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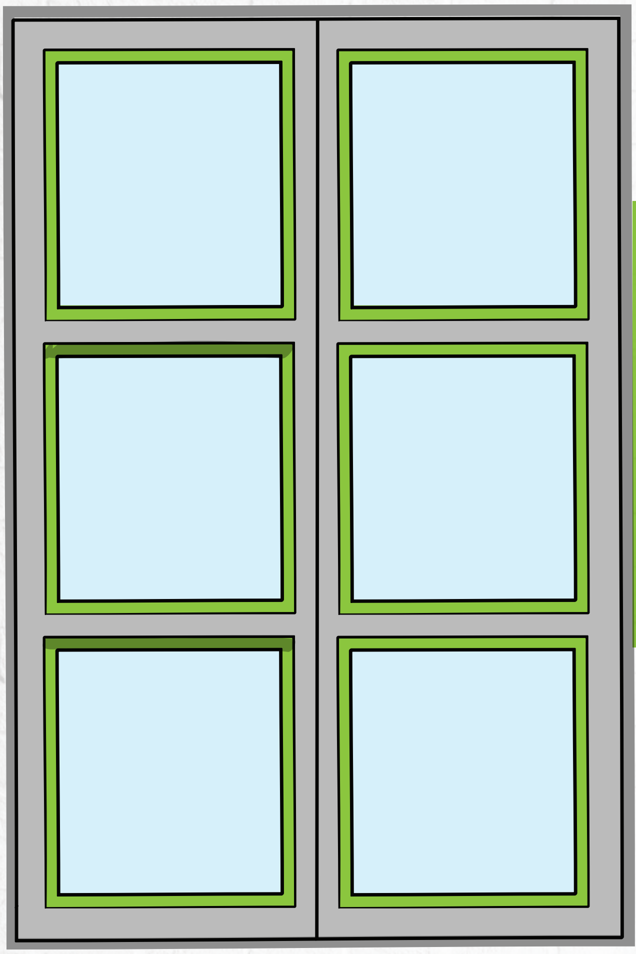

Projecting National Energy Saving Estimate from the Adoption of

High Performance Windows Glazing

in 2030

September 2018

Commissioned by:

Lawrence Berkeley National Laboratory
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Acknowledgement:
The authors would like to thank Dr. Nikit Abhyankar and Dr. Amol Phadke for their support and guidance through the course of this project. We are truly thankful for their active participation in strengthening this project.

We recognise the invaluable contributions of the various stakeholders and industry experts listed below.

For their expert inputs in the window labelling survey:
Mr. Arum Sharma, Aluplast India Pvt Ltd
Mr. Y P Singh, Fenesta Building Systems
Mr. A R Unnikrishnan, Saint Gobain India Pvt Ltd
Mr. Gohul Deepak, Glazing Society of India
Mr. Nitin Bhatia, Facet Façade Consultancy
Mr. Amit Khanna, AKDA
Mr. Avijit Paul, Roto Frank Asia Pacific

For helping us firm up our analysis by vetting some inputs and assumptions:
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Suggested citation:
Kumar, S., Sachar, S., Goenka, A., George, G., Singh, M., Kasamsetty, S., Rawal, R., Shukla, Y. (2018). Projecting National Energy Saving Estimate from the Adoption of High Performance Windows Glazing in 2030. New Delhi: Alliance for an Energy Efficient Economy.

Version: New-Delhi, September 2018

This project and report is prepared by Alliance for an Energy Efficient Economy and CEPT University for the Lawrence Berkeley National Laboratory.

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EXECUTIVE SUMMARY

Background

India's cooling energy needs are projected to grow significantly within the next decade, with far reaching environmental and societal impacts. The Government of India (GoI) has elevated addressing India's cooling challenge as a national priority and is actively engaged in developing a National Cooling Action Plan. A recent study by Alliance for an Energy Efficient Economy (AEEE) projects that just within the next decade, India's cooling energy demand will grow 2-3 times over the current level. Of this overall nationwide cooling demand, space cooling, i.e. comfort cooling in the building sector, comprises 50% of the total; this sector also shows the maximum improvement potential in terms of energy saving and carbon emission reduction. Space cooling thus represents a key opportunity area for proactively managing India's cooling energy demand.

With most of India's air-conditioner stock yet to come, now is the critical window of opportunity to build in interventions that will have a meaningful impact on the future energy consumption and emissions. These savings can be realized through a combination of interventions of which the building envelope is critical. Buildings can be intrinsically energy-efficient if they are well designed and adhere to building energy codes. Good building design can reduce heat gains, thereby reducing the cooling demand throughout the operational life of the building. In this regard, windows and particularly window glazing becomes an important area of exploration, to manage the heat gain and thus optimize the cooling needs of a building.

Heat gain in buildings is primarily due to conduction, convection and radiation through roofs, walls, windows and doors. Windows, glazing and shading are directly linked with these three modes of heat transfer and can form a key aspect of an efficient building design.

1.1. Project Scope and Objectives

The primary objective of the project is to estimate the potential of reducing cooling demand through the use of high performance glazing. The scope of this analysis is framed as follows:

- Since the objective is to estimate savings in cooling energy as a direct result of HP glazing, our analysis factors in only the actively air-conditioned built up area. While spaces cooled by other means, such as fans, will certainly experience enhanced thermal comfort due to HP glazing, there may not be a sizeable decrease in the respective energy used.
- The savings estimation primarily focuses on new construction, that is, yet to be built commercial stock between 2017 and 2030, since this stock represents true opportunity in terms of making glazing choices. Some portion of the existing buildings may opt for a retrofit and this is also factored into our analysis.
- Considering the non-standardized and arbitrary nature of windows in the residential sector in India, in terms of fenestration size, materials and quality, this study was limited to glazing in the commercial buildings.
- As this study is cooling-centric, the climate types considered are limited to hot and dry, warm and humid and composite.
- The estimation of nationwide energy savings presents the savings accrued from improvements in U-values and SHGC. Per our literature review, further savings can be gained using window shading.

- The energy savings calculations present savings for 1 year only i.e. 2030. Energy savings made over the life of the buildings will be much more.

Additional objectives of the project are to:

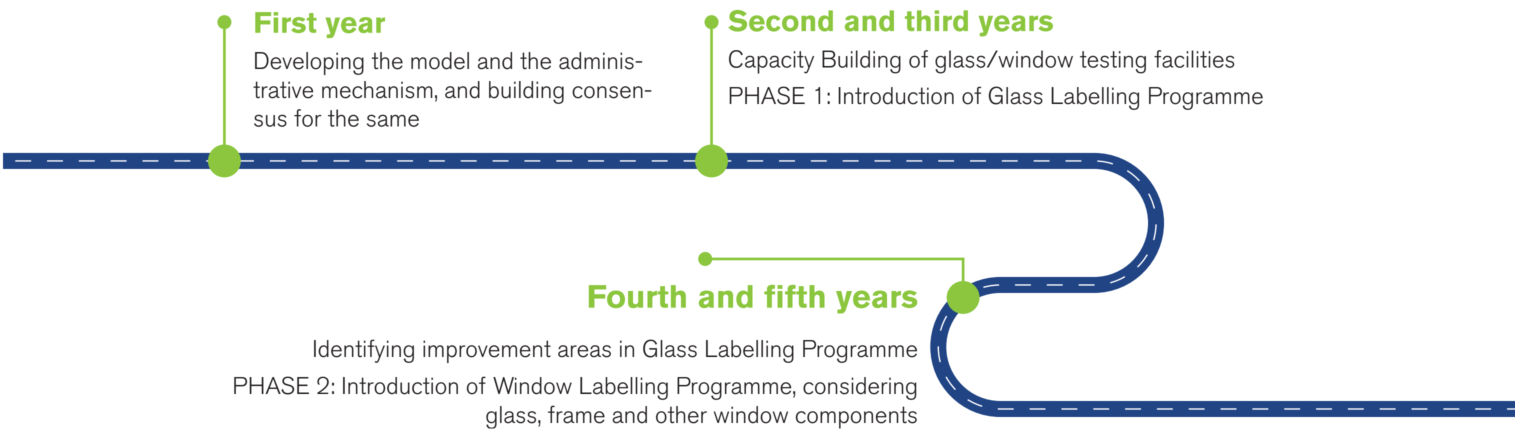
- Preliminary industry engagement to explore the feasibility and market-readiness for a mandatory window labelling program
- Evaluate the existing policy options for high performance glazing

The intended outcome of the project is two-fold:

- To project national energy savings in 2030 from the use of HP windows glazing in the upcoming and retrofitted commercial building stock
- Based on the research outcomes and the evaluation of the existing policy framework, recommend policy options and market transformation strategies, including a high-level roadmap to develop a window labelling programme, that would help achieve the energy savings potential from the adoption of HP windows glazing

Key Project Components

- **Literature review:** As a first step, an exhaustive literature review was carried out to bring together innovations in HP windows glazing technologies and their benefits, reported savings from demonstration projects, independent initiatives from the private sector and other independent studies pertaining to the Indian or similar climates. The literature review was used to obtain a sense of the magnitude of energy savings possible using energy-efficient windows and corroborate our own nation-wide estimation.
- **New Simulations:** New simulations were run at different values of the window properties that determine the energy performance of windows (U-values, Solar Heat Gain Coefficient (SHGC) and Window to Wall Ratio (WWR)) to estimate the impact of HP windows glazing on the Energy Performance Index (EPI) of a typical commercial building. The window properties were decided whilst keeping in mind the specifications of Energy Conservation Building Code (ECBC-2017).
- **Savings Estimate:** The 2030 commercial built up area (BUA), eligible for savings from HP windows glazing was projected and broken by building end-use and by climate-zone. Typical EPIs were then used to form the baseline energy consumption. New simulation results were used to estimate the absolute energy savings and savings potential in 2030, both by commercial building end-use and by climate.
- **Stakeholder Interaction:** The second component of the project was to explore the feasibility of a windows labelling programme in India. A survey was designed and implemented to understand the barriers and potential solutions to a window labelling programme in India from a whole-industry perspective. A brief questionnaire was shared with important industry stakeholders (window and glass manufacturers, architects and green consultants, industry association and testing facilities) followed by one-on-one consultations. Inputs were gathered on (1) Need and appetite for a window labelling programme in India (2) Willingness and readiness of sub-industries for a window labelling programme (3) Glazing labelling programme as a precursor to the window labelling programme (4) Top barriers to a window labelling programme in India (5) High-level road map (below).



- **Future Recommendations:** A final component of the project involved evaluating the current policy framework and building guidelines to gauge the place of HP windows and glazing as an acknowledged strategy for reducing energy consumption in buildings – emphasis was put on government building codes and other building guidelines. The project proposes a set of future recommendations that address existing policy gaps and are designed with the view of promoting a greater adoption of energy-efficient windows in the upcoming commercial building stock, including a high-level roadmap to develop a window labelling programme in India.

Nationwide Energy Savings Potential from the Adoption of High Performance Windows Glazing in 2030

The national level energy savings potential from HP windows glazing in commercial buildings is shown below.

Commercial Building Type	Total Energy Saving (GWh)			
	Warm and humid	Composite	Hot and dry	Total
Hospital	288	313	177	778
Hotel	142	150	81	373
Retail	330	360	204	893
Office	412	448	255	1115
Institute	112	122	69	302
Assembly Place	31	35	20	86
Transit	15	17	10	42
Total energy savings (GWh)	**1330**	**1444**	**814**	**3589**
Baseline energy consumption (GWh)	**19346**	**16987**	**10853**	**47185**
Saving potential	**7%**	**9%**	**8%**	**8%**

The key findings are:

- **A total of approximately 3.6 TWh (out of 47.2 TWh) of energy savings is possible from HP windows glazing in 2030 alone.** Energy savings over the lifetime of buildings will be much more. This energy saving will manifest in the energy consumed towards air-conditioning due to reduced heat gains from HP glazing.
- **In 2030, the energy savings potential from the use of HP windows glazing will be around 8% with respect to the total eligible commercial BUA** (i.e., air-conditioned BUA that stands to benefit from HP windows glazing); and **around 3% with respect to the total commercial BUA** (i.e., conditioned and non-conditioned).
- Our analysis shows that HP windows bring the most savings benefit in composite type climate.
- Our analysis indicates Office buildings and Retail sectors show maximum energy savings potential. These two sectors also have the greatest eligible BUA. The Education sector which has almost as large a BUA footprint as Retail shows a much lower savings potential relatively; this is due to the typically low wall-windows ratio and surface area of glazing in this sector.

Future Recommendations

Based on our learnings from the secondary literature and our surveys, and our review of the existing policy framework and the gaps therein with respect to HP Windows, we see three core strategies that can promote the adoption of energy efficient windows and glazing and help manifest the nationwide savings potential. Our recommendations grouped within these strategies are as follows:

Core Strategies	Specific Recommendations
Leveraging on-going government initiatives	• Government policies related to Smart Cities should advocate the inclusion of HP windows and glazing. • Make ECBC implementation mandatory in all states. Provide governance to ensure strict compliance with all mandatory codes.
Towards a windows energy labelling programme	• Facilitate R&D for HP windows and glazing. • Develop protocols for EE ratings for whole window systems; develop an S&L programme for windows. • Commission testing labs and enforce performance testing and certification of energy efficient windows. • Undertake capacity building, training and awareness exercises. • Create a robust knowledge-sharing and collaborative platform to bring together stakeholders across the window manufacturing and installation supply-chain from both the organised and unorganised sectors.
Consumer awareness and market transformation	• Establish policy to create state-level financial facilities for low-cost/preferential line of credit to real estate projects with a demonstrably energy efficient windows and glazing. • Introduce sustainable rating of architects/architecture firms based on a suitable building performance or energy efficiency quotient. • Create consumer awareness through campaigns, demonstration projects and infomercials.

Endnote: Areas for Further Investigation

- New simulations carried out for this project were limited to a typical office plate – these simulations were used to inform the % savings in EPI from the use of HP windows. It would be useful to carry out further simulations, modelling other types of commercial buildings to get a fuller sense of the role of energy efficient windows glazing.
- The study should be extended to residential sector, considering its footprint and the significance of the various growth drivers.

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1 INTRODUCTION

1.1. Background

India's cooling energy needs are projected to grow significantly within the next decade, with far reaching environmental and societal impacts. The Government of India (GoI) has elevated addressing India's cooling challenge as a national priority and is actively engaged in developing a National Cooling Action Plan. A recent study by Alliance for an Energy Efficient Economy (AEEE) projects that just within the next decade, India's cooling energy demand will grow 2-3 times over the current level. Of this overall nationwide cooling demand, space cooling, i.e. comfort cooling in the building sector, comprises 50% of the total; this sector also shows the maximum improvement potential in terms of energy saving and carbon emission reduction. Space cooling thus represents a key opportunity area for proactively managing India's cooling energy demand.

With most of India's air-conditioner stock yet to come, now is the critical window of opportunity to build in interventions that will have a meaningful impact on the future energy consumption and emissions. These savings can be realized through a combination of interventions of which the building envelope is critical. Buildings can be intrinsically energy-thrifty if they are well designed and adhere to building energy codes. Good building design can reduce heat gains, thereby reducing the cooling demand throughout the operational life of the building. In this regard, windows and particularly window glazing becomes an important area of exploration, to manage the heat gain and thus optimize the cooling needs of a building.

Heat gain in buildings is primarily due to conduction, convection and radiation through roofs, walls, windows and doors. Windows, glazing and shading are directly linked with these three modes of heat transfer and can form a key aspect of designing buildings.

1.2. Literature Review

In India, 80% of the total heat flow into buildings is by direct solar radiation on window glazing[1] . Energy-efficient windows can significantly cut down cooling energy consumption by intercepting solar insolation and reducing air leakages. Double and triple glazing windows equipped with special coatings ensure lower heat ingress. New technologies allow sandwiching of air or neutral gases between the glazing surfaces to cut down heat transfer through conduction. Shading devices, in addition to high performance (HP) glazing, can further minimise cooling requirements. Glazed areas that are fully shaded by an overhang from the outside reduce solar heat gain by as much as 80%[2] .

Singh & Garg (2009) carried out a detailed study in the Indian context to evaluate various glazing performances[3] . Cooling energy savings up to 25% were achievable by deploying solar controlled double glazing reflective film coatings in hot and dry, composite and warm and humid climates for all orientations except for North which showed savings of around 17%. NREL (2000) in their study on the effects of HP glazing on residential energy use in hot and dry climate, indicated savings of up to 11%[4] . Wipro Infotech located in the temperate climate of Bengaluru could avail total energy savings of 28% by installing double glazed windows with low U-value and SHGC.

Dutta & Samanta (2018)[5] carried out a study to investigate the cooling load reduction in tropical climates by means of HP glazing. They employed five leading window glazing units comprising both single and double-glazed units to quantify the decrease in energy consumption. Nano (double-glazing) which has a U value of 1.8 W/m2K and SHGC of 0.2 resulted in maximum reduction in energy consumption of up to 6.4%. Application of switchable glazing (dynamic glazing) could help reduce annual cooling electricity consumption by up to 6.6%[6] .

The most effective way to reduce the solar load on fenestration is to intercept direct radiation from the sun before it reaches the glass[7]. There are various methods to shade windows – overhangs, awnings, louvres, vertical fins, light shelves and natural vegetation. These can reduce cooling energy consumption by 10-20%[8]. NREL (2000) in their study, gauged the potential of effective shading strategies on cooling load reduction. The results showed reductions in cooling energy consumption of up to 22%.

Wong et al (2007) studied the impact of increasing the depth of shading devices on cooling loads in hot and humid climates. An effective depth of 30, 60 and 90 cm could result in savings of 2.62-3.24%, 5.85-7.06% and 8.27-10.13% respectively[9]. Yu et al (2008) in their study estimated savings of 11.3% by incorporating envelope shading[10]. Lau et al (2016) evaluated the saving potential in a typical high-rise office building by application of shading strategies and double-glazing windows for all facades. Egg-crate shading devices offer more cooling energy savings compared to horizontal and vertical shading features in the range of 5% - 9.9%[11].

Energy Conservation Building Code (ECBC) [2017][12] laid out compliance requirements for vertical fenestrations in terms of Solar Heat Gain Coefficient (SHGC) and U-factor as summarized in Table 1. The maximum allowable Window Wall Ratio (WWR) is 40%.

Table 1 : Vertical fenestration assembly U-value and SHGC requirements for ECBC, ECBC+ and SuperECBC buildings

	Composite	Hot and dry	Warm and Humid	Temperate	Cold
	The values listed are in the following sequence ECBC/ECBC+/SuperECBC				
Maximum U-value (W/m2.K)	3/2.2/2.2	3/2.2/2.2	3/2.2/2.2	3/3/3	3/1.8/1.8
Maximum SHGC Non-North	0.27/0.25/0.25	0.27/0.25/0.25	0.27/0.25/0.25	0.27/0.25/0.25	0.62/0.62/0.62
Maximum SHGC North for latitude ≥ 15°N	0.5/0.5/0.5	0.5/0.5/0.5	0.5/0.5/0.5	0.5/0.5/0.5	0.62/0.62/0.62
Maximum SHGC North for latitude < 15°N	0.27/0.25/0.25	0.27/0.25/0.25	0.27/0.25/0.25	0.27/0.25/0.25	0.62/0.62/0.62

2 APPROACH AND METHODOLOGY

2.1. Project Objective

With the projected exponential growth in the Indian AC market, there is a lot of speculation on the GHG and load impacts, and the possible mitigation strategies. However, wide variation in some of the key assumptions and parameters being used to estimate these numbers may cause uncertainty for policy makers. Additionally, there are unknowns such as, how might the national demand for cooling energy be impacted using specific space cooling strategies. This project strives to uncover the impact of one such strategy: HP windows glazing. Through a deep-dive research, under the guidance of LBNL, and in collaboration with CEPT University, the primary objective of this project is to:

- Evaluate the impact of HP windows glazing on the energy consumption of the upcoming and retrofitted commercial building stock in 2030

2.2. Framing the Project Scope

The primary objective of the project is to estimate the potential of reducing cooling demand through the use of high performance glazing.

The project includes additional related components that are:

- Preliminary industry engagement to explore the feasibility and market-readiness for a mandatory windows labelling program
- Evaluate the existing policy options for high performance glazing

The project scope is framed as per the following parameters:

- Since the objective is to estimate savings in cooling energy as a direct result of HP glazing, our analysis factors in only the actively air-conditioned built up area. While spaces cooled by other means, such as fans, will certainly experience enhanced thermal comfort due to HP glazing, there may not be a sizeable decrease in the respective energy used.
- The savings estimation primarily focuses on new construction, that is, yet to be built commercial stock between 2017 and 2030, since this stock represents true opportunity in terms of making glazing choices. Some portion of the existing buildings may opt for a retrofit and this is also factored into our analysis.
- Considering the non-standardized and arbitrary nature of windows in the residential sector in India, in terms of fenestration size, materials and quality, this study is limited to glazing in the commercial buildings.

The intended outcome of the project is two-fold:

- To project national energy savings in 2030 from the use of HP windows glazing in the upcoming and retrofitted commercial building stock
- Based on the research outcomes and the evaluation of the existing policy framework, recommend policy options and market transformation strategies, including a high-level roadmap to develop a window labelling programme, that would help achieve the energy savings potential from the adoption of HP windows glazing

2.3. Overarching Methodology

As a first step, an exhaustive literature review was carried out to bring together innovations in HP windows glazing technologies and their benefits, reported savings from demonstration projects, independent initiatives from the private sector and other independent studies pertaining to the Indian or similar climates. The literature review was used to obtain a sense of the magnitude of energy savings possible using energy-efficient windows and corroborate our own nation-wide estimation.

New simulations were run at different values of the window properties that determine the energy performance of windows (U-values, Solar Heat Gain Coefficient (SHGC) and Window to Wall Ratio (WWR)) to estimate the impact of HP windows glazing on the Energy Performance Index (EPI) of a typical commercial building. The window properties were decided whilst keeping in mind the specifications of Energy Conservation Building Code (ECBC- 2017).

The 2030 commercial built up area (BUA), eligible for savings from HP windows glazing was projected and broken by building end-use and by climate-zone. Typical EPIs were then used to form the baseline energy consumption. New simulation results were used to estimate the absolute energy savings and savings potential in 2030, both by commercial building end-use and by climate.

The second component of the project was to explore the feasibility of a windows labelling programme in India. A survey was designed and implemented to understand the barriers and potential solutions to a window labelling programme in India from a whole-industry perspective. A brief questionnaire was shared with important industry stakeholders (window and glass manufacturers, architects and green consultants, industry association and testing facilities) followed by one-on-one consultations. Inputs were gathered on

1. Need and appetite for a window labelling programme in India
2. Willingness and readiness of sub-industries for a window labelling programme
3. Glazing labelling programme as a precursor to the window labelling programme
4. Top barriers to a window labelling programme in India
5. High-level road map.

A final component of the project involved evaluating the current policy framework and building guidelines to gauge the place of HP windows glazing as an acknowledged strategy for reducing energy consumption in buildings – emphasis was put on government building codes and other building guidelines. The project proposes a set of future recommendations that address existing policy gaps and are designed mainly with the view of promoting a greater adoption of energy-efficient windows in the upcoming commercial building stock, including a high-level roadmap to develop a window labelling programme in India.

3 ESTIMATION OF NATIONAL ENERGY SAVINGS FROM HIGH PERFORMANCE GLAZING

3.1. Scope

As aforementioned, this analysis is limited to the study of high performance glazing in: commercial buildings, focusing on actively air-conditioned built up area, in predominantly yet to be built commercial stock between 2017 and 2030, since this stock represents true opportunity in terms of making glazing choices. Some portion of the existing buildings may opt for a retrofit and this is also factored into our analysis. Other parameters that define the boundaries of the analysis are:

- As this study is cooling-centric, the climate types considered are limited to hot and dry, warm and humid and composite.
- The estimated savings present the savings accrued from improvements in U-values and SHGC. Per our literature review, further savings can be gained using window shading.
- The energy savings calculations present savings for 1 year only i.e. 2030. Energy savings made over the life of the buildings will be much more.

3.2. Simulation Model Description and Key Results

A typical daytime office, cooled by a VRF system, was simulated (Figure 1) on EnergyPlus. The volume of VRFs in India is increasing significantly at 15% CAGR[13] in commercial buildings. The installed capacity of VRF systems is expected to outnumber the centralised air conditioning system by 2030[14]. The key assumptions and input parameters (fixed and variable) have been listed in Tables 2A and 2B.

Figure 1: Zoning of simulation model

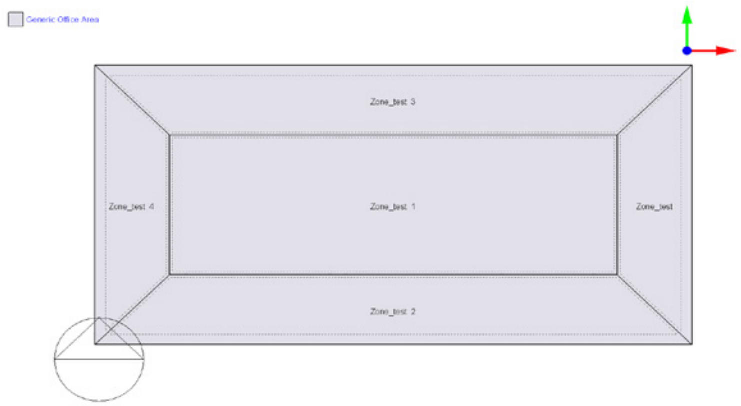


Table 2A: Simulation – non-variable and design parameters

Parameters	Input Values	Notes
Building geometry	Length: 16m, Width: 8m, Height: 3.5m	
	Fenestration	Equal windows on all 4 walls – therefore, the simulation results are independent of direction
	Envelope	ECBC 2017 compliant
Building operation	Operation type: Office (10 hours/day, 250 days/year)	Typical daytime office
Zoning	5 zones (4 perimeter and 1 core zone)	
Wall U-value (W/m².K)	0.4	ECBC 2017 compliant
Shading	None	The estimated savings will be accrued from improvements in U-values and SHGC. Per our literature review, further savings can be gained by the use of window shading.
Cooling system	VRF (COP = 3.5)	Per ECBC 2017, minimum COP value for VRF systems is 3.28; a 5% improvement in efficiency in 2030 is considered with technological advancements and better O&M practices
Heating	Off	
Lighting power density (W/m²)	9.50	ECBC 2017 compliant
Lighting control	None	
Equipment power density (W/m²)	7.5	BAU (Assumption)
Occupancy (m²/person)	7.5	
Diversity Factor	0.7	
Natural Ventilation	None	

Table 2B: Simulation - variable parameters

Parameters	Input Values	Notes
Climate type	Hot and dry	As this study is cooling-centric, temperate and cold climates are not considered
	Composite	
	Warm and humid	
Window SHGC Value	0.39	Non-ECBC 2017 compliant
	0.27	ECBC 2017 compliant
	0.25	ECBC+/SuperECBC compliant
Window U Value (W/m²K)	4	Non-ECBC 2017 compliant
	3	ECBC 2017 compliant
	2	ECBC+/SuperECBC compliant
WWR	60%	These were chosen to represent typical WWRs in different commercial building types (the WWR for a large private office building would be different from that for a government hospital).
	40%	
	20%	

The simulation outputs provided the best and worst EPIs in different climate types at a WWR -the full set of simulation results can be viewed in Appendix. Utilizing these EPIs, we derived the savings potential for different climate zones at specific WWRs. These are summarized below in Table 3.

Table 3: Simulation – saving potentials in EPI

WWR	Warm and humid	Composite	Hot and dry
20%	5%	6%	5%
40%	8%	10%	9%
60%	11%	13%	11%

3.3. 2030 Commercial Built Up Area (BUA) Eligible for Energy Savings

Upcoming stock: This study considers the following building end-uses in the 2030 commercial building stock in India that will be eligible for energy savings from HP windows glazing: hospitals, hotels, office buildings, educational buildings, retail, assembly places and transit junctions. AEEE (2017)[15] estimated the total built up area in India in 2017 at ~1.1 billion m^2 and the segment-wise projected growth rates. The rapid growth in service sectors (IT and ITES), telecom and e-commerce will result in increased demand for office spaces, which will be the key driver for the growth in the commercial building sector. The hotel industry will continue to grow because of the growing economy, increased business travels and tourism. The Central and State Governments are also focused on infrastructure development in the coming decade. The energy intensity of the upcoming commercial building stock is likely to increase with increasing penetration of air-conditioning in offices, multi - speciality hospitals, luxury hotels and retail malls.

Retrofitted stock: It is assumed that with greater awareness of the benefits of HP windows coupled with a growing penetration of air-conditioning and the associated increase in energy bills, some portion of the existing building stock will opt for window-glazing retrofits to reduce the heat gain. For the purpose of this study, we assume that approximately 20% of the existing air-conditioned commercial building stock will be retrofitted by 2030.

The total eligible BUA: The 2030 commercial BUA in India that will be eligible for energy savings from HP windows glazing is presented in Table 4. This area is derived as follows:

- **Upcoming BUA:** This is the air-conditioned portion of the total commercial BUA that will be constructed between now and 2030 and can benefit from HP glazing. The assumptions for the percentages of air-conditioned BUA for different building end-uses have been vetted by building
- industry experts. More detailed information on deriving this area is presented in Appendix 2 (Table 12).
- Retrofitted BUA: This is the portion of the existing commercial BUA which is or will be air-conditioned by 2030, and will undergo a retrofit in order to benefit from HP glazing.
- Total Eligible BUA = Upcoming BUA + Retrofitted BUA. For the purpose of our study, this area represents **the portion of the air-conditioned BUA in 2030 that stands to benefit from HP glazing.** This area then represents the baseline BUA and the corresponding baseline energy use for cooling.

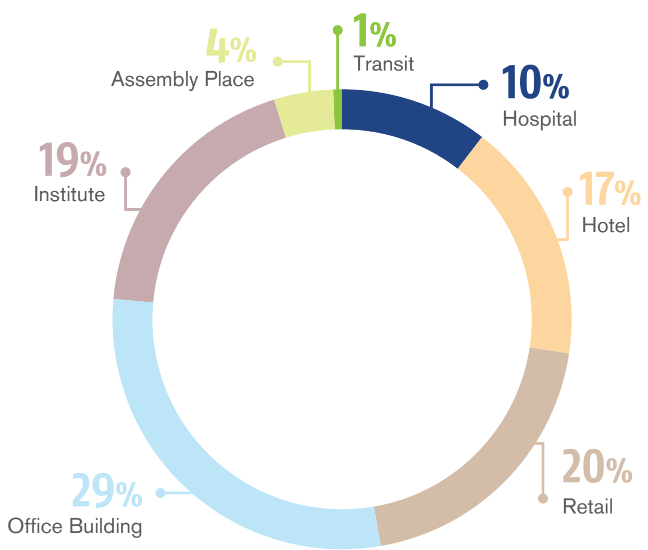
Also, listed in Table 4 are typical EPIs for each of the commercial building segments – these have been adapted from AEEE (2017). These should be considered as an indicative only, as they largely depend on operating hours, energy efficiency measures, sample sizes and climatic zones.

Table 4: 2030 commercial BUA eligible for energy savings from HP windows glazing and associated baseline EPIs

Commercial building type	Commercial building segment	Upcoming BUA (million m^2)	Retrofitted BUA (million m^2)	Total eligible BUA (million m^2)	Baseline EPI (kWh/m^2/year)
Hospital	Government urban hospital	17.13	1.96	19.08	165
	Government rural hospital	1.38	0.03	1.41	55
	Private (multi-speciality) hospital	27.92	2.81	30.73	220

Commercial building type	Commercial building segment	Upcoming BUA (million m²)	Retrofitted BUA (million m²)	Total eligible BUA (million m²)	Baseline EPI (kWh/m²/year)
Hotel	1-star	0.13	0.04	0.17	55
	2-star	0.31	0.09	0.40	110
	3-star	0.56	0.18	0.74	140
	4-star	0.57	0.27	0.84	165
	5-star	1.27	0.59	1.86	195
	Other	0.22	0.01	0.23	85
	Heritage	0.11	0.04	0.16	220
	Restaurant	71.16	7.60	78.76	75
Retail	Mall/modern store	23.30	5.69	28.99	275
	Small retail shop	43.01	1.64	44.65	40
	Medium retail shop	21.30	2.89	24.19	65
Office	IT/ITES	67.07	9.65	76.72	110
	Banking, Service, Finance and Insurance (BSFI)	19.39	2.78	22.17	85
	Central government	6.47	1.25	7.71	100
	State government	16.73	3.27	20.00	75
	Quasi government	11.73	2.27	14.01	86
	Local body	1.92	0.35	2.27	35
Institute	School	29.55	3.05	32.59	40
	Institute of national importance	0.96	0.14	1.09	55
	College	52.03	2.25	54.29	44
	Standalone institution	3.93	0.34	4.26	35
Assembly Place	Super large place of worship	0.80	0.25	1.05	88
	Large place of worship	8.30	0.64	8.94	44
	Other	8.87	1.66	10.54	45
Transit	Airport	0.70	0.68	1.37	300
	Bus stand	0.48	0.02	0.49	80
	Railway Station	1.07	0.05	1.12	50
Total		438.36	52.49	490.85	

Figure 2: Building-type distribution of total eligible BUA



Total eligible BUA = 491 million sqm

Table 5: Eligible BUA in context of total BUA

	Total (i.e. conditioned and non-conditioned) BUA (million m²)	Eligible (air-conditioned area that stands to benefit from HP glazing) BUA (million m²)	% Eligible
2017 commercial BUA	1109	266	24%
2030 commercial BUA	1499	704	47%

3.4. Distribution of BUA by Climate

Per National Building Code (2005), India is divided into five climate zones i.e. hot and dry, warm and humid, composite, temperate and cold (Figure 3). The temperature and relative humidity (RH) characteristics of these five climates are captured in Table 6. As this study is cooling-centric, the climate types considered were limited to hot and dry, warm and humid and composite, as listed in Table 7, which essentially cover a significant portion of the country's footprint as highlighted in Figure 3.

Figure 3: Climate zone map of India. Source: Bureau of Indian Standards 2005.

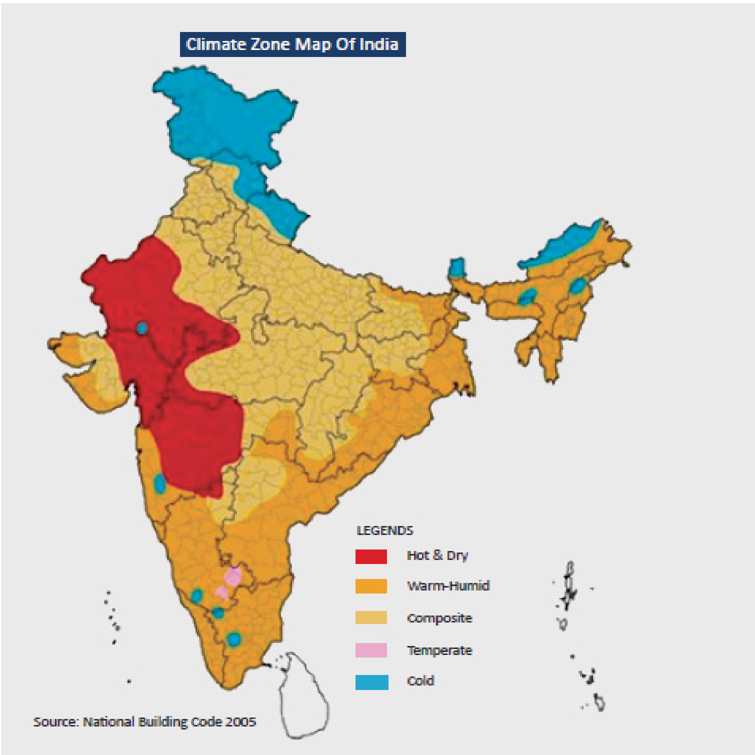


Table 6: Temperature and RH characteristics of India's climate types

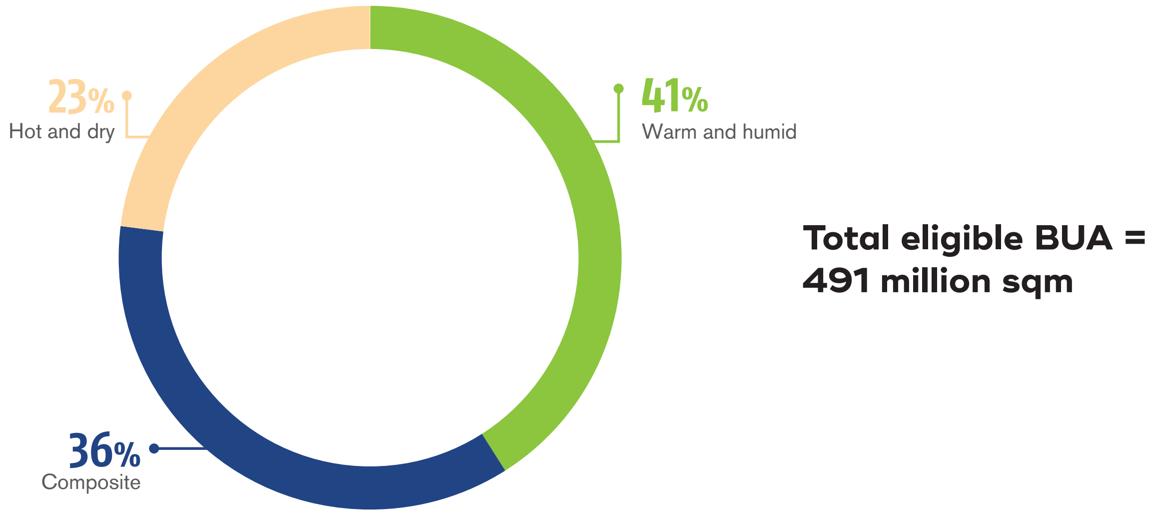
Climate type	Summer time temperature	Winter time temperature	RH
Hot and dry	20°C -45ºC	0°C -25ºC	55%
Warm and humid	25°C –35ºC	20°C –30ºC.	70-90%
Composite	27°C -43ºC	4°C -25ºC	20-25% (Dry) 55-95% (Wet)
Temperate	17°C -34ºC	16°C -33ºC	<75%
Cold	17°C –30ºC	-3ºC to 8ºC	70-80%

Table 7: Distribution of Indian States by climate

Climate type	State (or UT)
Hot and dry	Gujarat, Maharashtra, Rajasthan
Warm and humid	Andhra Pradesh, Telangana, Assam, Goa, Karnataka, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Tamil Nadu, Tripura, West Bengal
Composite	Bihar, Chhattisgarh, Haryana, Jharkhand, Madhya Pradesh, Punjab, Uttar Pradesh, Chandigarh, Delhi

Using the state-wise 2026-27 projections of commercial electricity consumption projected by Central Electricity Authority (2017)[16] we proportionately distributed the 2030 commercial BUA (presented in Table 4), in order to group the BUA into the three climate zones (Figure 4).

Figure 4: Climate-wise distribution of total eligible BUA



3.5. Methodology

- The simulations were used to obtain savings potential in EPI by climate type at 3 typical WWRs.
- The total BUA eligible for energy savings from the use of HP windows glazing was estimated and categorised by building end-use and by climate type.
- Typical EPIs (listed in Table 4) were used to construct the baseline energy consumption. In this context, 'baseline' means 'without the use of HP windows glazing'. 'Baseline' should not be confused with 'business-as-usual': ECBC 2017, which prescribes HP windows glazing, has already been notified in several States, whilst others follow, and the next decade is likely to see the construction of several new ECBC 2017 compliant buildings with HP windows glazing.
- Each commercial building segment was then assigned the WWR most widely used in them, based on industry inputs (detailed out in the Appendix).
- Now, each commercial building segment was assigned a climate type and a WWR value – this climate-WWR combination, the baseline energy consumption and the EPI savings potential were used to estimate the absolute energy savings.

3.6. Results and Discussion

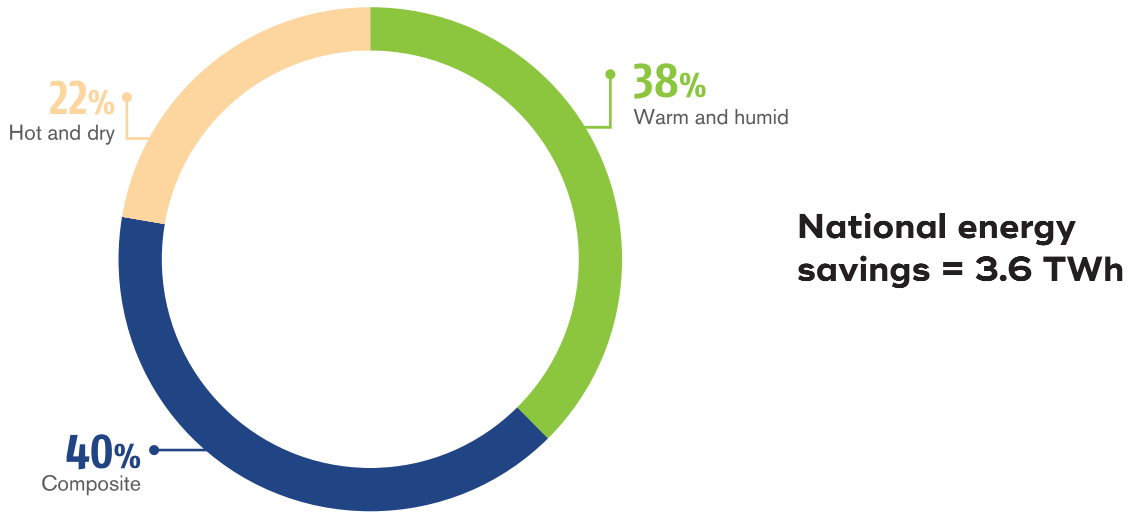
The national level energy savings potential from HP windows glazing in commercial buildings are presented in Table 8. The energy savings potential presented in below is purely a technical potential in new and retrofitted buildings that puts in perspective the energy-related benefits of HP windows glazing vis-à-vis low performance windows glazing.

Table 8: Summary of results

Commercial Building Type	Total Energy Saving (GWh)			
	Warm and humid	Composite	Hot and dry	Total
Hospital	288	313	177	778
Hotel	142	150	81	373
Retail	330	360	204	893
Office	412	448	255	1115
Institute	112	122	69	302
Assembly Place	31	35	20	86
Transit	15	17	10	42
Total energy savings (GWh)	**1330**	**1444**	**814**	**3589**
Baseline energy consumption (GWh)	**19346**	**16987**	**10853**	**47185**
Saving potential	**7%**	**9%**	**8%**	**8%**

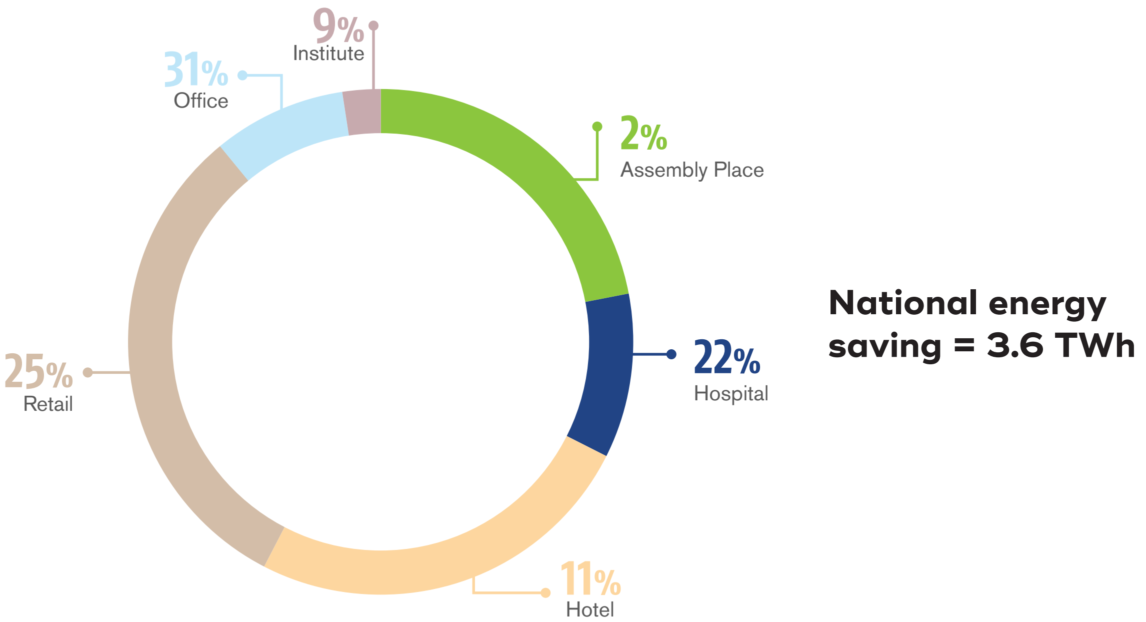
- A total of approximately 3.6 TWh (out of 47.2 TWh) of energy savings is possible from HP windows glazing in 2030 alone. Energy savings over the lifetime of buildings will be much more. This energy saving will manifest in the energy consumed towards air-conditioning due to reduced heat gains from HP glazing.
- In 2030, the energy savings potential from the use of HP windows glazing will be around 8% w.r.t the total eligible (air-conditioned BUA that stands to benefit from HP windows glazing) commercial BUA and 3% w.r.t the total (conditioned and non-conditioned) commercial BUA.
- Our analysis shows that HP windows will be most effective in composite type climate (compare Figures 4 and 5).

Figure 5: National energy savings by climate type



- Our analysis indicates Office buildings and Retail sectors show maximum energy savings potential (Figures 6). These two sectors also have the greatest eligible BUA (refer Figure 6). The Education sector which has almost as large a BUA footprint as Retail shows a much lower savings potential relatively; this is due to the typically low wall-windows ratio and surface area of glazing in this sector.

Figure 6: National energy savings by commercial building type



3.7. A High-level Estimate of the Incremental Cost of HP Windows Glazing

Per glazing manufacturers' inputs, ECBC non-compliant glazing are typically single-glazed units and can cost anywhere between 400 and 1500 INR/m^2, depending on the quality of the glass, the level of glass processing and the application of coatings and tints. However, the specifications of ECBC non-compliant glazing used in this study (i.e. U Value = 4 W/m^2K and SHGC = 0.39) would push the price point towards the higher end of this range. ECBC compliant glazing are typically heat insulating double-glazed units and cost around 2600 INR/m^2 i.e. they are less than twice as expensive as low performance glass. Also, glazing typically accounts for 15-20% of the total cost of the building cladding for a commercial building of 20-40% WWR. Using these estimations and inputs from the simulation model, it is estimated that the construction cost of a typical commercial building with HP (or ECBC compliant) windows glazing would be 10-15% higher than the construction cost with ECBC non-compliant glazing.

4 STAKEHOLDER INTERACTION ON WINDOW ENERGY LABELLING PROGRAMME IN INDIA

4.1. Background

India has been successful in implementing mandatory S&L programmes for appliances like room air conditioners and refrigerators. Countries like the US, Australia, UK, China, South Africa and Ireland have already successfully implemented a window labelling program. With a significant growth in the real estate sector on the horizon, it is important to understand the challenges in rolling out a window labelling programme for India and potential solutions. Window labelling can help developers and end users choose the right windows for minimising the ingress of heat into buildings, thereby reducing the cooling energy consumption needed for maintaining satisfactory levels of indoor thermal comfort.

4.2. Objective and Approach

The objective of this survey is to understand the barriers and potential solutions to a window labelling programme in India from a whole-industry perspective.

A brief questionnaire (see Appendix 7.3) was shared with important industry stakeholders (window and glass manufacturers, architects and green consultants, industry associations and testing facilities) followed by one-on-one consultations. Inputs were gathered from several other industry experts at the 'World of Fenestration 2018' held in New Delhi in February 2018.

4.3. Key Findings

1. Need and appetite for a window labelling programme in India

Majority stakeholders view window labelling as a necessity in India. Windows are being increasingly manufactured in factories and sent to building construction sites as opposed to fabrication in-situ in the past. This can ease the enactment and implementation of a window labelling mechanism. Beyond energy-related benefits, programmes like these can lend credibility to manufacturers, increase their business and add value to customers. Moreover, there is better awareness in builders and consumers about using energy efficient windows.

2. Willingness and readiness of sub-industries for a window labelling programme (on a scale of 1 to 3, where 1 is least willing/ready)

Sub-industry	Willingness	Readiness	Remarks
Window frame (section) design and extrusion	2	1.5	The window frame industry is ~80% aluminium and ~20% UPVC. UPVC manufactures are mainly Europe-based and will be more supportive towards a window labelling program. Within the aluminium subsector, 10-15% is organised and will be willing, whereas the others are local manufacturers and unorganized, who may be reluctant to adopt new standards
Window elevation design i.e. building architecture	2	1.5	Limited role of architects and designers who are mostly concerned with glazing rather than the whole window
Window hardware (hinges, gaskets, rollers and others)	1.5	1	The gasket industry will play an important role in this
Glass manufacturing	3	3	
Glass processing	2.5	2	
Window assembly and installation	2	1.5	

3. Is a glazing labelling programme more realistic and achievable and should it be a precursor to the window labelling programme?

There is divided opinion on this:

- A collaborative approach between all sub-industries should be employed. The glass industry focuses on expensive high-performance glass, but overall energy requirements can be met with simple designs and more cost-effective options.
- Given the maturity of the supply chain and complexity of performance parameters, it would be ideal to start with a glazing labelling program as a precursor to the window labelling program. Glass being the major component occupying the largest amount of area in the fenestration, this rating program would be representative enough of the windows. In a tropical country like India, where direct solar heat gain is the main source of heat ingress, the solar control performance of the glass would be directly proportional to that of the window and as such can be a good starting point for a labelling mechanism. A glass labelling would be much simpler and easier in terms of both process and inclusion into the system.

4. Top barriers to a window labelling programme in India

- The industry reckons there is no major technological barrier in rolling out a window labelling programme. Frame (UPVC and aluminium) and glass manufacturers are confident that their products can keep up with energy standards.
- Lack of adequate testing facilities: only 2 centres in East and West are present in India as of now, capable of performing the testing required for window labelling. At least 2 more centres in North and South are required to cater to the demand which is expected to come.
- Window manufacturing being primarily dominated by the unorganized sector, there are no forums to share knowledge amongst all sectors. Window frame material manufactures, glass manufacturers and glass processors are mostly organized but window frame construction and assembly are highly unorganized.
- Poor quality installation with air gaps causing increased heat loss to the surrounding air

5. High-level road map

- **In the next 1 year:** Developing the model and the administrative mechanism and building consensus for the same; training & awareness.
- **In the next 3 years:**
  - i. Capacity ramping up in terms of testing infrastructure and training and awareness to be scaled up
  - ii. PHASE 1: Glass Labelling Programme (for windows, facades, doors and skylights): The parameters that need to be considered for the glass-based rating programmes for the fenestration in Indian Buildings are

U Value, SHGC, VLT and emissivity. A glass-based rating program will have following advantages:

- Easy implementation: it is easy to impleme\nt the glass-based rating program for all types of glass at a shorter duration
- Test facilities to test these parameters are already available in India; duration of testing is minimum
- This would result in immediate savings of energy in all the upcoming new buildings

▪ In the next 5 years:

i. Further improvement in PHASE 1 of the programme and launching of PHASE 2

ii. PHASE 2: Window Labelling Programme (for pre-fabricated/factory made windows only): This program would consider the entire system including glass, frame and other components. The collective performance of the system would be considered for the window rating program. The parameter to be checked are U Value, SHGC, VLT, Air Leakage (AL) and Condensation Resistance (CR).

5 EVALUATION OF CURRENT POLICY FRAMEWORK

This chapter explores key policies, codes and guidelines that advocate reducing cooling demand by HP glazing and windows.

The Energy Conservation Building Code (ECBC) 2007[17] under its mandatory requirements for building envelope necessitates the following minimum requirements for fenestration: U-value and SHGC of the overall fenestration product (including the sash and the frame) in accordance with ISO-15099; air leakage from fenestrations to not exceed 2.0 litre/(m^2.s) In the case of rated products, the compliance must be in accordance with ISO 15099, by an accredited independent laboratory and labelled and certified by the manufacturer or other responsible party. In the case of unrated products, the code instructs U-value and SHGC to be compliant per Table 9. Under the prescriptive requirements, the code requires compliance with vertical fenestration and minimum visible transmission value.

Table 9: Defaults for unrated vertical fenestration (overall assembly)

Frame Type	Glazing Type	Clear Glass			Tinted Glass		
		U-value (W/m².K)	SHGC	VLT	U-value (W/m².K)	SHGC	VLT
All frame types	Single Glazing	7.1	0.82	0.76	7.1	0.70	0.58
	Double Glazing	3.4	0.56	0.56	n/a	n/a	n/a
Wood, vinyl, or fiberglass frame	Single Glazing	3.4	0.59	0.64	3.4	0.42	0.39
	Double Glazing	2.6	0.52	0.57	2.6	0.34	0.21
Metal and other frame types	Single Glazing	5.1	0.68	0.66	5.1	0.50	0.40
	Double Glazing	4.0	0.60	0.59	4.0	0.42	0.22

The ECBC 2017[18], in continuation to its 2007 version, includes fenestration, visual light transmittance (VLT) under its mandatory requirements and fenestration sealing requirement (discussed under building "envelope sealing criterion").

The ECBC-R[19] (Energy Conservation Building Code for Residential) Part-1 focuses on minimising heat transfer through the building envelope to achieve comfortable indoors. The Code requires compliance with fenestration component- U-value and SHGC. It indicates "Residential Envelope Transmittance Value (RETV) for building envelope (except roof) for four climate zones, viz. Composite, Hot and dry, Warm and humid and Temperate, shall comply with the maximum RETV of 15 W/m²." Further, the Code requires compliance of VLT of non-opaque building envelope components with the minimum VLT values as given in Table 10.

Table 10: Minimum visible light transmittance (VLT) requirements

Window-to-wall ratio	Minimum VLT
WWR ≤ 20%	≥ 75%
20% < WWR ≤ 30%	≥ 50%
30% <WWR ≤ 35%	≥ 40%

NBC 2016[20] Volume 2, Part 11 – Approach to Sustainability, Section 8 – Envelope Optimisation provides guidance on building envelope including fenestration. The Code promotes minimising heat transfer through fenestration and provides specifications for window size and placement, glazing, and frame. While selecting glazing, the code provides the following guidance: selecting between dual pane and single pane glazing, selecting a spectrally selective glazing (to keep off infra-red and permit visible light), balancing between glare and light, trading off window size and glazing selection, dark or tinted glass and solar control, glazing as just one of the many options to reduce heat gain and discomfort, selection of frame for glazing and varying the selection and configuration of a glazed facade. Further, Code recommends sealing some edges and corners to reduce heat ingress. While the guidance for an energy-efficient glazing and frame is provided, it lacks supporting the provisions with numbers.

The Building Energy-Efficiency Project (BEEP) design guidelines for energy-efficient multi-storey residential buildings (composite, hot and dry[21] and, warm and humid climate[22]) highlights window properties such as: single glazing or double glazing, VLT and U-value, amongst many other factors influencing the demand for cooling and thermal comfort in a residential unit. The guidelines promote window shading over Double glazed unit (DGUs) and don't highlight benefits of well-designed fenestration.

The Model Building Bye-Laws[23] encourage provisions of ECBC guidelines, and Model Energy Efficiency guidelines[24] (NSMH Sub report by Bureau of Energy Efficiency) into the state respective building bye-laws. The Model Energy-Efficiency guidelines refer to ECBC 2007 for fenestration U-factor and SHGC.

The review of existing policy framework provides enough evidence that there is emphasis on use of HP glazing in building sector. Minimising heat transfer by restricting to prescribe SHGC, U-value, VLT, single glazed unit (SGU) and DGU values/ranges is being practiced in India building widely. While these parameters are discussed in more detail in energy codes, detailed inclusion and maintaining stringency of the high-performance glazing design parameters in building codes will reap high energy savings.

6 FUTURE RECOMMENDATIONS

1. Leveraging on-going government initiatives to support energy savings from HP glazing

- Government policies related to Smart Cities should advocate the inclusion of HP windows and glazing. We recommend developing sustainably cooled 'Demonstration Projects' in a few sites, piloting innovative window solutions. The calculated energy saving outcomes in these demonstration projects should be highlighted through Government Technology Alerts to create awareness and establish credibility of HP glazing in enhancing thermal comfort and reducing the building's cooling needs.
- Make ECBC implementation mandatory in all states. Provide governance to ensure strict compliance with all mandatory codes. Over time, develop variants of ECBC or simplified energy efficiency codes/ guidelines to cover smaller commercial buildings. ECBC 2017 prescribes WWR, U-values and SHGC (Table 1) – our analysis shows that even with base ECBC 2017 compliance half of the total energy savings potential can be realised.

2. Towards a windows energy-labelling programme

- Facilitate R&D for HP glazing.
- Develop protocols for EE ratings for whole window systems; develop an S&L programme for windows and enforce stringency of energy performance thresholds. This can help in the implementation of building codes like ECBC.
- Commission testing labs and enforce performance testing and certification of energy efficient windows.
- Undertake capacity building, training and awareness exercises including setting up a centre of excellence for HP windows and glazing. Facilitate upgradation of existing curricula across relevant streams/ branches/ fields of study to include sustainable cooling techniques.
- Create a robust knowledge-sharing and collaborative platform to bring together stakeholders across the window manufacturing and installation supply-chain from both the organised and unorganised sectors.

3. Consumer awareness and market transformation

- Establish policy to create state-level financial facilities for low-cost/preferential line of credit to real estate projects with a demonstrably energy efficient building envelope, including HP windows.
- Promote the concept of 'Green Leasing' in commercial spaces: the idea is that the building owners could charge a premium rent for an energy efficient space, and the tenant would benefit from enhanced occupant comfort and operational savings achieved through lower energy bills.
- Introduce sustainable rating of architects/architecture firms based on a suitable building performance or energy efficiency quotient (e.g. the average EPI of operational project portfolio). Mandating minimum eligibility criteria for practicing architects in terms of these ratings will help ensure a constant push towards embodiment of energy efficiency and sustainability features in their projects, including energy efficient windows glazing.
- Create consumer awareness through campaigns, demonstration projects, infomercials, and stakeholders across the construction supply-chain that focus on promoting and cultivating energy conserving behaviour in space cooling; educate customers to make informed product choices based on operational savings, rather than the first cost alone.

7 APPENDIX

7.1. Simulation Results

Table 11: Appendix – simulation results

WWR	U-value (W/ m2.K)	SHGC	EPI (kWh/m2/year)		
			Composite	Hot and dry	Warm and humid
20%	2	0.39	187	205	201
20%	2	0.27	185	202	198
20%	2	0.25	182	199	196
20%	3	0.39	188	206	201
20%	3	0.27	185	202	198
20%	3	0.25	183	200	196
20%	4	0.39	189	207	202
20%	4	0.27	185	202	198
20%	4	0.25	184	201	197
40%	2	0.39	205	225	217
40%	2	0.27	199	218	211
40%	2	0.25	194	212	206
40%	3	0.39	207	227	218
40%	3	0.27	199	218	211
40%	3	0.25	196	215	207
40%	4	0.39	208	229	218
40%	4	0.27	199	219	210
40%	4	0.25	197	217	208
60%	2	0.39	223	244	233
60%	2	0.27	214	234	223
60%	2	0.25	206	225	216
60%	3	0.39	225	246	233
60%	3	0.27	214	234	222
60%	3	0.25	208	228	217
60%	4	0.39	227	249	233
60%	4	0.27	214	235	221
60%	4	0.25	211	232	218

7.2. Commercial building stock

Table 12: Appendix – commercial building stock

Commercial building type	Commercial building segment	2017 BUA (million m^2)	2017 BUA: % Air-conditioned area		CAGR	2030 BUA (million m^2)	2030 BUA: % Air-conditioned area		Typical WWR
			Min	Max			Min	Max	
Hospital	Government urban hospital	30.1	30%	35%	1.5 - 2%	37.9	60%	80%	20%
	Government rural hospital	8.3	1%	3%	1 - 1.5%	9.8	10%	20%	20%
	Private (multi-speciality) hospital	31.2	40%	50%	3-4%	49.1	80%	90%	40%
Hotel	1-star	0.4	50%	55%	1 - 1.5%	0.4	70%	80%	20%
	2-star	0.9	50%	55%	1 - 1.5%	1.0	70%	80%	20%
	3-star	1.7	50%	60%	1 - 1.5%	2.0	70%	80%	20%
	4-star	1.5	85%	95%	2 - 3%	2.1	90%	95%	40%
	5-star	3.3	85%	95%	2 - 3%	4.6	90%	95%	40%
	Other	0.4	5%	10%	3-4%	0.6	25%	50%	20%
	Heritage	0.4	60%	65%	0.5 - 1%	0.4	80%	90%	20%
	Restaurant	80.0	45%	50%	4-5%	143.7	70%	80%	20%
Retail	Mall/modern store	35.6	75%	85%	3 - 4%	55.9	90%	95%	40%
	Small retail shop	205.3	3%	5%	1 - 1.5%	243.1	15%	25%	20%
	Medium retail shop	26.3	50%	60%	3-4%	41.7	80%	90%	20%
Office	IT/ITES	91.9	50%	55%	3 - 4%	145.8	70%	85%	40%
	Banking, Service, Finance and Insurance (BSFI)	26.5	50%	55%	3 - 4%	42.1	70%	85%	40%
	Central government	27.8	20%	25%	0.5 - 1%	30.7	30%	50%	20%
	State government	72.7	20%	25%	0.5 - 1%	80.4	30%	50%	20%
	Quasi government	50.5	20%	25%	0.5 - 1%	55.9	30%	50%	20%
	Local body	7.7	20%	25%	0.5 - 1%	8.6	30%	50%	20%
Institute	School	121.8	10%	15%	3 - 4%	191.7	15%	30%	20%
	Institute of national importance	1.7	35%	45%	3 - 4%	2.7	50%	70%	40%
	College	75.1	10%	20%	3 - 4%	118.6	30%	70%	40%
	Standalone institution	6.8	20%	30%	3 - 4%	10.6	30%	70%	40%
Assembly Place	Super large place of worship	10.0	10%	15%	0%	10.0	15%	25%	40%
	Large place of worship	160.0	1%	3%	0-0.5%	166.0	3%	10%	40%
	Other	16.6	45%	55%	3 - 4%	26.2	60%	70%	40%
Transit	Airport	4.0	80%	90%	0.5 - 1%	4.4	90%	95%	40%
	Bus stand	3.8	1%	3%	1 - 2%	4.7	5%	15%	20%
	Railway Station	6.5	3%	5%	1 - 2%	8.1	10%	20%	20%
Total BUA		1109				1499			

8 SURVEY QUESTIONNAIRE

1. Being an important industry stakeholder, please provide your perspective on the (a) need and (b) appetite for a window labelling programme in India. What are the benefits or drawbacks of such a programme?

2. The window industry is a combination of various sub-industries, each at different levels of organisation. Please rate the (a) willingness and (b) readiness of these sub-industries for a window labelling programme in India, on a scale of 1 to 3, where 1 is least willing/ready.

Sub-industry	Willingness	Readiness
Window frame (section) design and extrusion		
Window elevation design i.e. building architecture		
Window hardware (hinges, gaskets, rollers and others)		
Glass manufacturing		
Glass processing		
Window assembly and installation		

3. Do you think a glazing labelling programme is more realistic and achievable and should be a precursor to the window labelling programme?

4. Please indicate the top 2 barriers to a window labelling programme in India under each of the following headings: (a) technology barriers (b) market barriers.

5. (a) In how many years do you envision a window labelling programme in India under implementation?

   (b) Please suggest action items toward a window labelling programme to overcome the barriers cited above, that should be implemented in the next (i) 1 year (ii) 3 years and (iii) 5 years.

6. Please can you suggest names (and provide their contact details too) of other stakeholders whose perspectives we should obtain.

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