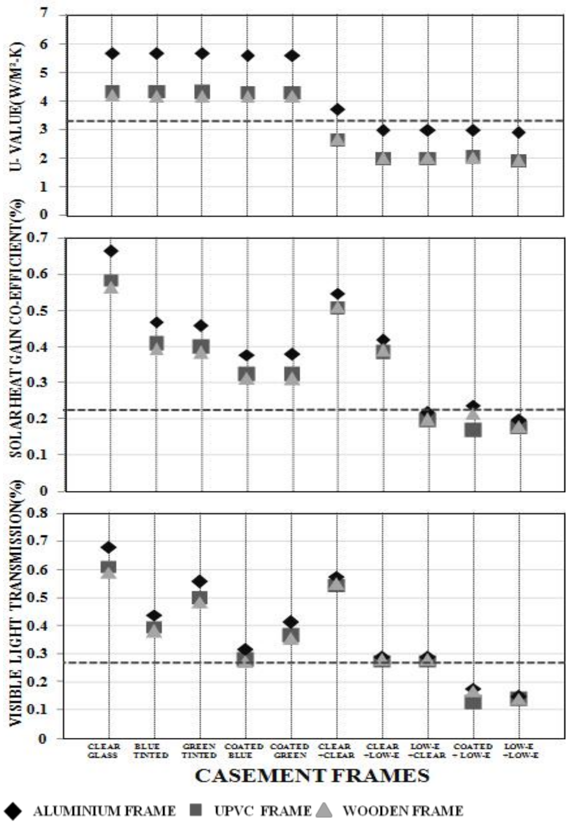

Figure 4: 30 cases of casement operation using three window frame material and 10 types of glazing panes.

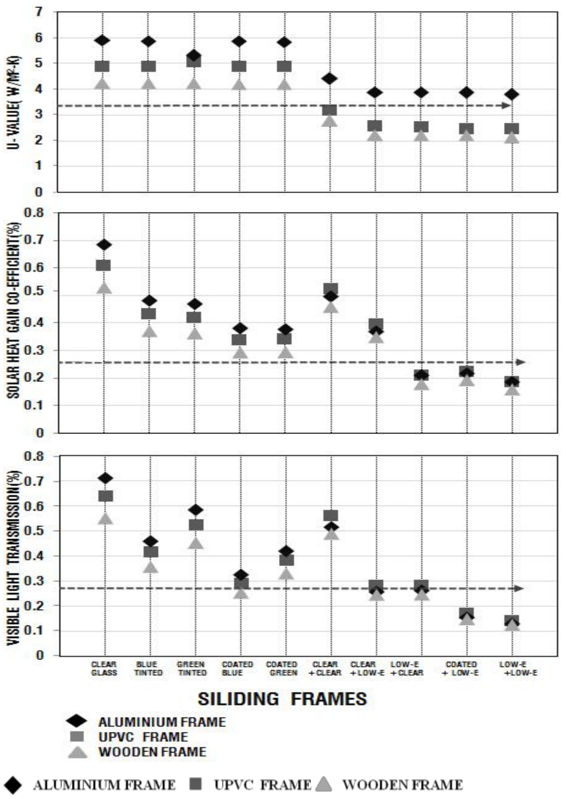

Figure 5: 30 cases of sliding operation using three frame materials and 10 types of glazing panes.

Following inferences were made from this part of the study.

a) Single pane window options do not meet the ECBC U-factor and SHGC requirement for, irrespective of operation type or frame material.

b) All double pane options meet the U-factor requirements but fail to meet SHGC and VLT requirements simultaneously.

c) To meet all three parameters of ECBC, the window needs to have double pane and one of the glasses should be coated.

d) Frame and operation has a considerable impact on window performance but policy intervention or labeling program may not differentiate between operation and frame materials.

e) Window label may remain the same for all climate zones except moderate.

Evaluation of energy saving potential of code compliant windows

To ensure market acceptability towards labeled windows, it is essential to demonstrate the energy saving potential of these windows, along with the long term economic benefits. . The last part of the study demonstrates the extent of energy saving potential in various climate zones with varied window to wall ratio (WWR). In order to do this, buildings of three sizes, two operation schedules and three WWRs (20%, 40%, 60%) were simulated using EnergyPlus in five climate zones of India. The run chart shown in Figure 6 depicts various building configurations analyzed for the study.

Table 8: Combination of cases

CASE	BAU	BAU+	ECBC
WINDOW TYPE	BAU	ECBC Compliant	ECBC Compliant
BUILDING	BAU	BAU	ECBC Compliant

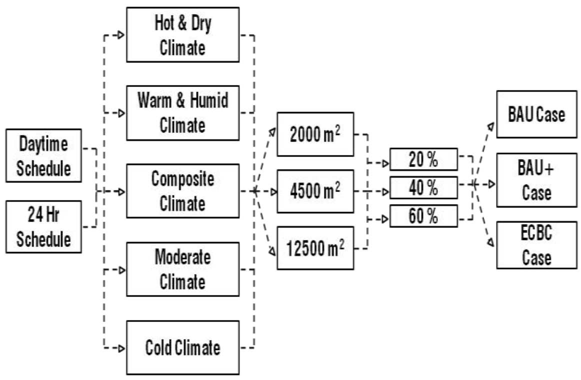

Figure 6 Run Chart

Simulation:

The basic model is a five-zone, five-storey square building with floor height of 3m. Table 9 shows some of the input parameters used in the simulation. Perimeter zone depth was taken as 4m from building façade.

Table 9: Model Inputs

INPUT PARAMETERS	**ECBC**	**BAU**
LPD (W/m^2)	10.80	13.99
EPD (W/m^2)	12.90	12.9
OD (sq-m/person)	9.30	9.3
Cooling CoP	2.60	2.05
Infiltration (ach)	0.10	0.25
Cooling Set-point (^{0}C)	24.00	24.00
Heating Set-point (^{0}C)	18.00	18.00
Daylight Control	Yes	No

The building envelope and system characteristics for simulation were bundled as follows:

a) BAU Case: Business-as-usual (BAU) building envelope (wall, window and roof construction) and BAU HVAC and lighting systems

b) BAU+ Case: BAU wall and window construction, BAU HVAC and lighting systems, with ECBC compliant windows

c) ECBC Case: ECBC compliant envelope and systems.

The properties of BAU and ECBC compliant envelope for different climate zones and operation are listed in Table 10 and Table 11 respectively.

Table 10: Window Properties

TYPE	WWR	U-FACTOR	SHGC	VLT
BAU	20%	5.8	0.82	0.8
BAU	40%	5.8	0.82	0.8
BAU	60%	5.8	0.82	0.8
ECBC (CP, HD, WH)	20%	3.3	0.25	0.27
ECBC (CP, HD, WH)	40%	3.3	0.25	0.2
ECBC (CP, HD, WH)	60%	3.3	0.2	0.13
ECBC (Moderate)	20%	6.9	0.4	0.27
ECBC (Moderate)	40%	6.9	0.4	0.2
ECBC (Moderate)	60%	6.9	0.3	0.13
ECBC (Cold)	20%	3.3	0.51	0.27
ECBC (Cold)	40%	3.3	0.51	0.2
ECBC (Cold)	60%	3.3	0.51	0.13

Table 11: Envelope Properties

TYPE	DAYTIME SCHEDULE		24 HR SCHEDULE	
	MAX WALL U-VALUE	MAX ROOF U-VALUE	MAX WALL U-VALUE	MAX ROOF U-VALUE
BAU	1.99	2.98	1.99	2.98
ECBC (HD,WH,CP)	0.44	0.409	0.44	0.261
ECBC (Moderate)	0.44	0.409	0.44	0.409
ECBC (Cold)	0.352	0.409	0.369	0.261

Results:

Graphs plotted illustrate the energy savings achievable by use of ECBC compliant windows for different building type and floor sizes in all five climate zones of India.

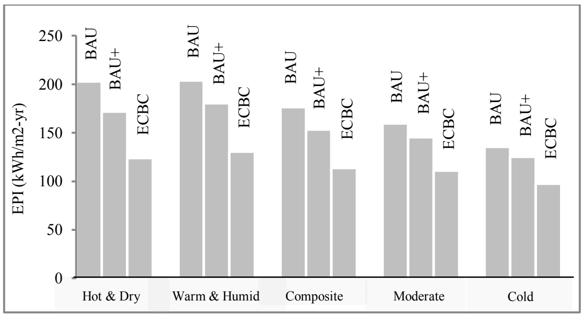

Figure 7: Annual Energy Performance Index (EPI) for three types of 4500 m2 Daytime use building with 40% WWR in all five climates.

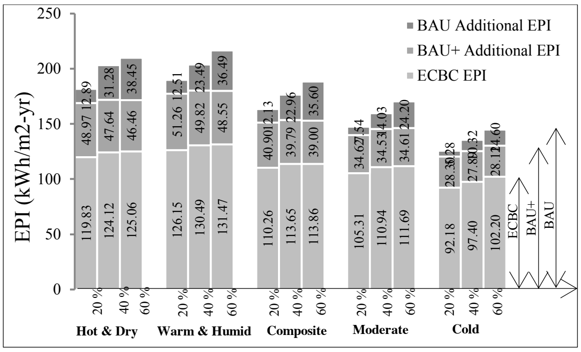

Figure 8: Incremental EPI for deviation from ECBC compliance for 4500 m2 daytime use building with three WWR in all five climates.

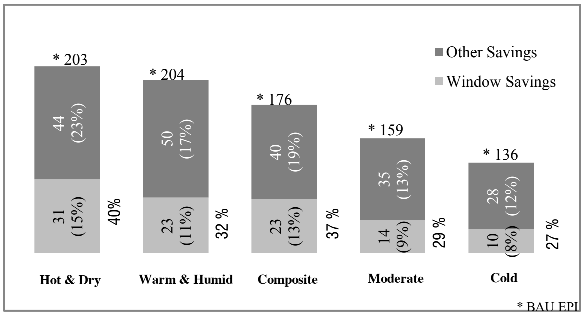

Figure 9: EPI savings due to windows and other ECBC measures for 4500 m2 daytime use building with 40% WWR in all five climates.

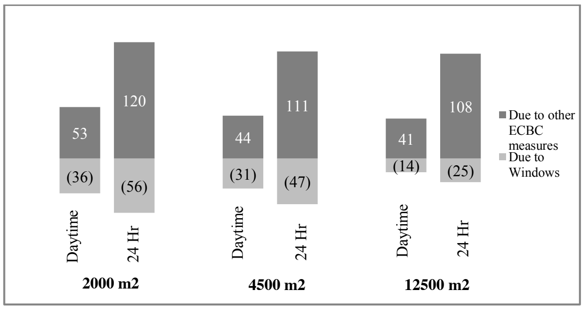

Figure 10: EPI savings due to windows and other ECBC measures for three building sizes and 2 schedules in Hot & Dry climate with 40 % WWR.

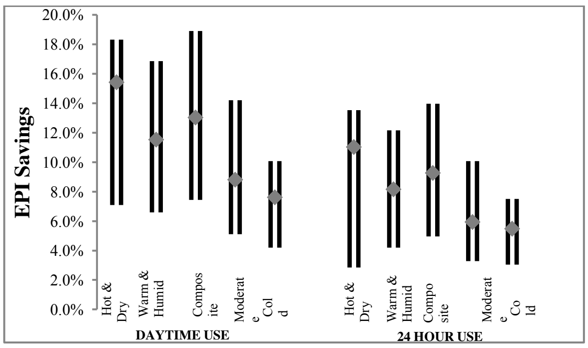

Figure 11: Range of EPI savings due to Window ECBC compliance for 4500 m2 daytime and 24 hr

use building in all five climates with varying WWR from 20% to 60%.

Payback and life cycle cost analysis

Simple payback calculation is a widely adopted method for making decisions regarding capital investments. Life Cycle Cost Analysis (LCCA) is an economic examination of alternative allocation of Capital resources that considers all significant costs of ownership over the economic life of the alternatives. This takes into account the costs of acquiring, operating, maintaining and ultimately disposing off the alternative. The formulae used for calculation are:

Simple Payback Period (years) = Initial Incremental Investment/ Annual Energy Cost Savings.

Life Cycle Cost (Rs) = I + Repl - Res + E + OM&R (Fuller 1995)

Where,
I = Present Value Investment Cost
Repl = Present Value Replacement Cost
Res = Present Value Residual Cost
E = Present Value Energy Cost
OM&R = Present value Operation, Maintenance and Repair Cost

Life cycle cost and payback analysis is conducted for the cases analyzed to understand the trade-offs between initial investment and energy savings during operation of buildings as well as the 'return on investment' scenarios.

Simple payback analysis was used to calculate the time period in which the ECBC compliant window would payback their incremental investment by saving the operational cost of the building in terms of electricity. Downsizing of HVAC equipment is not considered for simple payback calculations as it may not be possible to replace the equipment in line with the glazing retrofits in existing buildings. In new constructions, these may add up for added returns.

Inputs

LCC calculation requires Present-Value (PV) factors that take into account the rate of escalation, rate of interest. The study followed the NIST Handbook[1] for calculation of LCC and savings of the range 3% to 17% were observed for different types and size of buildings in various climates due to ECBC compliant windows. Study of LCC taking into account the actual discount rates and escalation in energy prices for Indian context has been incorporated as a future scope of the study.

The electricity cost considered is Rs 6.25 per kWh and the window costs have been listed in Table 12.

Table 12: Window Costs

FRAME	GLASS	U-FACTOR	SHGC	VLT	COST/M2
ALU	Clear Glass (6mm)	5.8	0.82	0.8	1250
ALU	Lowe+5.4mm air + Clear	3.3	0.25	0.27	2575
ALU	Coated+5.4mm air + Lowe	3.3	0.25	0.2	2575
ALU	Lowe+9mm air +Lowe	3.3	0.2	0.16/0.13	3250
ALU	Super Silver Blue Coated	6.9	0.4/0.3	0.27/0.2/0.16/0.13	1300
UPVC	Clear+12mm air +Clear	3.3	0.51	0.27/0.2/0.16/0.13	2250

Results

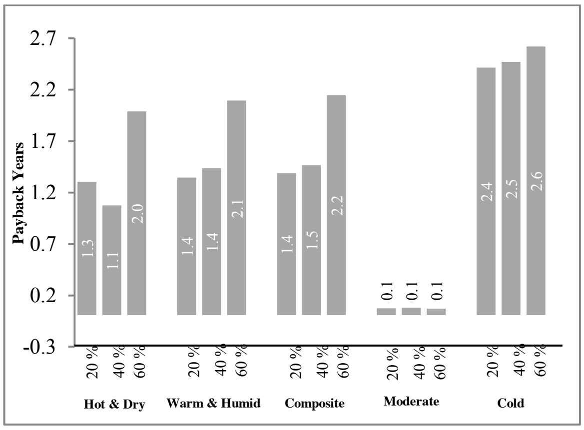

Figure 12: Payback period (years) of ECBC compliant windows for 4500 m2 daytime use building with three WWR and in five climates

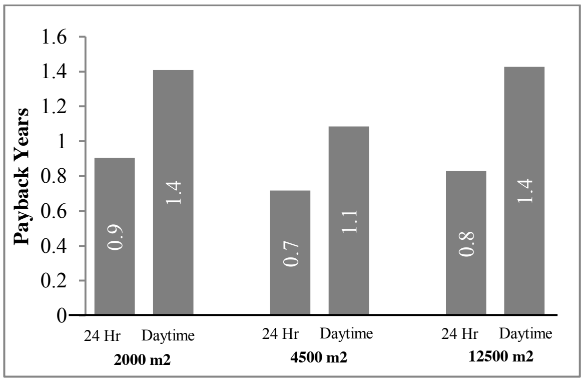

Figure 13: Payback period (years) of ECBC windows for three building sizes and two operation schedules with 40% WWR in Hot and Dry climate

CONCLUSION

The study first conducted extensive review of various window labelling programs throughout the world and identified key performance criteria used in the labelling programs as well as acceptable window testing standards. For the survey, The study found three key parameters used in window labelling programs were - U-value, SHGC, and VLT.

The study then conducted extensive survey of existing window installation practices in India and identified 180 glass and frame combination for the analysis. Thermal and visual performance of various glass combinations were tested using ISO 9050 standard. This extensive analysis indicated that various double pane window combinations meet the U-factor requirements but fail to meet SHGC and VLT requirements simultaneously. Further analysis also yielded that to meet all three parameters of ECBC, the window needs to have double pane and one of the glasses should be coated. Also a substantial difference in performance could be observed in U-value for windows with and without frames. The above results clearly indicate the necessity for considering window as a whole for compliance with a specific standard, rather than looking at the glazing in an isolated manner.

From the above analysis, study found that window frame type and operation type have significant important on of overall window performance. The analysis also suggests that window labelling performance criteria could be uniform for all climate zones except for moderate zone. However, for ease of implementation, it is recommended to have uniform window standard applicable for all windows and all climate zones.

The energy saving potential of ECBC compliant windows vary depending on the climate, building size and type, schedule. Foror a building with occupied area of 4500 m2, the energy savings fall in the range of 4% to 19% when daytime schedule was followed and 3% to 14% in case of 24 Hr schedule with WWR varying from 20% to 60% in both the cases. The payback period for ECBC compliant windows for all the cases came out to be less than 2 yearswhich provides a strong reason to the customers to move towards energy-efficient windows.

This study provides thorough analysis on existing window practices of India and their performance against ECBC requirements. The study also indicates that huge energy potential could be achieved through installation of energy-efficient windows in the buildings. There is a strong need for a window labelling program in the country that could encourage progressive manufacturers develop energy-efficient products and create market differentiation for their projdct while providing consumers opportunity to save energy costs by investing in energy-efficient window products.

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