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Energy Saving and Thermal Comfort Improvement Potential of External Movable Shading System (EMSyS)

BEEP
BUILDING ENERGY
EFFICIENCY PROJECT

Energy Saving and Thermal Comfort Improvement Potential of External Movable Shading System (EMSyS)

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MESSAGE

BUREAU OF ENERGY EFFICIENCY (BEE)
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SAURABH DIDDI
Director, Bureau of Energy Efficiency

The Bureau of Energy Efficiency (BEE) has a multi-pronged approach to achieve thermally comfortable and energy efficient buildings in the country . When it comes to passive measures for controlling the heat ingress in a building, external movable shading systems (EMSyS) are the first line of defence. It directly cuts the heat entering inside a building and is a very efficient means to keep the building thermally comfortable. However, its usage in Indian buildings has been limited due to various factors like lack of awareness or easy access to economical products.

This policy paper '**Energy Saving and Thermal Comfort Improvement Potential of External Movable Shading System (EMSyS)**' identifies the barriers to large-scale adoption of EMSyS in the country and tries to address them. The paper demonstrates results from the real-life study done in the Indian environmental conditions on the effects of EMSyS on inside building operative temperature and related energy savings. This can be beneficial for architects, policy makers and the building industry alike to help utilise the potential of EMSyS to the full. Keeping India's geographic and climatic diversity in mind, the study has developed a model to help estimate the energy savings attributable to EMSyS in different seasons in different climatic zones of India.

Another key link in promoting the use of EMSyS is to understand the current market in India for EMSyS. The policy paper gives an overview of the EMSyS market in India, its features, and possible steps to increase the adoption of EMSyS by the Indian consumer. This was done by undertaking primary market research, and roundtable discussions with the EMSyS manufacturers and window industry stakeholders.

Deriving from the field study results and the current market conditions, the policy paper comes up with key measures that can help strengthen the uptake of EMSyS in building design. It identifies different strategies and key actions to be taken in this journey and the potential benefits that can result from the same.

I hope that the policy paper and its recommendations, equipped with results from real-life study, and overview of the EMSyS market and ecosystem in India, shall serve as a good resource for policy makers and other stakeholders to incorporate and utilise EMSyS in building design in India.

MESSAGE

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Swiss Agency for Development and Cooperation SDC

ANAND SHUKLA
Senior Advisor
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The Indo-Swiss Building Energy Efficiency Project (BEEP) has been a successful bilateral cooperation project between the governments of Switzerland and India since 2011. Together with Swiss and Indian partners, the Swiss Agency for Development and Cooperation (SDC) has made catalytic efforts to build on Switzerland's four decades of experience to co-develop knowledge and expertise on energy efficient building design, technologies, and policies in India.

The integration of passive design measures is essential to make buildings energy efficient and in achieving thermal comfort for the occupants. The installation of External Movable Shading Systems (EMSyS) is one such measure to minimize the heat transfer inside a building thus having high potential of energy savings. EMSyS can be installed in residential, commercial and institutional buildings. However, the current publication is prepared for the residential buildings in the urban context. In order to promote the use of EMSyS, several initiatives have been taken under the BEEP project through the awareness raising of stakeholders, market assessment, and its testing in practical conditions.

The present policy paper '**Energy Saving and Thermal Comfort Improvement Potential of External Movable Shading System (EMSyS)**' is to strengthen these initiatives and developed upon the results from a real-life study successfully conducted in Gurugram, and roundtable discussions held with the EMSyS and windows manufacturing industry. In addition, two market studies were also carried out in 2019 and 2022 to understand the on-ground EMSyS market and consumer behaviour. Together, these provide a holistic view of the current scenario and envisage the prospective role EMSyS can play in improving the energy efficiency of buildings. The policy paper has come up with some key insights into the potential of EMSyS, and possible approaches on how this potential could be explored.

The policy paper also looks at the development of the EMSyS in Europe, particularly in Switzerland where EMSyS is an integral part of the building architecture. For instance, in Switzerland, the installation of EMSyS is a pre-requisite to adding air conditioning to the building. Such policy measures have also aided the development of a robust EMSyS industry and market in Switzerland.

I hope that this policy paper will aid in creating a conducive environment, in terms of policies, market development, and awareness generation, and strengthens the role of EMSyS in improving the energy efficiency of buildings.

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EXECUTIVE SUMMARY

External movable shading system (EMSyS) is one of the key solutions to reduce the space cooling demand. EMSyS are shading devices that are installed outside the windows or glazed surfaces of a building's façade, which are dynamic and have the provision of moving or repositioning.

This policy paper estimates the energy saving and thermal comfort improvement potential of external movable shading system (EMSyS) in urban residential buildings in India and proposes key strategies towards realising the same. While this paper is relevant and useful for all building sector stakeholders, the key audience for this report are the policy makers as this paper can help them in developing a policy-driven detailed action plan to implement these strategies.

The policy paper consists of four chapters. Chapter 1 sets the overall context by providing information on relevant national goals, existing policy framework, energy use in buildings and current construction trends. Chapter 2 gives an overview of EMSyS products, current market, and key findings of a performance study. Chapter 3 gives the overall methodology of quantifying energy saving and thermal comfort improvements through EMSyS at state and national level under different scenarios till the year 2050. All the calculations are done only for 'urban residential' buildings. The last chapter (Chapter 4) details out policy recommendations and strategies for developing the market of EMSyS.

Why India needs EMSyS in large numbers

As we know, EMSyS helps in reducing the heat ingress into a building, which, in turn, can help reduce the energy consumption for space cooling (air conditioners). Although there have been sporadic efforts at popularizing EMSyS, sustained attention and focus has been missing on this aspect of energy conservation. Now the time has come for all building sector stakeholders to put much more focus on EMSyS primarily due to the following reasons:

1. India's global climate action commitments through 'Panchamrit' at COP26 in Glasgow (e.g., India to become Net Zero by 2070).
2. Projected urbanization level of about 50% by 2050 with a residential built-up area of about 48 billion m^2.
3. Ever increasing use of air conditioners with about 40% of rural and urban households expected to use air conditioners by 2037.[1]

These are staggering numbers that can potentially contribute to global warming and threaten the energy security of the country in no uncertain terms.

With windows contributing to 80% of heat ingress in residential buildings, the current trend of having larger glazed area or larger window-to-wall area ratio (WWR) without adequate shading (especially in high income housing) further compounds the problem.

[1] Maithel, S., Chandiwala, S., Bhanware, P., Rawal, R., Kumar, S., Gupta, V., Jain, M. (2020, June). Developing cost-effective and low-carbon options to meet India's space cooling demand in urban residential buildings through 2050. India Energy Transformation Platform

Abysmally low EMSyS market

The market of EMSyS in India is very small and the pace of growth of EMSyS market does not inspire confidence as of today. It consists of a few international players, a few organized sector small enterprises and an unorganized/ informal industry dealing with essentially low cost and short-lived solutions like bamboo *chiks* or green net. Some of the main EMSyS products in the Indian market are bamboo *chiks*, green net, external screens, vertical louvers, awnings, PVC blinds, lamella blinds, and monsoon blinds.

Different types of EMSyS products available in Indian market

A market study by BEEP revealed the key characteristics of the Indian EMSyS market, which are as listed below. The market of EMSyS in India is still small and evolving.

- It is still limited to a few high-end private residences.
- Affordably priced EMSyS products for mass application are not readily available.
- The high cost of EMSyS continues to be a major hindrance.
- There is a need for developing affordable, adaptable to the climate- and dust-resistant EMSyS products.
- Climate, geography, architecture, construction practice, consumer preference, awareness vary in different parts of India and need regional solutions.
- External shading is considered as a retrofit measure and is not part of the original design of the building. There are also apprehensions about the high operation and maintenance costs.
- Internal blinds are considered an integral aspect of the house décor and preferred over external shading.
- Lack of India-specific real-life monitoring data on the benefits of EMSyS.
- The manufacturers and architects feel that some incentive or push from the government, and policy intervention could be helpful.

EMSyS real-life test results, potential, and scenario building

Real-life monitoring study

This paper presents the results of a BEEP-driven real-life monitoring study on EMSyS on two test rooms – one with EMSyS and the other with internal curtain (IC). The monitoring showed that in the naturally ventilated mode, the test room with EMSyS had a 3.0–3.5 °C lower peak operative temperature as compared to the test room with IC. In air-conditioned (AC) mode, the test room with EMSyS had ~32% less cumulative cooling demand (thermal) as compared to room with IC.

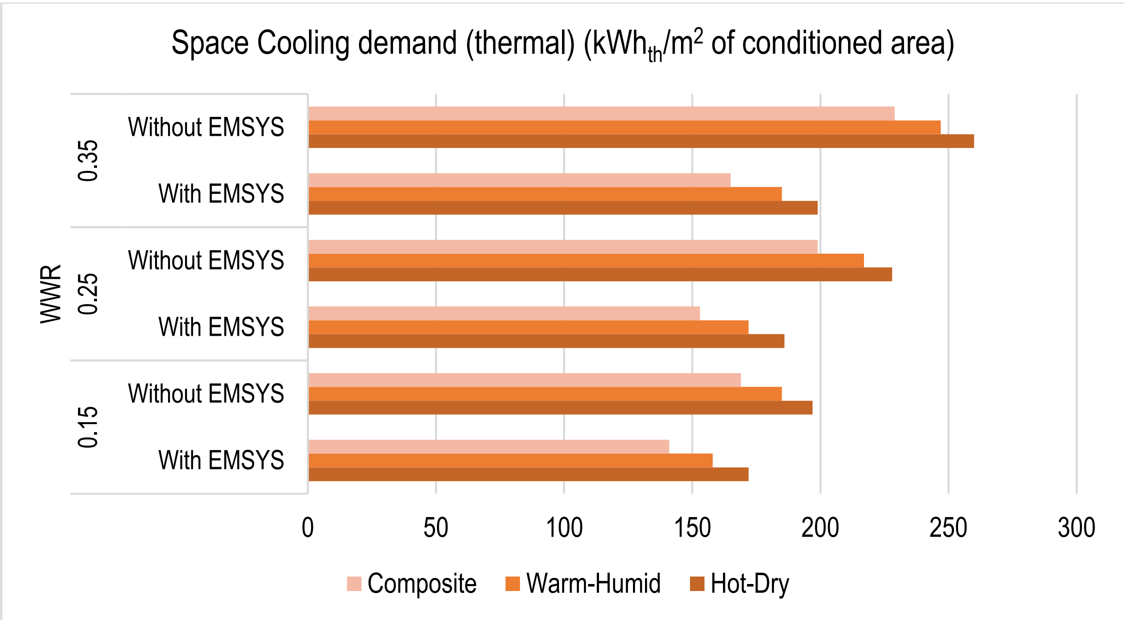
EMSyS potential estimation and scenario building

To quantify the energy savings and thermal comfort potential due to use of EMSyS in urban residential buildings in India, a simulation and modelling study was carried out. The study used a bottom-up approach involving the calculations for urban households at the district level for each district, which then are summed up at the state, climatic zone, and country levels. The two key steps in this are (1) Simulation study to calculate space cooling requirement and (2) Future projection and scenario building.

Simulation study to calculate space cooling requirement[2]

The simulation study used the process followed during the development of the Eco-Niwas Samhita (Part-I). As the study focused on EMSyS potential estimation, the study team made a few simplifications and customisation, which are detailed in the paper.

The simulations results were processed to calculate the impact of EMSyS for different climate zones and with different WWRs. The results for the space cooling requirement in air-conditioning mode are shown here, while similar results were calculated for discomfort hours (DH[3]) in the naturally ventilated mode.



Future projections and scenario building

The future projection work was built on the previous work done under India Energy Transformation Platform (IETP) study.[4] For projections and scenario building, 2020 is taken as the base year, and all the key parameters are estimated for the years 2030, 2040 and 2050. The key steps carried out for this are estimation of (1) residential built-up area (urban) at district level, (2) space cooling requirement in urban residential houses, and (3) cooling electricity demand and CO_2 emissions.

[2] The space cooling requirement (in kWh$_{th}$) is defined as the amount of thermal energy that needs to be removed from inside buildings to maintain thermal comfort.

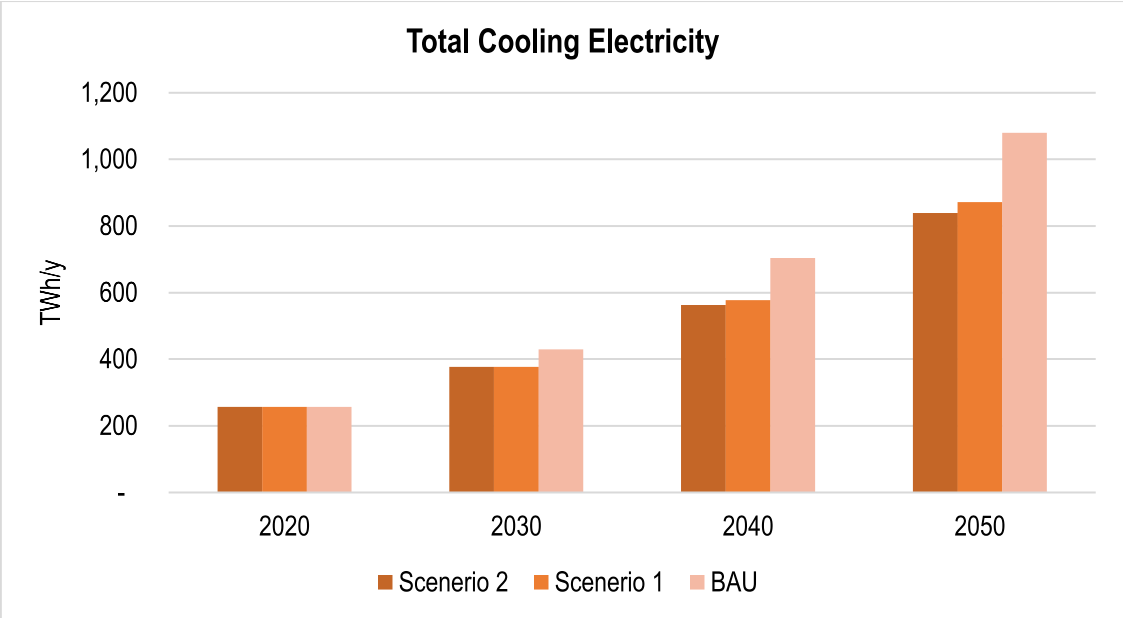
[3] It is calculated considering the India Model for Adaptive Thermal Comfort (IMAC), which is the summation of number of hours during the cooling period when the hourly inside operative temperature is more than IMAC band maximum temperature.

[4] Maithel, S., Chandiwala, S., Bhanware, P., Rawal, R., Kumar, S., Gupta, V., Jain, M. (2020, June). Developing cost-effective and low-carbon options to meet India's space cooling demand in urban residential buildings through 2050. India Energy Transformation Platform

The estimation was done for three scenarios:

- *Business-as-usual (BAU) scenario*, which assumes that in the absence of any additional measures, the trend of window to wall area, penetration of EMSyS will follow BAU trends.
- *Scenario 1*, in which EMSyS is made mandatory in urban residential buildings and WWR follows the BAU trend.
- *Scenario 2*, estimates the EMSyS potential, which considers that EMSyS is made mandatory in urban residential buildings and also limiting the WWR.

The cooling electricity demand for providing thermal comfort for all in urban residential buildings is estimated at 257 TWh/y for the year 2020. Under the BAU scenario, it is expected that the cooling electricity demand will increase to 1080 TWh/y in 2050. Under Scenario 1, for the year 2050 the cooling electricity can be reduced to 872 TWh/y, which is almost 19% less than that in the BAU scenario. With Scenario 2, it can be reduced further to 839 TWh/y, which is 22% lower as compared to BAU scenario.



In addition to a reduction in cooling demand or cooling electricity, the discomfort hours in the non-conditioned houses can be reduced by 20% to 60% by using EMSyS.

Under Scenario 2, in the year 2050, the electricity saving potential due to EMSyS is calculated as up to 241 TWh/y, which translates to an emission reduction of 171 million tCO_2/y (considering the emission factor for the year 2021/22 for India[5] as 0.71 tCO_2/MWh). Similarly, reduction in electricity consumption of 241 TWh/y (for 2050) will translate to avoidance of 43.3 GW of of power from thermal power plants (considering the average plant load factor of central sector thermal power plants[6] as 63.4%), using the full potential of EMSyS.

[5] Source: CO2 Baseline Database for the Indian Power Sector, Central Electricity Authority, Ministry of Power (https://cea.nic.in/wp-content/uploads/baseline/2023/01/Approved_report_emission__2021_22.pdf)
[6] Source: General Review 2022, Central Electricity Authority, Ministry of Power (https://cea.nic.in/wp-content/uploads/general/2022/GR_2022_FINAL.pdf)

Policy recommendations and strategies

The strategies to stimulate the external movable shading market should be built on a combination of various measures and activities.

Awareness building

a) Demonstration projects: There is a need to have a 'critical mass' of building projects with EMSyS; only after that further replications can be self-sustained. To achieve this, EMSyS can be installed in selected Government buildings, located in urban areas, and have high visibility. Progressive builders can be identified to showcase EMSyS in their projects through 'sample flats'. Existing buildings with high solar exposure should also be considered for demonstration projects.

b) Media campaign: Large media campaigns for various stakeholders, led by Government agencies (e.g. BEE), are done for the promotion of EMSyS, keeping the communication simple and easy to understand. EMSyS benefits are conveyed through short videos, advertisements, short quotes in property tax portals and electricity bills, key events of builders and architectural association, etc.

c) Special scoring in National Energy Efficiency Roadmap for Movement towards Affordable and Natural habitat (NEERMAN) award scheme for EMSyS use: Residential Envelope Transmittance Value (RETV) is a key criterion for scoring points for residential buildings. While EMSyS can reduce the RETV significantly, still there is no provision in the current scheme document to account for EMSyS. Therefore, it is recommended that a special scoring is added for the buildings which have implemented EMSyS. This would make people more aware about EMSyS as well as encourage them to opt for EMSyS.

d) Adding strong scoring for EMSyS use in green building rating systems: GRIHA (Green Rating for Integrated Habitat Assessment rating by GRIHA Council), IGBC Rating Systems (managed by Indian Green Building Council) and LEED (Leadership in Energy and Environmental Design) rating (by U.S. Green Building Council) have an option of accounting for EMSyS by using the energy simulation approach; none of these specify EMSyS in the prescriptive approach nor they specify simple factors to account for benefits of using EMSyS. It is recommended that all these rating systems should include EMSyS and corresponding scoring for it, in their rating documents.

Policy interventions at national level

a) Setting up a national task force: It is recommended to set up a national task force, led by Government agencies (e.g., BEE) and bring together EMSyS and the glazing industry. The task force plans and supports activities for rapid adoption of EMSyS in buildings.

b) Inclusion of EMSyS in Eco-Niwas Samhita (ENS)

Currently, ENS does not specify the factors for improvements in shading by having EMSyS installed. Therefore, the following updates are recommended in ENS:

- Adding shading factor for EMSyS to account its impact: It is recommended that suitable factor should be developed and added in the code document to account for EMSyS impact in the shading and thereby improvement in the RETV value.
- Making the code provisions more stringent and mandatory: Making code more stringent and mandatory (RETV requirement from 15 W/m^2 is reduced to 8 W/m^2),

would encourage projects to opt for EMSyS, especially if the projects are designed with higher WWR.

- Adding an Annexure on EMSyS in the code: An annexure, showing examples of EMSyS impact on RETV with varying WWR will help accounting its impact. As the ENS update is planned, it is recommended to add this Annexure along with the shading factor for EMSyS, during the updation process.

Capacity building

a) For students at curricula level: To make the future professionals ready to propose and implement EMSyS as key passive design strategy, they must learn about EMSyS in their curricula. It is recommended to add modules on EMSyS in architectural curricula by making it a part of the studio project and similarly, in engineering curricula, adding EMSyS examples in heat transfer and building physics.

b) For building sector professionals and builders: Develop and conduct specific capacity building programme with specific objective for specific stakeholder. <u>Architects</u> are able to propose best EMSyS solutions based on the climate and the building configuration. <u>Engineers</u> are able to calculate the impact of EMSyS on cooling requirements and design cooling systems accordingly. The <u>builders and developers</u> understand the financial implications of EMSyS and are able to take decision on EMSyS applicability for their projects. The <u>marketing team</u> of the building projects are able to convey the benefits of EMSyS to potential home buyers.

c) Skilled manpower for EMSyS installation: Develop and conduct training programmes for EMSyS installers, considering high-rise buildings in focus. Similar to the mason or plumber, there should be a service person with specialisation in EMSyS installation. Here, agencies like BMTPC and National Skill Development Corporation (NSDC) can play a major role.

Supply chain: develop more market-fit EMSyS products

There is a formal sector with good quality products, but the costs are high. There is an informal sector also with low-cost products, but the quality is low and the product life is short. Therefore, there is a lack of market-fit EMSyS products, which can provide a good balance of quality, cost, and product life. Two suggestions are recommended in this regard.

- Set up a technical support programme, which would aim to induce new industrial manufacturers to enter this sector. Government agencies like NITI Aayog (through Atal Innovation Mission), BMTPC, BEE, and DST can play a key role in this.
- Financial incentives for investment in EMSyS technical development, manufacturing and marketing, e.g. loans at lower interest rates and higher loan eligibility. The aim for such incentives would be to make the proposition for EMSyS financially better.

Based on the strategies proposed in the section above, there is a need to develop a policy-driven detailed action plan to implement these strategies. The main aim of the action plan remains that the EMSyS penetration in residential buildings reaches towards its potential.

1 INTRODUCTION

1.1 Context

The Intergovernmental Panel on Climate Change (IPCC) report[7] of 2021 shows that the world will probably reach or exceed 1.5 °C of warming above pre-industrial level, within the next two decades. The action taken in this decade will decide whether we will limit warming to this level or prevent the most severe climate impacts. Small-scale effort will not be sufficient; we will need rapid transformational change. To limit the rise of global temperature to 1.5 °C, greenhouse gas (GHG) emissions would need to be reduced by 45% by 2030 and reach net zero by 2050.

India enhanced its commitment to climate action at the COP 26 in Glasgow, announcing its 5-point climate target – 'Panchamrit' – aiming to become 'Net-zero by 2070' and cut down its net projected carbon emission by 1 billion tonnes from now until 2030.[8]

Amid the commitment, there lies another great challenge. In the year 2022, India witnessed its hottest March in 122 years (observed a maximum of 33.1 °C, with the anomaly of 1.86 °C). The heatwave in India had sparked extremely high energy demand to power air-conditioning and cooling systems. In April 2022, the total power demand rose 13.2% (135.4 billion kWh) and up to 75% in North India as compared to that in the previous year.[9] This has led to a coal shortage and one of the worst power crisis that India had seen. Share of space cooling in India's peak electricity load is projected to rise from 10% in 2016 to 45% in 2050 in the baseline scenario.[10] There is a strong need of cutting down energy demand, particularly for space cooling, for India to stay on course to fulfill its commitment at COP26.

The overall building energy use consumes 33% of India's total annual primary energy consumption (2017) and is the second-largest consumer of electricity. Out of the total electricity consumed in the building sector, about 75% is used in residential buildings.[11] On 12 July 2018, the Minister for Housing and Urban Affairs, Hardeep Singh Puri, while speaking at the High Level Political Forum (HLPF) on Sustainable Development,[12] said that India will have to build 700–900 million m^2 of urban space every year till 2030 to meet its urban demands. This demand, he stated, was equivalent to building a new Chicago annually.

A study done under India Energy Transformation Platform (IETP)[13] projected that India will have a residential total built-up area of 48 billion m^2, with a suggested urbanization level of about 50% by 2050. The annual electricity demand for providing thermal comfort

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[7] Intergovernmental Panel on Climate Change (IPCC). 2021. "IPCC Sixth Assessment Report". Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[8] https://www.pmindia.gov.in/en/news_updates/national-statement-by-pm-at-cop26-summit-in-glasgow/ (accessed on 21 January 2023)

[9] https://economictimes.indiatimes.com/industry/energy/power/unrelenting-heat-in-india-pushes-april-power-demand-to-record-high/articleshow/91253842.cms (accessed on 21 January 2023)

[10] International Energy Agency (IEA). 2018. World Energy Investment Report 2018. Paris: IEA

[11] Central Electricity Authority (CEA). 2017. Growth of Electricity Sector in India from 1947-2017. New Delhi: CEA, Government of India

[12] https://realty.economictimes.indiatimes.com/news/industry/india-must-build-700-900-sq-meters-every-year-till-2030-to-meet-urban-demand-housing-minister/64963580 (accessed on 21 January 2023)

[13] Maithel S, Chandiwala S, Bhanware P, Rawal R, Kumar S, Gupta V, Jain M. June 2020. Developing cost-effective and low-carbon options to meet India's space cooling demand in urban residential buildings through 2050. New Delhi, India Energy Transformation Platform

to all urban residential space is projected at about 583 TWh in 2050, which is 80% more than the projected demand for 2020. As per the India Cooling Action Plan[14] (ICAP), 80%–90% of the total stock of refrigeration and air conditioning (RAC) systems in 2037/38 is likely to be in the residential sector. Approximately 8% of the urban and rural households in 2017 in India had RAC systems, which is expected to rise to 40% by 2037.

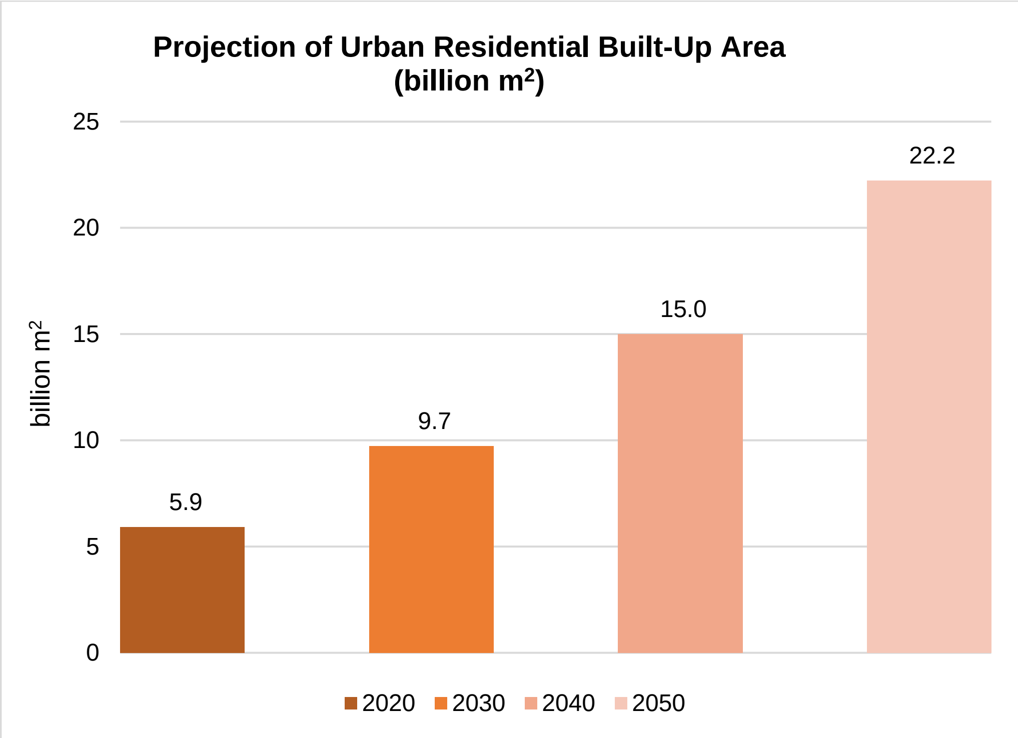

Figure 1. Estimation of urban residential built-up area

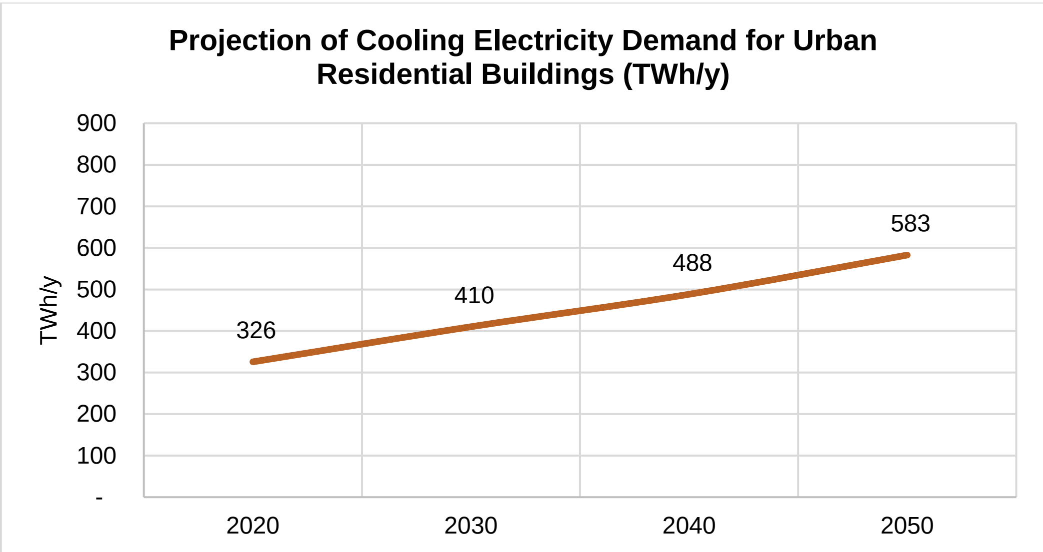

Figure 2. Estimation of cooling electricity demand for urban residential buildings
Source: Maithel S., Chandiwala S, Bhanware P, Rawal R, Kumar S, Gupta V, Jain M. June 2020. Developing cost-effective and low-carbon options to meet India's space cooling demand in urban residential buildings through 2050. New Delhi, India Energy Transformation Platform.

[14] Ozone Cell. 2019. Indian Cooling Action Plan (ICAP) 2019. New Delhi: Ozone Cell, Ministry of Environment, Forest, and Climate Change Government of India

The projected increase in the use of air-conditioners in the residential sector in India alone could be to the tune of over 1 billion, making India's energy consumption for cooling one of the highest in the world. Researchers in 2022 estimated that air conditioning globally is responsible for the release of 1950 million tonnes of carbon dioxide equivalent released annually, or 3.94% of global GHG emissions.[15]

It has been a challenge for policy makers in managing the energy demand from buildings while ensuring high quality of life. The Government of India has also given prominence to energy efficiency in buildings in order to moderate climate change as part of its climate action plan.

To address the issue in residential buildings, the Bureau of Energy Efficiency (BEE), under the Ministry of Power (MoP), has developed an Energy Conservation Building Code, which is called the Eco-Niwas Samhita (ENS). Part-I of the ENS was launched in December 2018 and it is focused on 'Building Envelope'. It sets minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climates), as well as for ensuring adequate natural ventilation and daylighting potential. The code provides design flexibility to innovate and vary important envelope components such as wall type, window size, type of glazing, and external shading to windows to meet the compliance.

There is a recent trend in India of having large floor to ceiling windows in residential buildings. Figure 3 shows the trend towards larger glazed area or larger Window-to-Wall area Ratio (WWR), especially in high-income housing. The WWR ranges from 20%–70% in living rooms and bedrooms. The reason for larger WWR perhaps is to get better views to the outside and to improve daylighting, but it also brings in excessive heat. The market data on sales of glass for building construction shows a rapid increase in demand for glass. There is an estimated 25%–30% CAGR (compounded annual growth rate) increase in the market of glass every year,[16] whereas there is only 4% CAGR increase in the total built-up area.[7] The increase in WWR is also accompanied by a trend to have less fixed shading or *chhajas* to protect the windows. These are worrying trends as the projects analysed under Indo-Swiss BEEP showed that the direct solar gains through the windows contributed up to 80% of the total heat coming from the building envelope.

[15] https://www.nrel.gov/news/press/2022/nrel-shows-impact-of-controlling-humidity-on-greenhouse-gas-emissions.html (accessed on 21 January 2023)

[16] Data gathered from the roundtable meeting with glass manufacturers, organised by BEEP

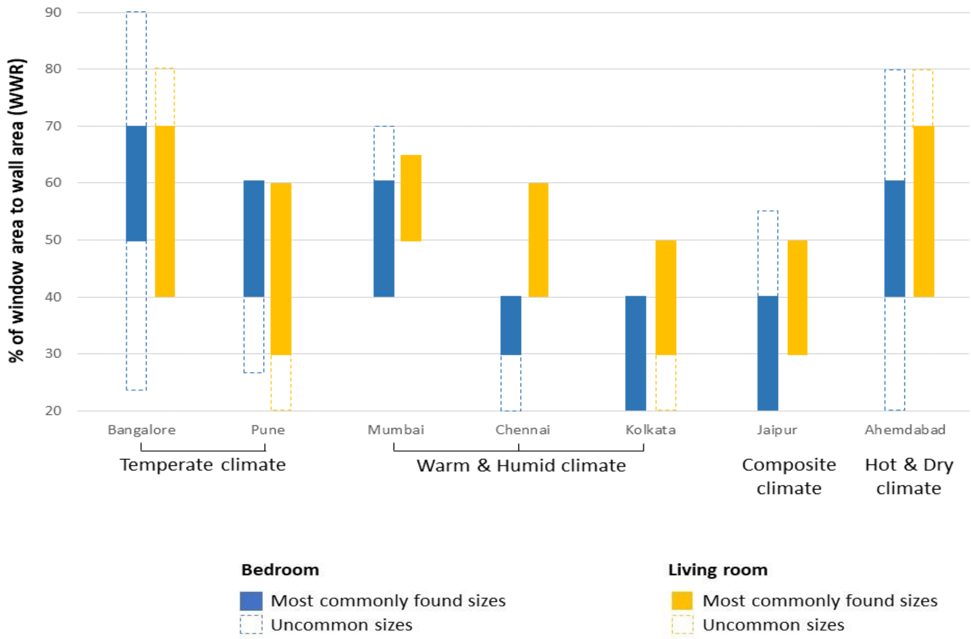

Figure 3. Window-to-wall area ratio (WWR) in recently constructed buildings
Source: Characterisation Study of Windows and Openings in Multi-Storey Residential Buildings: 2020 Indo-Swiss BEEP

1.2 Objectives and outline of paper

The above discussion highlights the need for reducing the space cooling demand in residential buildings to improve thermal comfort and to reduce the demand for air-conditioning. External Moveable Shading Systems (EMSyS) can help in achieving sharp reduction in the heat gains from windows. The main objective of this policy paper is to quantify the energy saving and thermal comfort improvement potential of EMSyS in urban residential buildings and give key policy recommendations and approach to realise this potential.

Chapter 2 of this paper gives an overview of EMSyS products, current market, and key findings of a performance study. Chapter 3 gives the overall methodology of quantifying energy saving and thermal comfort improvements through EMSyS at state and national levels under different scenarios till the year 2050. All the calculations are done only for 'urban residential' buildings. The last chapter (Chapter 4) details out the key policy recommendations and approach to realise EMSyS potential.

2 ABOUT EXTERNAL MOVABLE SHADING SYSTEMS (EMSYS)

2.1 EMSyS and its different kinds

External Moveable Shading Systems (EMSyS) are shading devices that are installed outside the windows or glazed surfaces of a building's façade, which are dynamic and have the provision of moving or repositioning. While fixed shading elements such as *chajjas*, box windows, and vertical fins are important and can provide shading on the northern and southern façades of the building when the sun is high up, it is dynamic/movable shading that can protect the eastern and western façades from the angular sun. Also, in a tropical country like India, which receives high amount of solar radiation, a significantly large fraction of the solar radiation is in the form of 'diffused' radiation because of dust and clouds present in the atmosphere. The share of diffused radiation may go up to 50% in summer months, and hence protection against diffused radiation is equally important. While fixed shading is useful to protect from 'direct' solar radiation, it has limited effectiveness against 'diffused' radiation. An external movable shading device/system (EMSyS) can be adjusted in different positions depending on the sun's trajectory throughout the day and block solar radiation from entering the building as they are placed outside the glass of the window. Such systems have the potential to reduce up to 80% of the solar gains coming inside the building through windows.

2.1.1 Different types of EMSyS

Depending upon factors such as construction and mode of use, there are different types of EMSyS products. Some of the main types of EMSyS are discussed here.

Retractable awnings
An awning is composed of fabric that is stretched and retracted on a sub-structure designed as a truss, space frame or a planar frame depending on the applicability. Awnings comprise a lightweight, frame structure over which the cover is attached. They are more suitable for outsides and patios. Available in multiple fabrics, colours, and customised choices, retractable awnings also add to the aesthetic appeal of the building.

Figure 4. Retractable PVC awnings

Shutters

Shutters are one of the most ancient external movable shading systems. Shutters allow to cut completely the direct and diffused radiation, but also darken the internal space completely. Shutters can be of different types depending on their operation and construction.

Plain shutters

Plain shutters are the basic opaque panels, one on each side of the window with two hinges for its movement from opened to closed.

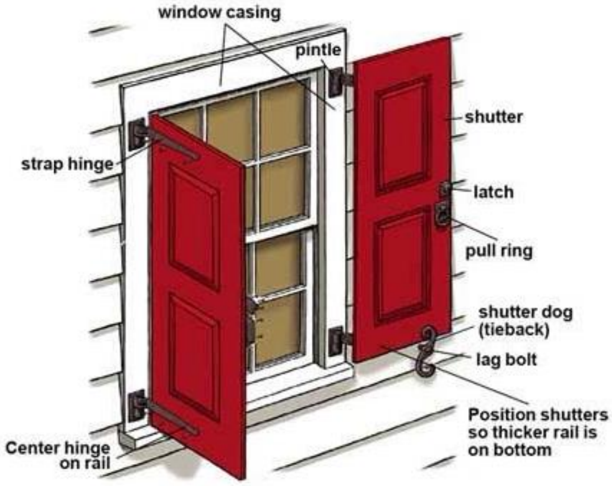

Figure 5. Plain shutters
Source: Gregory Nemec

Louvered shutters

Louvers are the angled slats attached to the steps of the shutter panel. Historically, the shutters have been louvered in hot climates allowing natural ventilation. One example of this can be seen at the heritage library of Jaipur in Rajasthan. The advantage of louvered shutters over opaque shutters is that they allow natural ventilation, even if the louvered area and openness is too small for enough air flow.

Figure 6. Louvered window shutters
Source: https://gharpedia.com/blog/types-of-window-shutters/ (accessed on 21 January 2023)

Other types of shutters include the rolling shutters and the sliding shutters.

Metal blinds

Metal blinds, which are known for their durability and easy maintenance, are usually made of aluminium or vinyl. The slats in the metal blinds are adjusted internally in the guide profile, providing the user control over their orientation. The blinds are operated using an articulated crank. They can also be used with motorised controls.

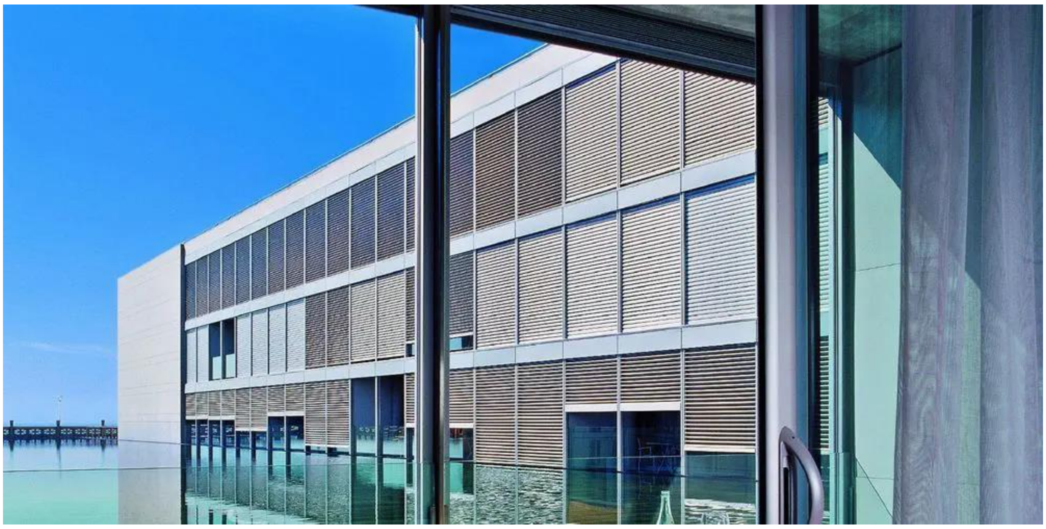

Figure 7. Metal blinds
Source: Greisser.ch

External lamella

Lamella shades have the mechanism for both controlling the inclination of lamella blades as well as for moving the blinds up and down over the window. In more advanced products, automatic control of blinds movements is done by motors. In high-end products, blinds with 'smart technology' use wind and solar sensors to determine the optimum blinds position and can be connected to a smartphone.

Figure 8. External lamella blinds (Horizontal and Vertical)

Lamella blinds are not extensively used in the Indian market as of now, but certain manufacturers/suppliers have started importing lamella blinds to develop a market for them.

2.2 Historical use of EMSyS in India, Europe, andUSA and current market trends (in EU & Switzerland)

External shading has been used throughout the world for centuries to provide protection against the sun, wind, and outdoors. It appears in different forms through different ages in different parts of the world.

In France, the Venetian blinds originated through Nimes and Lyon, which both lie on the ancient Silk Route, hinting to a possibility that these products were introduced by the traders on the Silk Route. Jalousies are a shading system characteristic of the Lyonnais and part of the Rhône and are regarded as a precious heritage to keep.

Figure 9. Examples of Lyonaise 'jalousie', which are now considered heritage

Awnings were popular across Chicago in USA during 1880–1920, in both commercial and residential buildings. However, with widespread adoption of home air conditioning, they began to disappear altogether by the 1950s.

Figure 10. Examples of awnings used in USA around 1910–20, before the advent of air conditioning
Source: http://dcmny.org/islandora/object/photosnycbeyond%3A30456/compound-parent-metadata (accessed on 05 January 2023)

2.2.1 External shading in Europe: technological timeline

The history of external shading in Europe closely followed the technological and scientific development of the age. It can be seen in the evolution of material, movement, and technology of shading.

The first companies producing external shading (like Schenker and Griesser) were founded in Switzerland in the late 19th century. Early 20th century saw roller blinds beginning to replace hinged shutters in the day-used spaces. Venetian blinds made of aluminium were first introduced in the 1940s, followed by electrically operated blinds in the late 1960s. These blinds worked with tubular motor for blinds, pioneered by French company, Somfy. The introduction of automation in external shading with weather automated blinds started in the 1980s followed by the 'smart blinds' in 2006, which communicate with the inside environment to adjust the shading for maintaining optimum lighting and temperature.

External shading has a strong market presence in Europe today. This is corroborated by the continuous growth of major market players like Griesser[17], Schenker[18] and Warema[19] in terms of revenues and expansion of business internationally.

2.2.2 External movable shading in Indian architecture

Numerous examples of external shading can be seen in historical Indian architecture through the ages suggesting that it has been consciously used for controlling heat gains in buildings. Some of these buildings can still be seen throughout the country and are even regarded as 'heritage'. Notable examples include the Jaipur Government Maharaja Public Library, the old-style buildings in Kolkata and Golconde in Puducherry.

Figure 11. Jaipur Government Maharaja Public Library with its louvered shutters

[17] Details can be found at www.griesser.ch
[18] Details can be found at www.schenkerstoren.com
[19] Details can be found at www.warema.com

Figure 12. Golconde, Puducherry, built in 1940s, one of the first 'modernist' buildings in India with EMSyS
Image courtesy: Komal Sharma

Figure 13. Shutters in old Kolkata home
Image courtesy: Sanjoy Ghosh

2.3 Market of EMSyS in India

The current external movable shading market in India consists of a few international players, a few organised sector small enterprises, and an unorganised/informal industry dealing with essentially low-cost and short-lived solutions such as bamboo *chiks* or green screen, which generally last for 2 to 4 years. In low- and middle-income residential buildings, ad-hoc arrangements (like fabric draped outside the window) can also be seen.

Figure 14. Some examples of ad-hoc arrangements used for external shading

To develop a better understanding of the market of EMSyS in India, BEEP conducted an on-ground market exploration. Discussions were held with some manufacturers, fabric providers, and architects who have implemented external movable shading in their projects. Also, to get an understanding of the ecosystem of window shading in India, discussions were done with the glass and glazing industry representatives as well.

2.3.1 Market status and barriers to adoption

Some of the characteristics of the Indian EMSyS market based on market exploration and stakeholder discussions are as listed below.

- Although external shading has been part of the Indian architecture since long and the benefits of daylight and shading are known, the market of EMSyS in India is still small and evolving.
- Regarding residential buildings, currently the implementation of EMSyS is limited to a few high-end private residences. Affordably priced EMSyS products for mass application are not readily available. The high cost of EMSyS continues to be a major hindrance to widespread acceptance of EMSyS as window shading solution. For developing affordable, adaptable to the climate- and dust-resistant EMSyS products for residential buildings, a concerted effort is required.
- Climate, geography, and architecture in different parts of India is very different. Cities like Bengaluru do not require AC for large part of the year and have different building construction as compared to those in North India. This non-uniformity is also seen in the window sizes, scale of windows, and types of windows adopted throughout India. Hence, the market for EMSyS can be very different from North to South. Consumer preferences and level of awareness also show large regional variations.
- External shading is considered as a retrofit measure and is not part of the original design of the building. End user realises the consequences upon occupation of the house when they face over-heating issues in their homes. A few EMSyS manufacturers have taken a lead in educating the architects in some of the regions in the country on EMSyS. Similarly, companies manufacturing and marketing fabrics for external shading have been involved in creating demand. Most of the marketing is passive in nature.
- Other factors that affect the uptake of EMSyS in residential buildings are (a) the added costs of its maintenance (EMSyS are perceived to be of high maintenance) and (b) their proper alignment with the outward opening windows.
- Bulk of the building market is residential. Internal blinds are considered an integral aspect of the house décor and preferred over external shading. The budget of internal décor is higher than that for the building façade for the end user.
- Overall, the manufacturers and architects are aware of the benefits of EMSyS for thermal comfort. They also feel that some incentive or push from the government, and policy intervention could be helpful in mainstreaming EMSyS in Indian buildings.

2.3.2 Steps needed to promote the EMSyS market in India

- Demand creation through increased end-user awareness is necessary. Consumer should be willing to invest in a product like EMSyS by being aware of the potential benefits and cost savings.
- Intervention at design stage of the project is necessary to ensure incorporation of EMSyS supporting features in building design. Provisions can then also be provided for adding EMSyS at a later stage.
- Cost of EMSyS needs to be brought down particularly for the lower- and middle-class housing.
- The market in India, in terms of acceptance of a new product, is very different between the north and the south and different regional marketing approaches are needed.
- EMSyS products customised to the Indian climate (high heat, dust, etc.) and the Indian customer preference need to be introduced for better uptake.
- EMSyS manufacturers and suppliers can also potentially participate in events such as Zak Doors & Windows Expo and Festival of Architecture and Interior Designing (FOAID) along with glass and glazing industry to collaborate on integrated window solutions.

2.4 EMSyS products in India

Some of the main EMSyS products in the Indian market are discussed here.

2.4.1 Bamboo chik and green net

These solutions are popular in some regions of the country (particularly in Gujarat, Rajasthan and some other states in north India), where they are used during summer season. With regular maintenance and appropriate fabric coverings such as Agronet, these simple and cheap systems can have an extended life up to 10 years.

Figure 15. Bamboo chiks and green net used on windows and balconies

2.4.2 External screens (like vertical awnings)

- External screens are composed of fabric that provides solar protection by folding or rolling vertically up and down over the surface of the opening.
- Screens have been introduced in the Indian market for balconies to combat the issue of non-standard window sizes in India, which makes mass production of

window blinds difficult. Sellers have found that the balcony sizes are more uniform in India compared to window sizes and the installation of screens there is easier. Manufacturers like Phifer, Renson, and Kelegent prefer installing balcony screens rather than other EMSyS solutions.

- Fabrics used to make these screens include Serge Ferrari, Dickson sun fabrics, and Sunbrella fabrics. Polyester and fibre glass are used for finer quality. These screens are also useful in retrofitting projects.

Figure 16. Balcony screens

Image courtesy: Private Residence in Chennai

2.4.3 Vertical louvers

- Adjustable vertical louvers, made of concrete or wood, have also been implemented in some residential projects by architects.
- These rotatable louvers operate with the help of an in-built lever or a rod slider.
- Some of the examples have been seen in Ahmedabad. These louvers seem to have a longer life and require lesser maintenance than the fabric louvers.

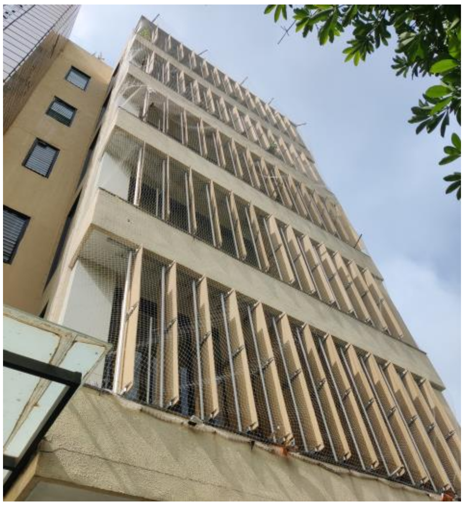

Figure 17. Karma building in Ahmedabad with external louvers

2.4.4 Awnings

Fabric-based awnings are used for window coverings. The fabric is usually polyester. Examples were also seen of retrofitting retractable awnings into residences where the purpose was aesthetic and functional (privacy also being an important reason).

Figure 18. Awnings in a residential project
Source: https://www.galaxyawnings.co.in (accessed on 10 January 2023)

2.4.5 Exterior blinds

PVC blinds

PVC vertical blinds are used as external shading for solar control. They have a functional life of 2–3 years.

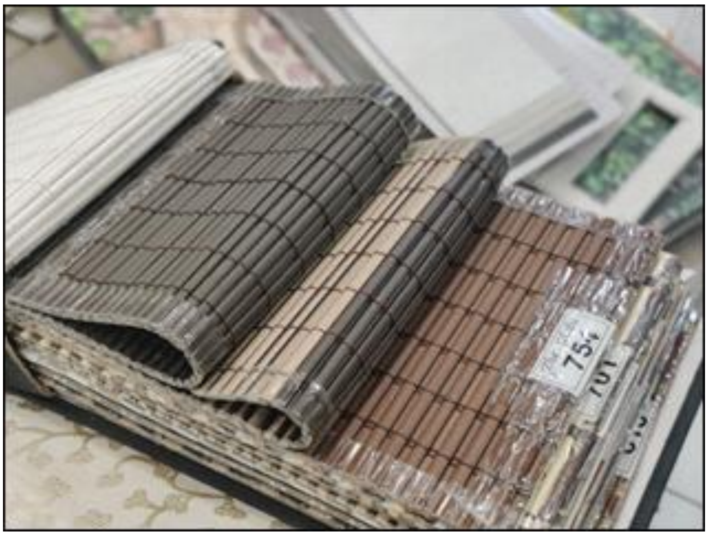

Figure 19. PVC blinds

Lamella blinds

Lamella blinds are not that extensively used in the market as of now but EMSyS players have exported lamella blinds for the demand likely to come in future.

Figure 20. Lamella blinds

Monsoon blinds

Blinds used in windows as a protection against rains during the monsoon season are quite popular in Mumbai and South India. These blinds are used in balconies, but mainly for resistance against wind and rain.

Figure 21. Monsoon blinds

2.4.6 Price range of EMSyS products in India

As described, there is a wide range of EMSyS products, and depending on their construction, average life, and durability, they come at different price ranges. Based on the discussions done with the industry during the market study, the prices for EMSyS products available in the Indian market have been compiled in Table 1.

Table 1: Price range of EMSyS products

S. no	Product	Price range (₹/ft^2)
1	Green net	3–6
2	Bamboo chik	5–6
3	External screens	350–800
4	PVC blinds	300–350
5	Awnings	200–500
6	Monsoon blinds	~1000
7	Lamella blinds	~2000
8	Vertical louvers	2200–3000

2.5 Performance monitoring of EMSyS

One of the key barriers to popularising modern EMSyS is the lack of performance results of real-life monitoring studies in the public domain, quantifying the energy savings and thermal comfort improvements using EMSyS. To address this barrier, the Indo-Swiss BEEP conducted performance monitoring of EMSyS, during 2020/21, in a newly constructed housing project. The monitoring was aimed at quantifying the savings in electricity consumption and improvements in thermal comfort by using EMSyS.

2.5.1 Monitoring space

For the monitoring, two identical flats (3 BHK) located at 10th and 11th floors of a multi-story residential tower located at Gurugram were selected. Within these flats, a west-facing bedroom was selected as test room for conducting the measurements (Figures 22–25).

Figure 22. Building showing the location of flats on 10th and 11th floors

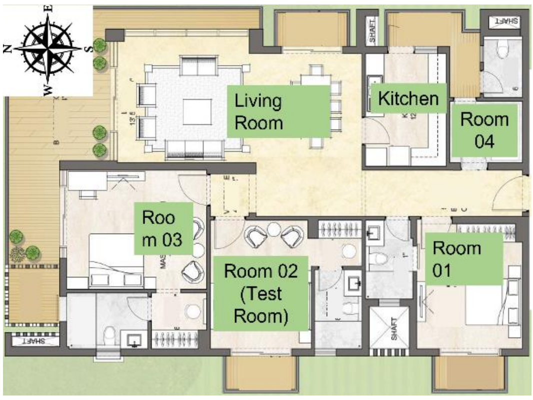

Figure 23. Floor plan of the flat showing the test room

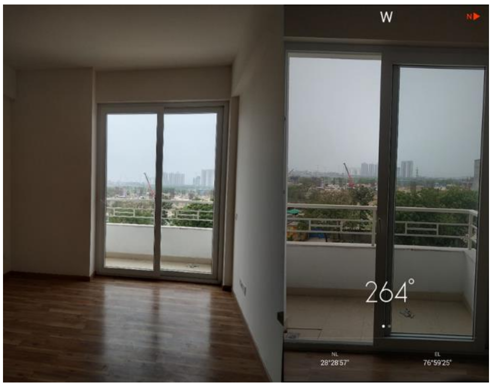

Figure 24. Inside view of the test room with sliding door orientation and coordinates

Figure 25. Balcony of the test room

2.5.2 EMSyS and internal curtains

For comparing the performance, the glazed door in the test room of 10th floor flat was equipped with internal curtains (IC), while the test room of 11th floor flat was equipped with EMSyS. The photographs of the EMSyS Product 1 (Figure 26), EMSyS Product 2 (Figure 27), and IC (Figure 28) are shown, which were used during the monitoring.

EMSyS Product 1 and Product 2 had an effective SHGC[20] of 0.25 and 0.18, respectively. Product 1 was used in the monitoring conducted during March–April 2021, while Product 2 was used during the monitoring conducted in June 2021.

Figure 26. EMSyS Product 1

Figure 27. EMSyS Product 2

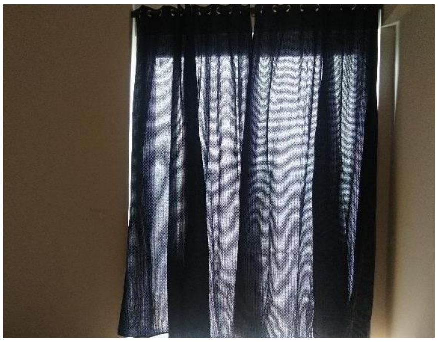

Figure 28. Internal curtain (IC)

2.5.3 Key results of natural ventilated mode

Operative temperature[21] was used as key output parameter for defining thermal comfort in the natural ventilation case. The difference in operative temperature results for 'Test room with IC' and 'Test room with EMSyS' quantified the improvement in thermal comfort due to EMSyS.

In the naturally ventilated (NV) mode, on a clear sunny day, the room with EMSyS had 3.0–3.5 °C lower peak operative temperature as compared to the room with IC. This was observed in both sets of monitoring done with EMSyS Product 1 in the month of March (Figure 29) and with EMSyS Product 2 in the month of June (Figure 30).

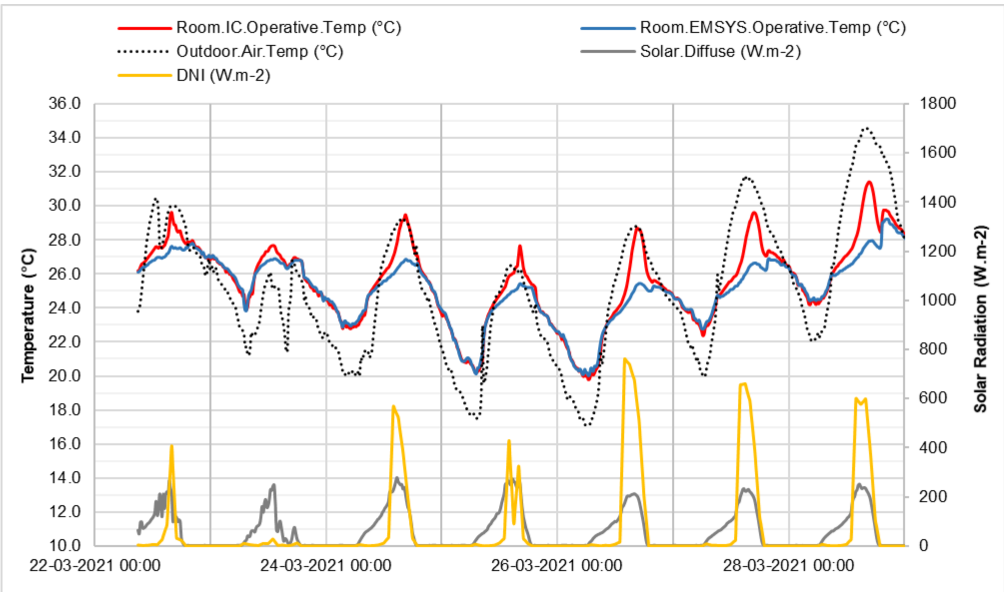

Figure 29. Operative temperature based on performance monitoring (March 2021)

[20] The SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's SHGC, the less solar heat it transmits.

[21] Operative temperature is a calculated from measured parameters such as air temperature, globe temperature, and air velocity. The operative temperature is derived using the given formula as per ISO 7726.

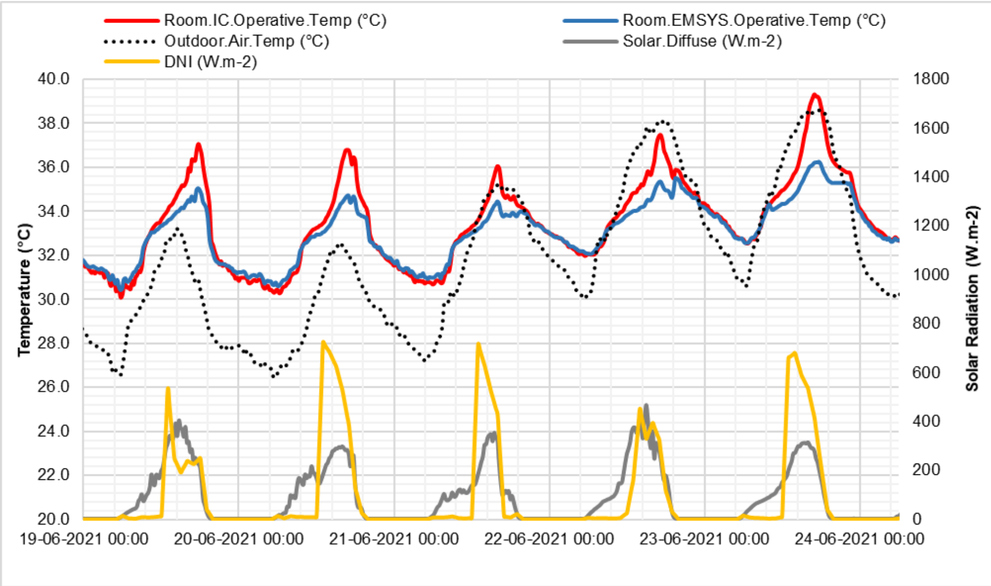

Figure 30. Operative temperature based on performance monitoring (June 2021)

2.5.4 Key results of air conditioning mode

Cooling demand was used as the key output parameter and the difference in cooling demand results for 'Test room with IC' and 'Test room with EMSyS' will quantify the impact of EMSyS. The difference in cooling demand results for 'Test room with IC' and 'Test room with EMSyS' will quantify the energy savings due to EMSyS. The set temperature for the AC during the monitoring is 24 °C. There was a loss of data on Day 2 of the experiment.

In AC mode, the room with EMSyS had ~32% less cumulative cooling demand (thermal) as compared to the room with IC. This was observed with monitoring done with EMSyS Product 1 in the month of April.

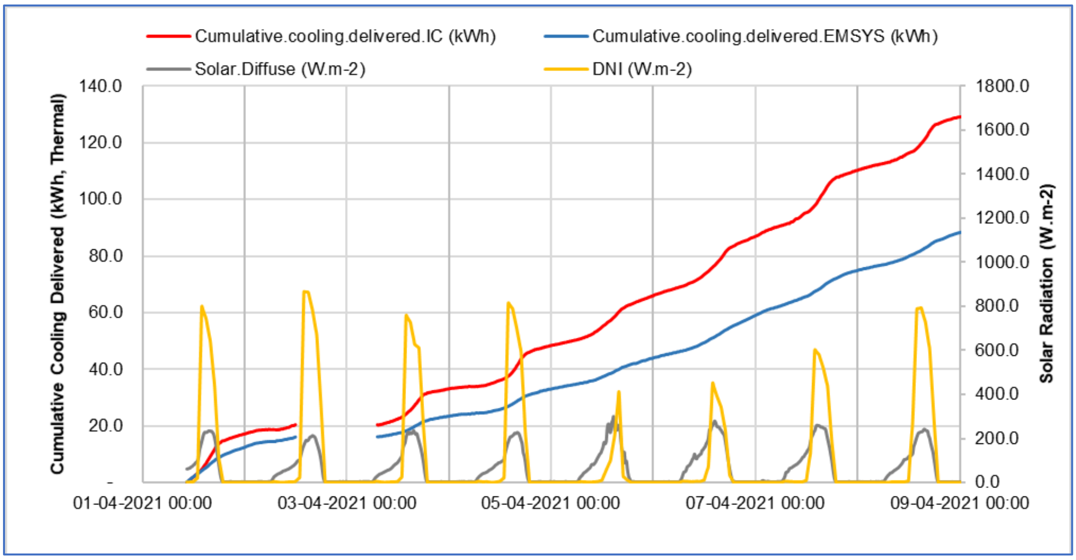

Figure 31. Cumulative cooling delivered of the test rooms in the air-conditioned mode (April 2021)

3 ESTIMATION OF EMSYS ENERGY SAVING AND THERMAL COMFORT POTENTIAL IN URBAN RESIDENTIAL BUILDINGS

In the previous chapter, we saw the performance of EMSyS through a real-life monitoring study carried out in two test rooms (one with IC and the other with EMSyS). The results showed that the test room with EMSyS delivered far better performance than the test room with IC in terms of both energy savings and thermal comfort improvements. The study does prove the efficacy of EMSyS beyond doubt.

This chapter goes a step further and quantifies the energy savings and thermal comfort potential due to use of EMSyS in urban residential buildings in India through a simulation and modelling study. The chapter also explains the methodology to estimate the space cooling requirement and cooling electricity demand, with the EMSyS penetration in India using a bottom-up approach. The calculations are done for urban households at the district level for each district, which then are summed up to estimate the space cooling requirement and cooling electricity demand at the state, climatic zone, and country levels for the base year (2020) and then projected under different scenarios till 2050.

The estimation followed 4 key steps (Figure 32):

1. Step-1: Simulation study to calculate space cooling requirement[22]
   Simulation study used all the basic inputs which were used during the ENS development. The simulation study was simplified to optimise the number of simulation runs, while adding the EMSyS and WWR as key variables. This step resulted in quantifying the space cooling requirement per unit of conditioned area for the year, for different combinations of climate, WWR and with/without EMSyS.
2. Step-2: Estimation of residential built-up area (urban) at district level
   Using the key inputs such as population growth, household size, and built-up area per household, the estimations were done for the urban residential built-up area for all the districts till 2050.
3. Step-3: Estimation of total space cooling requirement in urban residential houses
   The key consideration for the calculations was the principle of equity, i.e., providing thermal comfort for all the households throughout the year. Here, the estimations of total space cooling requirement was done using the simulation results from step-1 and the estimated urban residential built-up area from step-2.
4. Step-4: Estimation of cooling electricity demand and CO_2 emissions
   In this study, the advancement of cooling technology is not considered to solely focus on the electricity savings through EMSyS, and not to merge it with any other technology. Results from step-3 along with the efficiency of cooling systems were used to calculate energy saving. While the results from step-3 along with the emission factors were used to calculate CO_2 emissions.
   Three different scenarios were developed with varying EMSyS installation and WWR. Estimation of the cooling electricity demand and CO_2 emissions were done till the year 2050 under all three scenarios.

[22] The space cooling requirement (in kWh_{th}) is defined as the amount of thermal energy that needs to be removed from the inside of buildings to maintain thermal comfort. Simulation results were calculated to get the cooling requirement per unit of conditioned area for the year (i.e. kWh_{th}/m^2 of conditioned area per year).

All these steps are described in more detail in the subsequent sections.

Step-1: Simulation study to calculate space cooling requirement in kWh_{th}/m^2 of conditioned area.year

Input/Analysis:	Climate zone, WWR, EMSyS penetration

↓

Step-2: Estimation of residential built-up area (urban) at district level

Input/Analysis:	Population growth, household size, and built-up area per household

↓

Step-3: Estimation of total space cooling requirement in urban residential houses

Input/Analysis:	Simulation results from step-1, Data structure from step-2

↓

Step-4: Estimation of cooling electricity demand and CO_2 emissions

Input/Analysis:	*$CoP_{equivalent}$ of cooling technology	Electricity emission factor for India

Figure 32. Steps followed for EMSyS potential estimation

**Equivalent coefficient of performance* ($\mathrm{CoP}_{equivalent}$): It is the ratio of cooling provided (or heat removed) by the cooling system to the energy input to the cooling system. It gives the efficiency at which thermal energy will be removed, i.e., efficiency of the cooling technology employed.

$$\text{Cooling electricity demand (kWh)} = \text{Space cooling requirement } (\mathrm{kWh}_{th})/\mathrm{CoP}_{equivalent}$$

3.1 Step 1: Simulation study to calculate space cooling requirement

The key steps of the simulation methodology and its details are given below.

Climatic zone segregation and city selection in climatic zone

↓

Adopting ENS simulation model for typical floor plans

↓

Input parameters and their values for energy simulations

↓

Simulation results and their post processing

Figure 33. Simulation methodology flow chart

3.1.1 Climatic zone segregation and city selection in climatic zones

India has five climatic zones; out of which three climatic zones (Composite, Hot-Dry and Warm-Humid) have higher cooling requirement. As the key role of EMSyS is in reducing the cooling requirement (or heat gains), these three climatic zones were considered for the simulation study. Also, the cooling period in Composite and Hot-Dry regions remains similar (8 months) while in the Warm-Humid region, it is about 10 months.

Table 2. Different climatic zones with city adopted for simulation study

Climatic zone	Cities
Hot-Dry (1 City)	Ahmedabad
Composite (1 City)	New Delhi
Warm-Humid (2 Cities)	Mumbai, Chennai

3.1.2 Adopting ENS simulation model for typical floor plans

Majority of the new urban houses in India are in the form of multi-storey apartment buildings. The simulation model for ENS development focused on typical building floor plans in the urban area. A survey covering 40 residential projects (multi-storey apartment buildings in urban area) was conducted to understand the characteristics of residential buildings. The survey resulted in development of an average or representative dwelling unit plan and two predominant types of floor plans – Point Block (PB) and Doubly Loaded Corridor (DLC). Figure 34 shows the typical dwelling unit plan of a 80 m^2 house, Figure 35 shows the floor plan for the PB) configuration with the typical dwelling unit, and Figure 36 shows the floor plan for the DLC) configuration with the typical dwelling unit. These unit/floor plans were used during the ENS development and the same has been used here also.

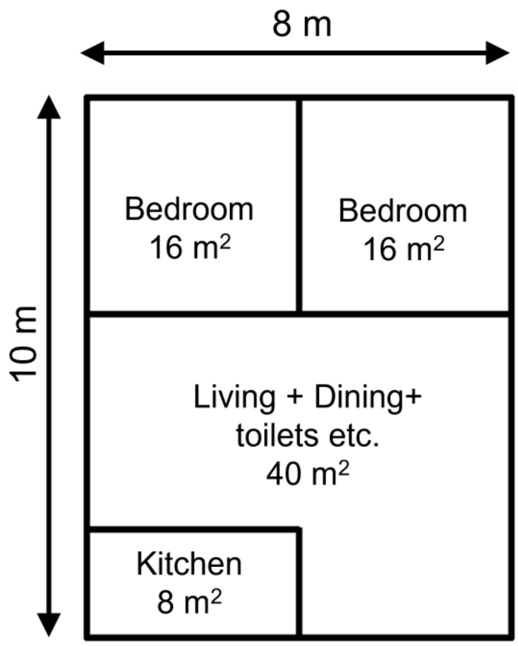

Figure 34. Dwelling unit plan (Area = 80 m^2)

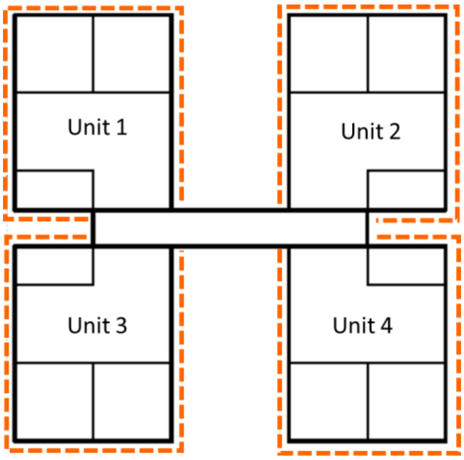

Figure 35. The floor plan for the point block

Exposed facades ---------

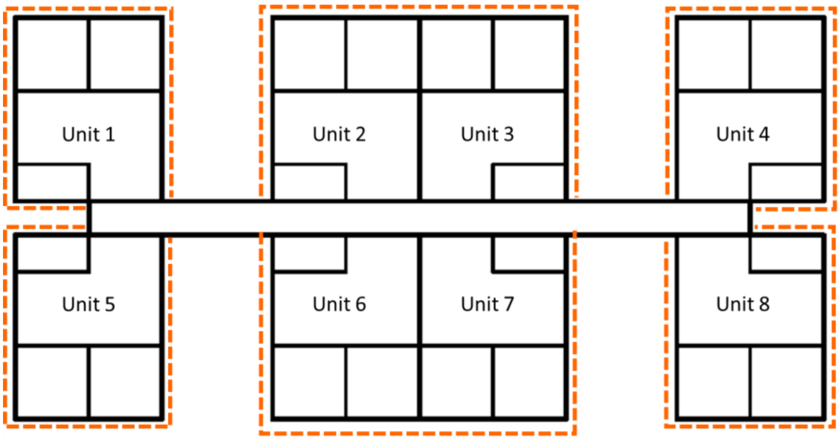

Figure 36. Floor plan for doubly loaded corridor type

3.1.3 Input parameter and their values for energy simulations

The simulation work during the ENS (Part-I) development considered large variations in different building envelope component options (walling, roofing, glazing, shading, window-to-wall area ratio, window openable area) with different locations, building layout and orientations. It resulted in about 30,000 simulation runs in total. For EMSyS potential estimation, the same models were used, but the parameters were limited, as the key impact of EMSyS will be on the heat gains from the windows. Therefore, under the building envelope component options, the variation in shading and window-to-wall area ratio were considered, while other parameters were taken as the predominant type. A total of 192 simulations cases were prepared with the combination of parameters as explained below.

External wall: From 2011 Census, it is noted that brick accounts for almost 70% of the total wall material in urban residential houses and it is likely to remain the predominant walling material in the near future as well. The simulation model considers external wall as 230-mm brick with plaster on both sides (U-value = 2.0 W/m^2.K) in all simulation cases.

Glazing: During the survey of 40 residential projects done during ENS Code development, it was found that most of the projects use 6-mm single clear glass. Therefore, only 6-mm single clear glass is considered as glazing construction type for energy simulation. Table 3 gives its U-value, solar heat gain coefficient (SHGC), and visual light transmittance (VLT) values.

Table 3. Glazing specifications

Construction	U-value ($W/m^2.K$)	SHGC	VLT
6-mm single clear glass	5.78	0.82	0.88

Shading: During the ENS survey, it was observed that a 300-mm overhang is most used and the same is used as fixed shading in all simulation cases. As the study aims to quantify the impact of EMSyS, half of the cases are considered with EMSyS and half of the cases without EMSyS. Table 4 captures the specifications of EMSyS considered for the study.

Table 4. EMSyS specifications

Parameter	EMSyS details used in simulations
Effective SHGC with product (from simulation)	0.18
Openness factor of product	4%
Reflectivity of product	46%

Window-to-wall ratio (WWR): During the survey conducted for ENS development, window-to-wall area ratio (WWR) for the projects varied from 8.4% to 21.6% with an average value of ~15%. The current trend of WWR was studied during the market assessment and the WWR value is estimated to go up to 35%. For energy simulation, WWR values varied from 15% to 35% with a step of 10% (i.e., 15%, 25%, 35%).

Openable area: During the survey for ENS development, it was found that the majority of the projects have two-pane sliding windows. Therefore, in all simulation cases, 50% (for a two-pane sliding window) openable area was considered, which can be opened for natural ventilation.

Orientation: The orientation of a building has a lot of impact on heat gains. The two extreme orientations – i.e., one case longer façade facing North-South and in the other case longer façade facing East-West – are considered to account for its impact.

Cooling scenario: All the cases prepared by a combination of different building envelopes were simulated with two cooling scenarios:

1. 100% air-conditioned with priority given to natural ventilation, i.e., if the set-points can be achieved by opening the window, then the cooling system remains OFF.
2. 100% naturally ventilated with no mechanical cooling.

Overall simulation cases: Table 5 shows the overall simulation cases with the combination of location, floor plan, orientation, WWR, and shading and cooling scenarios.

Table 5. Overall simulations cases

Variable	No. of values
Locations	4
Floor plan	2
External wall	1
Glazing	1
Shading (fixed shading without EMSyS and fixed shading with EMSyS)	2
WWR	3
Openable area	1
Orientation	2
Cooling scenario	2
Total (All possible combinations of different variable)	**192**

3.1.4 Simulation results and their post processing

The simulation runs and the post processing were done in two sets.

- Air-conditioned (AC) case
- Naturally ventilated (NV) case

AC Case

In the AC case, the objective of the simulation was to quantify the impact of EMSyS on reduction in space cooling requirement. Simulation runs were done for a ‘cooling period’, which varied as per climatic zone. For the warm-humid climatic zone, it was considered as 10 months (February to November) and for other climatic zones (composite, hot-dry, and temperate) it was considered as 8 months (March to October) in the year. The key parameter calculated from simulation results for the AC case was the space cooling requirement.

Space cooling requirement: It is defined as the total amount of heat (thermal) (kWh_{th}) removed by the air-conditioner from the cooled area for the entire year divided by the cooled area (m^2). Its unit is $kWh_{th}/m^2.y$.

The space cooling requirement is calculated for two scenarios: (1) Without EMSyS installed on the exterior windows and (2) With EMSyS installed on all the exterior windows.

All the energy simulations were done using ‘EnergyPlus’ simulation engine. The data from ‘EnergyPlus’ simulation result files were collated and analysed using ‘MS-Excel’. Table 6 shows the summary of space cooling requirement for the first scenario (without EMSyS); Table 7 reveals the data in the second scenario (without EMSyS). Figure 37 shows the results with the combination of climatic zone and WWR.

Table 6. Space cooling demand (thermal) without EMSyS ($kWh_{th}/m^2.y$)

Climatic zone	WWR = 0.15	WWR = 0.25	WWR = 0.35
Hot-dry	197	228	260
Warm-humid	185	217	247
Composite	169	199	229

Table 7. Space cooling demand (thermal) with EMSyS ($kWh_{th}/m^2.y$)

Climatic zone	WWR = 0.15	WWR = 0.25	WWR = 0.35
Hot-dry	172	186	199
Warm-humid	158	172	185
Composite	141	153	165

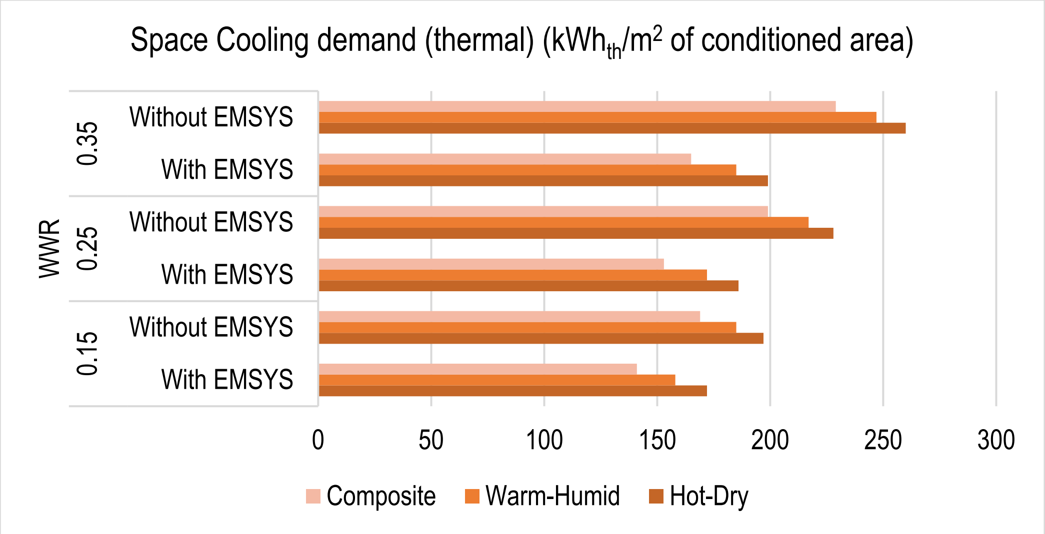

Figure 37. Space cooling demand (thermal) in the AC case for different WWRs and climate zones

The energy saving potential with the use of EMSyS ranges from 13% to 28%. Higher the WWR, higher is the saving potential. In other words, the maximum impact of using EMSyS is observed for higher WWR. However, the highest absolute savings can be achieved by limiting the WWR and by using EMSyS.

NV Case

In the NV case, the objective of the simulation was to quantify the impact of EMSyS on reduction in discomfort hours. Simulation runs were done for 10 months (February to November) and for predominant climatic zones (composite, hot-dry, warm-humid). The key parameter calculated from simulation results for the NV case was the discomfort hours.

The windows are opened for ventilation whenever outside air temperature is lower than the inside operative temperature and EMSyS are kept closed only when the solar limit exceeds (global radiation = 120 W/m^2) so as to prevent the heat from entering inside the building. The discomfort hour is calculated for two scenarios: (1) Without EMSyS installed on the exterior windows and (2) With EMSyS installed on all the exterior windows.

Discomfort hours are calculated based on the IMAC (India Model for Adaptive Thermal Comfort) Band. IMAC gives comfortable temperature bands (upper and lower limit) along with its acceptability percentage for air conditioned, naturally ventilated, and mixed-mode buildings. It is developed through an empirical field study specific to the Indian context. It defines a temperature band within which the space can be considered as thermally comfortable.

Discomfort hour (DH) is calculated for NV spaces for the cooling period based on IMAC, which is the summation of number of hours when the hourly operative temperature is more than the IMAC band maximum temperature. It is counted only for hours when the temperature goes outside the IMAC temperature band with 90% acceptability. If the operative temperature is lower than the IMAC band maximum temperature, then the space is considered thermally comfortable.

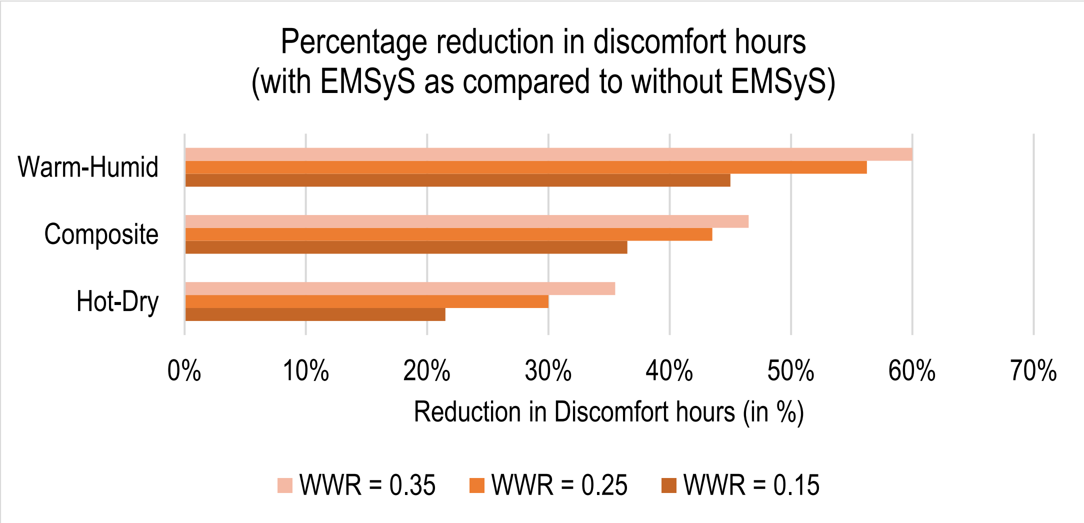

Figure 38. Percentage reduction in discomfort hours for the NV case with different WWRs and climate zones

EMSyS and natural ventilation together can produce the maximum reduction in discomfort hours by up to 60%. Among the climate zones, the highest reduction in discomfort hours due to use of EMSyS is observed in the warm-humid climate zone, followed by the composite zone and hot-dry zone.

3.2 Step 2: Estimation of residential built-up area (urban) at district level

With the simulation results available for space cooling requirement, there was a need to quantify the conditioned area in different climatic zones. Also, there was a need to define 'urban area' as this study is focused on only urban residential buildings. The future projection of urban areas was also needed for future space cooling requirement estimations. For this, district-level data for population, household area, conditioned area, urbanisation rate, etc. was required. To develop this framework for calculation and future projections, the methodology used in IETP study,[23] is also used here. For this analysis, 2020 is taken as the base year, and all the key parameters are estimated for the years 2020, 2030, 2040, and 2050. The key steps are given here while more details are added in Annexure A.1.

- Projection of population and the number of households in urban areas of each district: Based on the district-wise population and the number of households data from census 2001 and 2011, and projections of country's population available for 2050,[24]

[23] Maithel S, Chandiwala S, Bhanware P, Rawal R, Kumar S, Gupta V, Jain M. June 2020. Developing cost-effective and low-carbon options to meet India's space cooling demand in urban residential buildings through 2050. India Energy Transformation Platform

[24] http://iess2047.gov.in/ (assessed on 21 December 2022)

the district-wise population and the number of households are projected until 2050. The number of households in urban areas is also projected for each district based on the urbanization trend.

- Projection of urban residential built-up area is done as follows:
    - NSSO 2008 provides data on state-wise average built-up area per household during 2006/07. The same data is assumed as the average built-up area per household for the year 2011 also.[25]
    - The average residential area per capita versus GDP per capita (purchasing power parity [PPP]) has been plotted for different countries by IEA (Figure 39). It is observed that though all countries show an increase in average residential area per capita with GDP growth, China shows higher average floor space (~40 m^2/person) at the per capita GDP of around USD 20,000, while Mexico, at similar per capita GDP, shows a smaller average floor area (~25 m^2/person) and Korea, at almost twice the per capita GDP of China (~USD 40,000), has only around 30 m^2/person. Some studies[26] project India's per capita GDP (PPP) to reach to around USD 40,000 by 2050. So, the question is whether India will follow Korea or China in terms of floor area per capita growth during the 2020–50 period. Recent literature on current trends in urban residential housing in India indicates that in the coming decade, a large part of new urban housing in India is to be expected in the form of affordable housing[27] and co-living spaces[28] emerging as preferred option by the younger generation. If both trends persist until 2050, the increase in per capita urban residential floor area will be relatively small. From an environmental sustainability viewpoint also, less resource use in new construction and compact cities are desirable. Considering these trends, we expect only a marginal increase in per capita residential floor area in India.

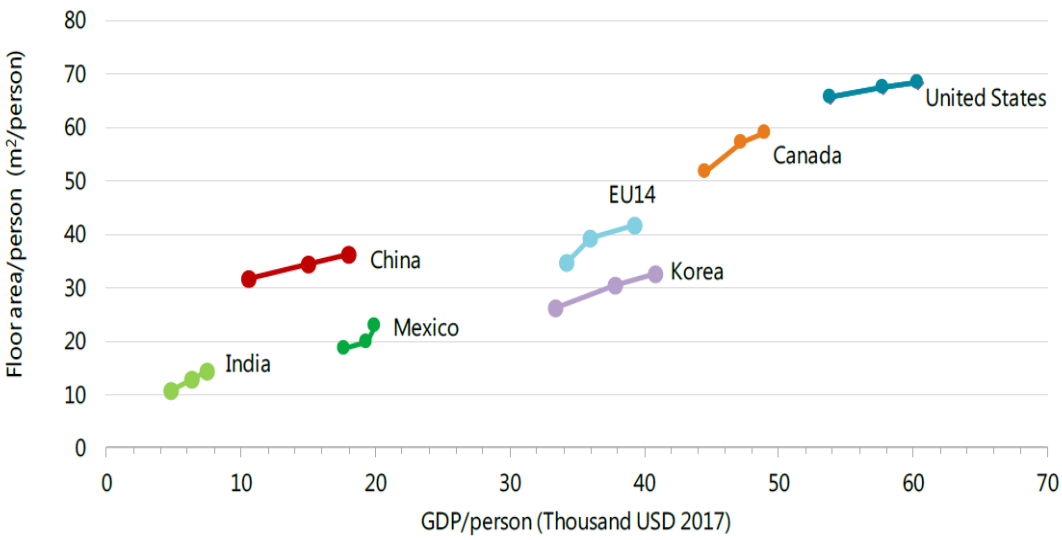

Figure 39. Average residential area per capita versus GDP in selected countries

Source: IEA, 2019

[25] Household Consumer Expenditure in India, 2006-07, National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Government of India, October 2008

[26] https://www.pwc.com/gx/en/issues/economy/the-world-in-2050.html (assessed on 21 December 2022)

[27] https://www.cbre.co.in/en/about/media-centre/cbre-credai-real-estate-in-2030 (accessed on 21 January 2023)

[28] http://www.businessworld.in/article/How-Co-Living-Is-Addressing-The-Challenges-Of-India-s-Real-Estate-Space/24-08-2019-175157/ (accessed on 21 January 2023)

Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) publishes detailed guidelines on the minimum and recommended (ideal) amount of living space that a person should have to have a 'healthy and culturally fulfilling life'.[29] As per these guidelines, the recommended (ideal) amount of floor space required for a household for leading a fulfilling life with various lifestyle activities is 20 m^2 × no. of people + 15 m^2 in urban areas and 25 m^2 × no. of people + 25 m^2 in rural areas. For our analysis, it has been assumed that by 2050 the average built-up area per household in India will be equal to the Japanese recommended norms. For the intermediate years, i.e., between 2011 and 2050, linear interpolation has been used to calculate the built-up area per household. The assumptions made in our study result in an average urban residential area per capita of 24.2 m^2 in 2050.

- The total built-up area is segregated into existing and newly constructed area for each of the time periods, i.e., 2020–30, 2030–40, and 2040–50. For this, the life of a building is assumed to be 50 years and further that the built-up area existing in 2020 will be demolished at a uniform rate every year until 2070 and will be replaced by new buildings. This segregation helps us in developing different strategies for improving building envelope properties of existing and new buildings.

3.3 Estimation of total space cooling requirement in urban residential houses

- The space cooling requirement ($kWh_{th}/m^2.y$) for the combination of climatic zone, EMSyS penetration, and WWR was defined in Section 3.1.4. As the calculations are done 'bottom-up', using the data at district level; all the information / data is collated for each district.
- The space cooling requirement depends on the climate. A state-wise list of all the districts as per the 2011 census and their respective climatic zone[30] was prepared.
- Intermediate floor of the household is considered to estimate the space cooling requirement. The data from the census 2011 is used to pick the predominant walling material for all districts and is assumed to remain the same for all future constructions. Other key envelope parameters such as window glass properties and window fixed shading are kept the same for all districts and assumed to remain the same till 2050.
- Cooled area: 70% of the total built-up area is considered for estimating the space cooling requirement, assuming that only 70% of the built-up area of each household needs to be cooled (excluding kitchen and toilet areas) for providing thermal comfort.
- Estimation of total cooling requirement (kWh_{th}/y): It is calculated by multiplying the 'space cooling requirement' for the district (based on combination of climatic zone, EMSyS penetration, and WWR) and the 'cooled area' for the district.

29 https://resources.realestate.co.jp/living/how-much-living-space-does-the-average-household-have-in-japan/ (accessed on 21 January 2023)

30 India's predominant three climatic zones as per the National Building Code are considered in this study i.e., Warm-Humid, Hot-Dry, and Composite.

- For each district, separate calculation is done for existing and new buildings. The WWR and EMSyS penetration vary with time under different scenarios and calculations are done accordingly.

3.4 Estimation of cooling electricity demand and CO_2 emissions

- Estimation of cooling electricity demand in different scenarios: The equivalent coefficient of performance ($CoP_{equivalent}$) of cooling appliances is taken as 2.75 for the base year 2020,[31] and assumed to remain constant to estimate the cooling electricity demand.
- Estimation of CO_2 emission: This is done by multiplying the cooling electricity demand with the emission factor (0.71 kg CO_2/kWh).[32] The emission factor is assumed to remain constant for the 2020–50 period.

3.4.1 Scenarios

In this study, the focus is on the implication of EMSyS in India. As building envelope materials are assumed to remain unchanged for the next 30 years, the cooling electricity demand of a building will depend on two factors:

1. The trend of window-to-wall area ratio.
2. Penetration of EMSyS.

For the projected cooling electricity demand until 2050, 3 scenarios are considered:

- **Business-as-usual (BAU) scenario**, which assumes that in the absence of any additional measures, the trend of window-to-wall area ratio and the penetration of EMSyS will follow BAU trends.
- **Scenario 1,** in which EMSyS is made mandatory in urban residential buildings and window-to-wall area ratio follows the BAU trend.
- **Scenario 2** estimates the EMSyS potential by assuming that EMSyS is made mandatory in urban residential buildings and also limiting the window-to-wall area ratio.

The target values set for EMSyS penetration and window-to-wall area ratio under the two scenarios are discussed in the following sections.

Window to wall area ratio and EMSyS penetration

Tables 8–10 set the target values of **window-to-wall area ratio and EMSyS penetration** for existing and new building stock during different time periods until 2050 under three scenarios, respectively. Based on these two factors, the total cooling demand per conditioned area (kWh_{th}/m^2) is calculated for the three scenarios.

To understand the EMSyS penetration in the current market (till year 2022), various webinar and roundtable meetings were conducted among key stakeholders under Indo-Swiss Building Energy Efficiency Project (BEEP). It is estimated that around 75,000 m^2 of EMSyS fabric is installed on exterior window of residential houses. The corresponding EMSyS penetration number to this number is 0.0073%.

[31] http://iess2047.gov.in/ (assessed on 20 January 2023)
[32] https://cea.nic.in/wp-content/uploads/baseline/2023/01/Approved_report_emission__2021_22.pdf (assessed on 20 January 2023)

Table 8. Total cooling demand (thermal) per unit conditioned area under BAU scenario

Existing buildings	2020	2030	2040	2050
Hot-dry (kWh_{th}/m^2)	197	197	196	196
Warm-humid (kWh_{th}/m^2)	185	185	184	184
Composite (kWh_{th}/m^2)	169	169	169	169
WWR (fraction)	0.15	0.15	0.15	0.15
EMSyS penetration (%)	0.007	0.021	1.987	2.00
New buildings		**2020–30**	**2030–40**	**2040–50**
Hot-dry (kWh_{th}/m^2)		202	227	226
Warm-humid (kWh_{th}/m^2)		190	215	214
Composite (kWh_{th}/m^2)		174	198	197
WWR (fraction)		0.165	0.25	0.25
EMSyS penetration (%)		0.0124	2.75	5.0

Table 9. Total cooling demand (thermal) per unit conditioned area under Scenario 1

Existing buildings	2020	2030	2040	2050
Hot-dry (kWh_{th}/m^2)	197	197	184	172
Warm-humid (kWh_{th}/m^2)	185	185	171	158
Composite (kWh_{th}/m^2)	169	169	155	141
WWR (fraction)	0.15	0.15	0.15	0.15
EMSyS penetration (%)	0.007	0.012	50.0	100.0
New buildings		**2020–30**	**2030–40**	**2040–50**
Hot-dry (kWh_{th}/m^2)		172	186	186
Warm-humid (kWh_{th}/m^2)		158	171	171
Composite (kWh_{th}/m^2)		141	153	153
WWR (fraction)		0.15	0.25	0.25
EMSyS penetration (%)		100.0	100.0	100.0

Table 10. Total cooling demand (thermal) per unit conditioned area under Scenario 2

Existing buildings	2020	2030	2040	2050
Hot-dry (kWh_{th}/m^2)	197	197	184	172
Warm-humid (kWh_{th}/m^2)	185	185	171	158
Composite (kWh_{th}/m^2)	169	169	155	141
WWR (fraction)	0.15	0.15	0.15	0.15
EMSyS penetration (%)	0.007	0.012	50.0	100.0
New buildings		**2020–30**	**2030–40**	**2040–50**
Hot-dry (kWh_{th}/m^2)		172	176	176
Warm-humid (kWh_{th}/m^2)		158	162	162
Composite (kWh_{th}/m^2)		141	145	145
WWR (fraction)		0.15	0.18	0.18
EMSyS penetration (%)		100.0	100.0	100.0

Figure 40 shows the EMSyS penetration for total building stocks over the years till 2050 under different scenarios. The national average for window-to-wall area ratio is assumed to follow the trend under different scenarios as shown in Figure 41.

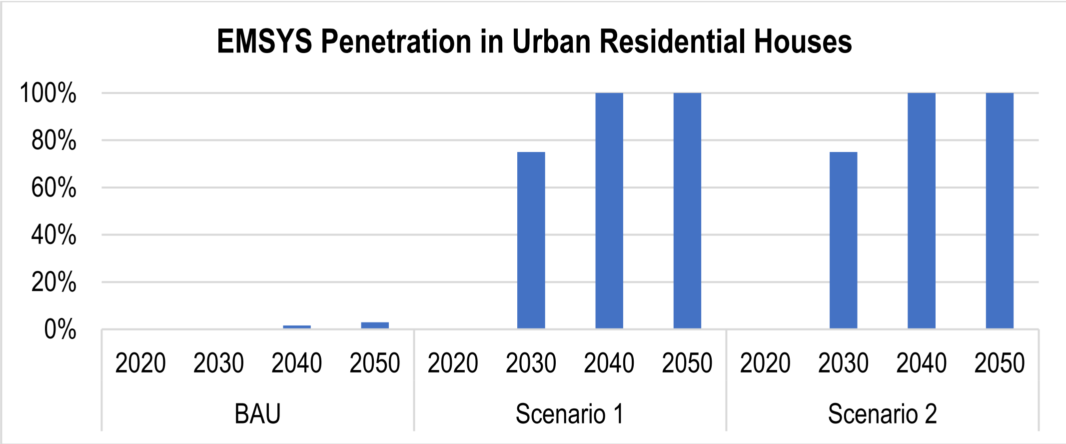

Figure 40. EMSyS penetration under different scenarios

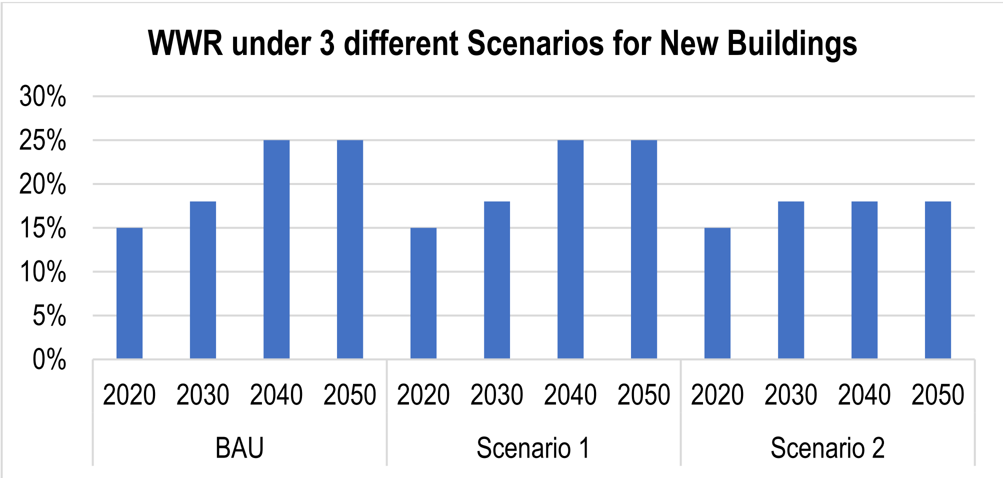

Figure 41. Window-to-wall area ratio under different scenarios

3.4.2 BAU Scenario

The BAU scenario assumes slow implementation of EMSyS adoption and slow expansion of market. As ENS 2018 is applicable to residential buildings constructed on a plot size of ≥500 m^2, a large part (≥50%) of the residential construction is assumed to remain outside the purview of ENS 2018. Further, it assumes no update of ENS 2018 during 2020–50.

It assumes no policy action taken to retrofit existing residential building stock and hence no improvement in the Residential Envelope Transmittance Value (RETV) of existing residential buildings during the entire 2020–50 time period.

The WWR is assumed to follow the current trends of new building constructions of high glazing. The WWR ratio is expected to increase to 25% for urban residential houses by 2040 with current market trends and remain at the same level thereafter.

3.4.3 Scenario 1

In this scenario, the installation of EMSyS significantly improves as ENS incorporates EMSyS and implementation of ENS is taken up in a mission mode by the Government of India. The link between ENS code and EMSyS can be understood in Annexure A.4. It is further assumed that the EMSyS industry and the glass/window industry develops a strong partnership resulting in affordable products suitable for mass consumption that are adopted by the building industry. A market transformation programme (consisting of labelling, industrial support, procurement, etc.) on EMSyS is launched. However, in this scenario, the WWR follows the BAU trends (expected to increase to 25% by 2040 and remain at the same level thereafter).

3.4.4 Scenario 2

Scenario 2 is a variation of Scenario 1, in which increased awareness and stronger implementation of ENS result in stopping the trend towards large WWR and the average WWR increases to 18% by 2030 and remains at the same level thereafter till 2050. All other parameters remain the same as Scenario 1.

3.5 Results

3.5.1 Space cooling requirement

The space cooling requirement for urban residential buildings for providing thermal comfort for all is expected to increase from 707 TWh_{th}/y in 2020 to 2970 TWh_{th}/y in 2050 in the BAU scenario. Improvement in EMSyS penetration as per Scenario 1 can help in reducing the space cooling requirement to 2397 TWh_{th}/y in 2050, which is about 19% lower compared to that of BAU Scenario. At the same time, about 22% savings in thermal cooling demand could be achieved by following Scenario 2.

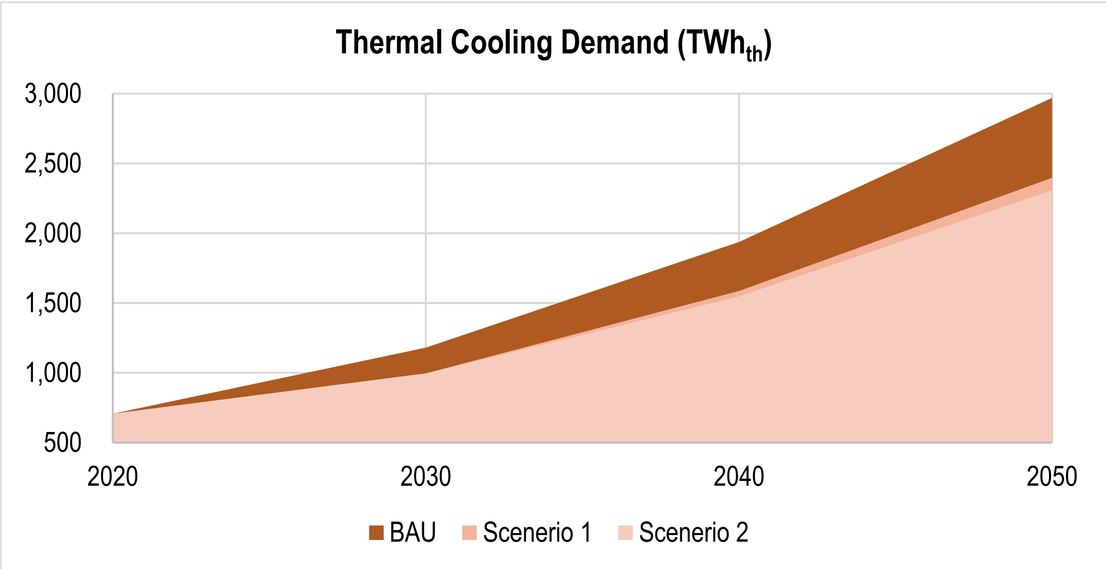

Figure 42. Space thermal cooling demand under three different scenarios

The total projected savings will depend on the climate conditions and the urban built-up area. Figure 43 shows the potential of cooling electricity saving in urban residential building by using EMSyS for different states of India. This can help in targeting key states, which can be focused first.

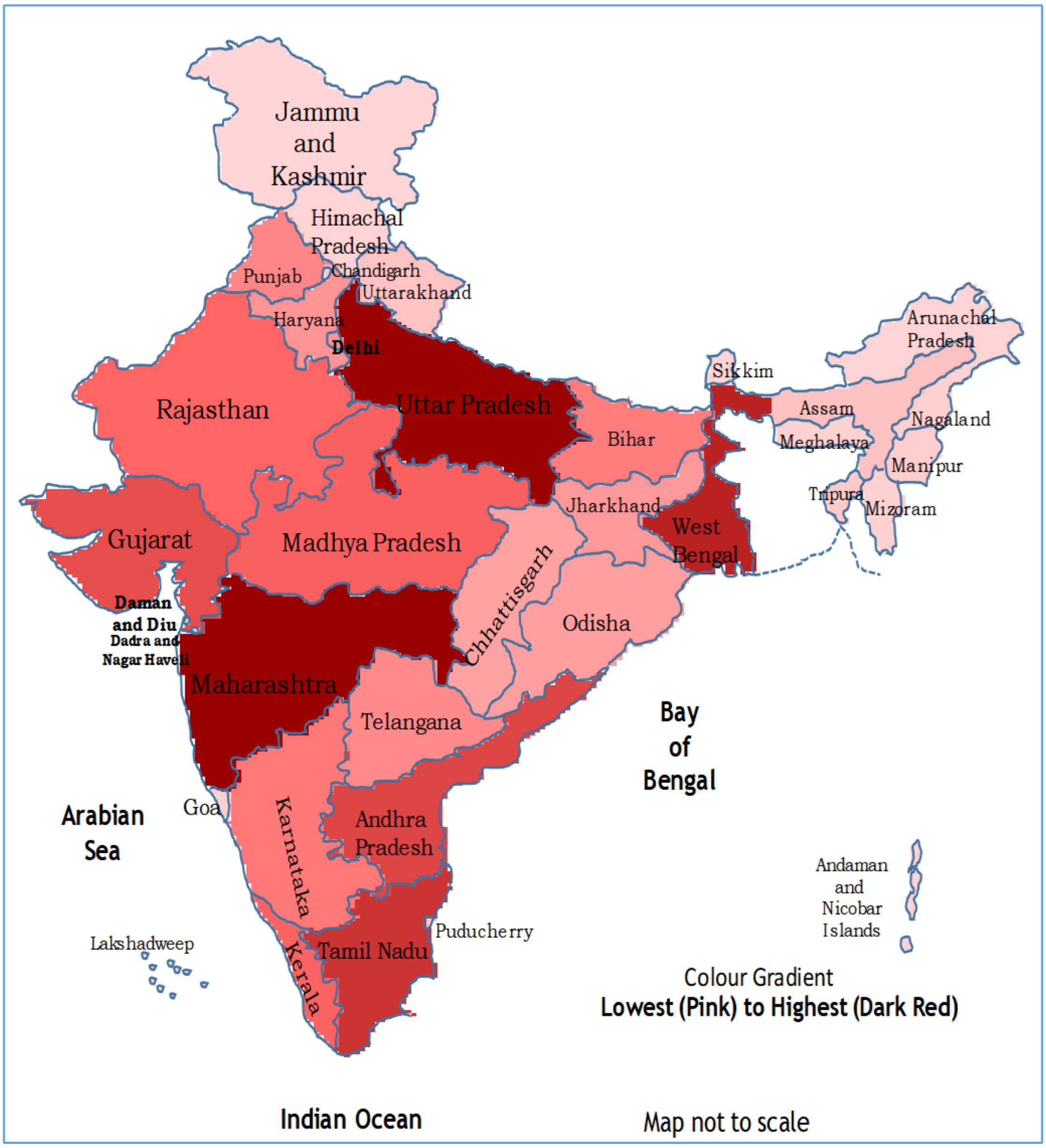

Figure 43. Space thermal cooling saving potential for different states of India

Thermal demand saving potential is maximum in Maharashtra, Uttar Pradesh, and West Bengal with combined savings of up to 200 TWh_{th}/y in the year 2050.

In addition to reduction in cooling demand, the discomfort hours in the non-conditioned houses can be reduced by 20% to 60% by using EMSyS.

3.5.2 Cooling electricity demand and CO_2 emission

The cooling electricity demand for providing thermal comfort for all in urban residential buildings is estimated at 257 TWh/y for the year 2020. Under the BAU scenario, it is expected that the cooling electricity demand will increase to 1080 TWh/y in 2050. Under Scenario 1, for the year 2050, the cooling electricity can be reduced to 872 TWh/y, which is almost 19% less than that in the BAU Scenario. With Scenario 2, it can be reduced further to 839 TWh/y, which is 22% lower as compared to BAU Scenario.

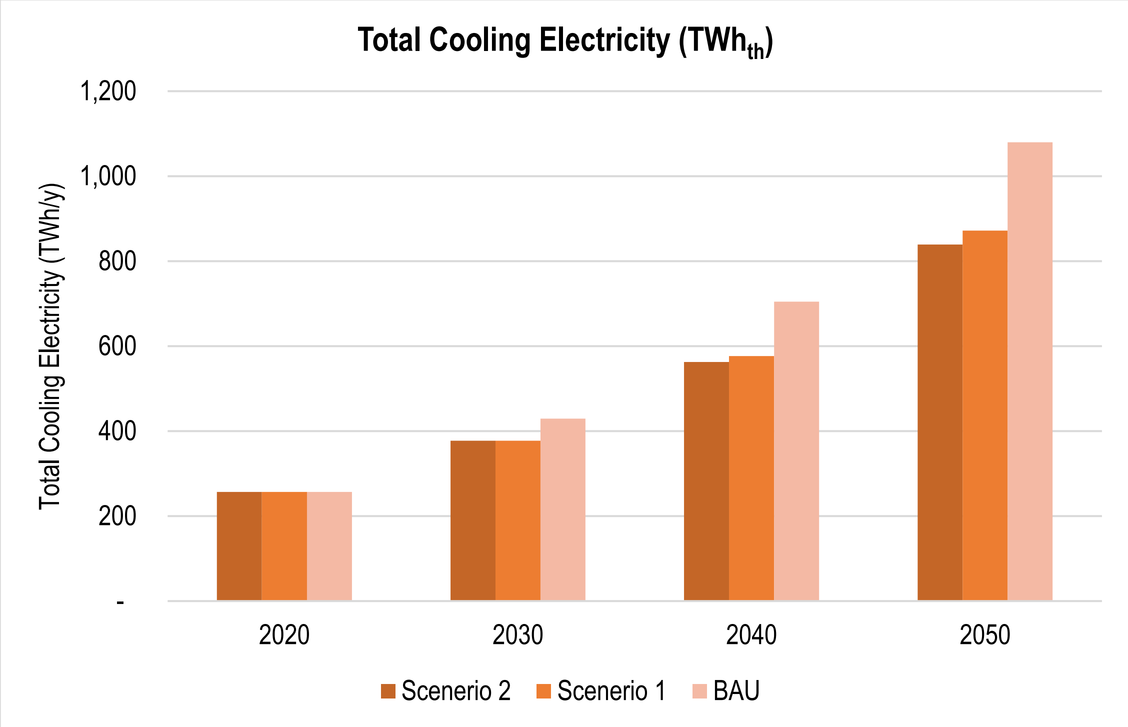

Figure 44. Cooling electricity under different scenarios

Under Scenario 2, in the year 2050, the electricity saving potential due to EMSyS is estimated to be up to 241 TWh/y, which translates to an emission reduction of 171 million tCO_2/y (considering the emission factor for FY21/22 for India[33] as 0.71 tCO_2/MWh). Similarly, the reduction in electricity consumption of 241 TWh/y (for 2050) will translate to avoidance of 43.3 GW of power generated from thermal power plants (considering the average plant load factor of central sector thermal power plant[34] as 63.4%), using the full potential of EMSyS.

[33] Source: CO2 Baseline Database for the Indian Power Sector, Central Electricity Authority, Ministry of Power (https://cea.nic.in/wp-content/uploads/baseline/2023/01/Approved_report_emission__2021_22.pdf)
[34] Source: General Review 2022, Central Electricity Authority, Ministry of Power (https://cea.nic.in/wp-content/uploads/general/2022/GR_2022_FINAL.pdf)

4 POLICY RECOMMENDATIONS AND STRATEGIES FOR DEVELOPING THE MARKET OF EMSYS

4.1 Introduction and rationale

EMSyS: Important measure for an energy efficient building

The way to net zero energy and carbon in buildings is only possible if all the passive, highly efficient active and renewable energy systems are used in combination.

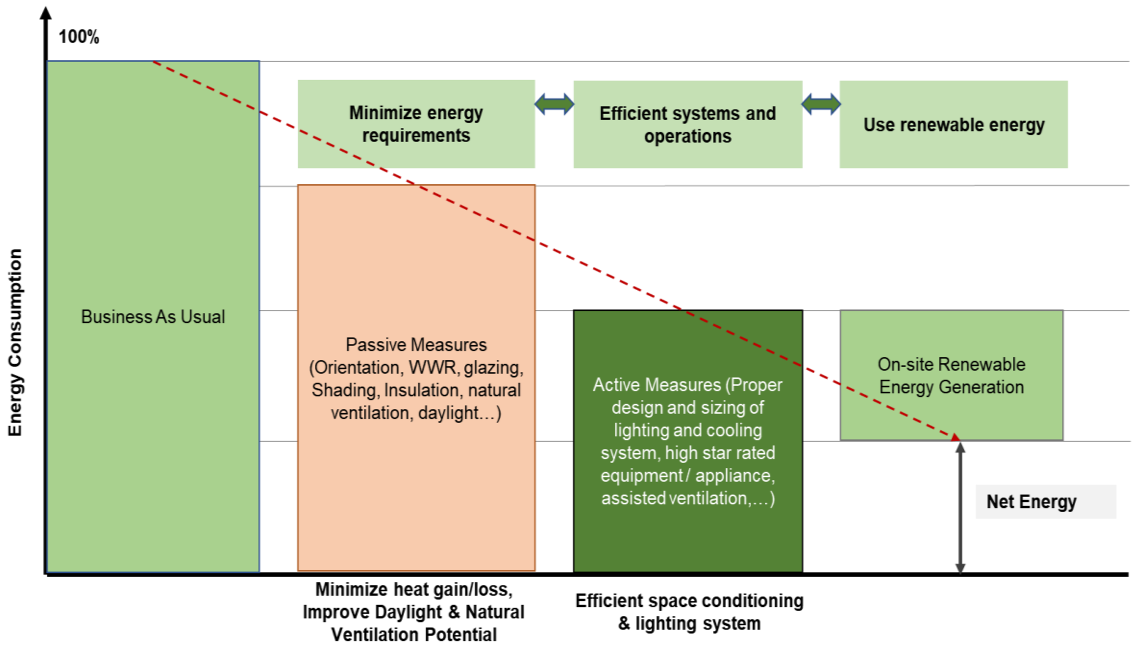

Figure 45. Approach for an energy efficient building

If we follow the above approach to minimise the 'cooling electricity consumption in residential buildings', we will focus on the following key actions.

1) First reduce the heat gains through the building envelope to eliminate / minimize cooling requirement. Key measures that can help in this are listed below.
    a) Reasonable insulation level
    b) Reasonable windows-to-wall area ratio
    c) Accessible thermal mass
    d) Effective night cooling by natural ventilation or by ventilative cooling
    e) Use of external movable shading systems (EMSyS)
2) If we still need cooling, we would install a highly efficient cooling system.
3) We would install renewable energy systems to meet the energy requirement, thereby, avoiding the use of fossil fuels.

Improved climate resilience for thermal comfort

Another important issue for the future is also to improve the resilience for the thermal comfort when there are heatwaves of longer duration as well as possible simultaneous power outage. EMSyS contributes in a significant way to improve the resilience of thermal control in buildings.

Zero or minimal operating cost

Another advantage of EMSyS is that they involve only one-time initial cost. Except for some minor maintenance costs, there is no other energy related expenditure required unlike in active cooling systems. EMSyS is therefore independent of energy costs.

High energy saving and thermal comfort potential

By using the full potential of EMSyS (Scenario 2), in the year 2050, the electricity saving potential due to EMSyS is estimated to be 241 TWh/y, which translates to an emission reduction of 171 million tCO_2/y and avoidance of 43.3 GW of power generated from thermal power plants. Also, the discomfort hours can be reduced from 20% to 60% in houses with the use of EMSyS.

Indirect impact on the sizing of capacity of air conditioners

In Indian market, the predominant capacity of ACs installed in residential buildings, is 1.0–1.5 TR (~80% of the total sales[35]). When considering EMSyS and lower cooling demand by a stringent value of RETV, the predominant capacity required of ACs would be smaller (0.5 to 1 TR), and this would have huge impact on peak electricity demand as well as the operating expenditure of air-conditioners for the households.

Current market scenario

This study shows that for a business-as-usual scenario in India, it is unlikely to achieve a fast growing market demand and corresponding manufacturing capabilities. This technology has for various practical reasons not been used in the past decades. The main reasons for this are listed below.

- Newer buildings in India have followed a trend for higher use of glass with lesser use of shading, which was not the usual practice in the past. This trend looks to be influenced by some developed countries. However, there are examples of some of the European countries where external movable shading in any kind of form is being commonly used.
- The awareness about the benefits of EMSyS has remained very low.
- Some of the international EMSyS manufacturers that have entered the Indian market have relied on expensive imported systems, and they are yet to invest in setting up local manufacturing facilities. These expensive products have remained niche products in the market mainly used in high-end buildings, such as individual bungalows and penthouses.
- The informal sector providing cheap and poorly engineered chicks has also remained marginal and have not seen product improvement/modernisation needed to meet the requirement of current housing.
- Equally important is the status symbol of AC, which is strongly pushed in the market.

Considering the present status, significant efforts and time would be needed to realise the potential of this technology. The key strategies for the same are discussed here.

[35] https://www.clasp.ngo/wp-content/uploads/2021/01/RAC-policies-and-market-transformation-in-India.pdf (accessed on 21 January 2023)

4.2 Strategies

The strategies to stimulate the EMSyS market should be built on a combination of various measures and activities.

4.2.1 Awareness building

A multi-pronged approach to build awareness amongst building end-users and building industry is suggested.

4.2.1.1 Demonstration projects

There is a lack of sufficient numbers of residential buildings having EMSyS, which can be showcased as demonstration buildings. 'Seeing is believing' and if one is not able to see, at least a few buildings with EMSyS, they will not be aware of it. Therefore, there is a need to have a 'critical mass' of building projects with EMSyS. The strategies for having demonstration projects are given below.

- Government should set the example by implementing EMSyS in selected government buildings, which have high visibility, located in major urban agglomerations.
- Identification of progressive builders / developers, who are willing to showcase EMSyS in their housing projects. Install EMSyS in the 'sample flats' to demonstrate its impact and ensure to have provision for EMSyS installation on all exposed glass windows / doors.
- As EMSyS can be applied to existing buildings as well; target existing buildings first to fast-track the demonstration projects.
- Demonstration projects can have a 'simple' energy / comfort monitoring system to showcase the real-life impact of EMSyS.

4.2.1.2 Media campaign

Large media campaigns for various stakeholders, led by government agencies (e.g. BEE), are done for the promotion of EMSyS, keeping communication simple and easy to understand. This should include the following:

- EMSyS benefits are communicated in a manner that is easy to relate to the end consumer. For instance, adding EMSyS can save as much as electricity which a high performance air-conditioner can save as compared to a poor efficiency air-conditioner, up to 4 °C lower temperature can be achieved by using EMSyS, up to 30% of cooling electricity can be saved by using EMSyS.
- Short videos and advertisements are developed and used to communicate the benefits of EMSyS.
- Large-scale dissemination is done to reach out to masses, e.g. short quote on EMSyS is added in the electricity bills, portal for property tax, etc.
- Media campaigns are organised in association with builder associations andarchitectural associations and showcased in their key events.

4.2.1.3 Special scoring for the NEERMAN awards for EMSyS use

The National Energy Efficiency Roadmap for Movement towards Affordable and Natural habitat (NEERMAN) Awards, given by BEE, for Energy Efficient Building Design in India are constituted with the objective to acknowledge and encourage exemplary building designs complying with BEE's Energy Conservation Building Codes. 'Residential' buildings are evaluated based on Eco-Niwas Samhita 2018 and there is a key criterion based on Residential Envelope Transmittance Value (RETV). While EMSyS can reduce the RETV significantly, still there is no provision in the current scheme document to account for EMSyS. Therefore, it is recommended that a special scoring is added for building projects, which have implemented EMSyS. This would help in making people more aware about EMSyS as well as encourage them to opt for EMSyS.

4.2.1.4 Adding strong scoring for EMSyS use in green building rating systems

In India, there are three predominant green building rating systems for residential buildings:

- GRIHA (Green Rating for Integrated Habitat Assessment) rating by GRIHA Council
- IGBC Rating Systems managed by Indian Green Building Council (IGBC)
- LEED (Leadership in Energy and Environmental Design) rating by U.S. Green Building Council (USGBC)

While all these rating systems have an option of accounting for EMSyS by using the energy simulation approach, none of these specify EMSyS in the prescriptive approach nor they specify simple factors to account for benefits of using EMSyS. It is recommended that all these rating systems should include EMSyS and corresponding scoring for it in their rating documents.

These rating documents also take reference from the relevant code document, i.e., Eco-Niwas Samhita (ENS). Having EMSyS added in the ENS, it will be easier for the rating agencies to include EMSyS in their respective rating documents as well.

4.2.2 Policy interventions at the national level

4.2.2.1 Setting up a national task force

The round table, initiated by BEE with BEEP, involving windows and EMSyS manufacturers/suppliers, should be continued as it has brought together some major actors in India. From the round table, which is an informal set-up, one can consider setting up a national task force, in which various stakeholders would become formally more involved. Setting up the task force can be led by Government agencies (e.g., BEE), involving EMSyS and the glazing industry. The task force plans and supports activities for the rapid adoption of EMSyS in buildings.

4.2.2.2 Inclusion of EMSyS in Eco-Niwas Samhita

The current residential code, Eco-Niwas Samita, does not specify the factors for improvements in shading by having EMSyS installed. Therefore, it is recommended that ENS update should encourage EMSyS adoption by following the strategies listed below.

Adding shading factor for EMSyS to account its impact

There are external shading factors defined in ENS to account the impact of static shading devices (overhang and side fins), while it does not give any factor for EMSyS. Therefore, it is recommended that suitable factors should be developed and added in the code document to account for EMSyS impact in the shading and thereby improvement in the RETV value.

Making the code provisions more stringent and mandatory

Make the residential building code more stringent and mandatory (RETV requirement from 15 W/m^2 is reduced to 8 W/m^2), rendering the use of EMSyS almost mandatory to reach the threshold value especially with larger window-to-wall area ratio. This would help in jump-starting the manufacturing and market supply.

Adding an Annexure on EMSyS in the code

An annexure showing the impact of EMSyS on the RETV can be added in the code document. For various reasons (international influence, builders' arguments, etc.), there is a general trend to increasing window-to-wall area ratio (WWR). The annexure could also highlight if a project wants to have higher WWR, then it must use EMSyS to meet the RETV requirement as per the code. As the ENS update is planned, it is recommended to add this Annexure during the updation process.

4.2.3 Capacity building

Capacity building is essential for key building sector stakeholders, so that they have the required understanding on EMSyS and know how it should be implemented in the building projects they are involved in. Different strategies are recommended for the capacity building for different stakeholders.

4.2.3.1 For students at curricula level

Getting architectural and engineering students aware about EMSyS and its benefits at curricula levels will make them better prepared to propose / implement EMSyS as key passive design strategy. They can apply this when they do their thesis, internship or start working as a professional. Therefore, it is recommended to introduce EMSyS curricula in architectural and engineering colleges.

- Make external movable shading as part of the studio project in architecture. Students are asked to design customised shading solution for their projects.
- Develop and get special modules in heat transfer and building physics curricula in engineering colleges with focus on solar gain reduction through passive measures. Illustrative calculations / examples for shading impacts, internal vs. external and static vs. movable should also be added.

4.2.3.2 For building sector professionals and builders

The capacity building programme for key stakeholders should aim for the following:

- Architects are able to propose best EMSyS solutions based on the climate and the building configuration.
- Engineers are able to calculate the impact of EMSyS on cooling requirements and design cooling systems accordingly.
- The builders and developers understand the financial implications of EMSyS and are able to take decision on EMSyS applicability for their projects.
- The marketing team of the building projects are able to convey the benefits of EMSyS to potential home buyers.

4.2.3.3 Skilled manpower for EMSyS installation

- Develop and conduct training programmes for EMSyS installers, considering high-rise buildings in focus. Similar to the mason or plumber, there should be a service person with specialisation in EMSyS installation. Here, agencies like BMTPC and National Skill Development Corporation (NSDC) can play a major role.

4.2.4 Supply chain: develop more market fit EMSyS solutions

As the awareness about EMSyS is still low, they are essentially three kinds of manufacturers ranging from the informal sector up to international companies exporting to India with local branches.

- With a very small penetration in the market, mostly in the high-end section, a few suppliers are importing part or full systems to be sold in India. They supply good quality but very high-cost systems, which cannot be afforded by middle- and low-income housing dwellers or buyers.
- At the bottom end, there are essentially informal sector artisans like manufacturers making chicks. These are not well engineered / finished products and also often have very short life.
- In between, there are a few organised small-scale enterprises, which can offer decent engineered external movable shading systems at a reasonable price. They seem to be a better fit for the market, but their scale, variety, and reach are limited.

Unless this gap between the informal and high-end formal sector is bridged, the penetration of EMSyS will remain low and slow in growth. The key action points are as follows:

- Set up a technical support programme to induce new industrial manufacturers to enter this sector. Government agencies like NITI Aayog (through Atal Innovation Mission), BMTPC, BEE, and DST can play a key role in this.
- Financial incentives for investment in EMSyS technical development, manufacturing, and marketing, e.g., loans at lower interest rates, higher loan eligibility, etc. The aim for such incentives would be to make a proposition for EMSyS financially better.

4.3 Next steps

The potential of EMSyS has been nearly achieved in the residential sector in a few countries such as Switzerland and Greece. Although they have a long tradition of having EMSyS in some form or the other (e.g., shutters, rolling shutters, fabric blinds, and adjustable lamella blinds), it was due to strong policy interventions from their governments that these countries were able to achieve what they have achieved.

In India too, based on the strategies proposed in the previous section, there is a need to develop a policy-driven detailed action plan to implement these strategies. The main aim of the action plan remains that the EMSyS penetration in residential buildings reaches its potential. The action plan should define the outcomes, specific outputs, details of the activities to be conducted, key stakeholders and their roles, timelines for all activities and the resources required.

Annexure A Modelling Approach and Methodology

A.1 Estimation of residential built-up area (urban and rural) at the district level

A.1.1 List of districts

- The list of districts as per the Census of India 2011 was mapped with respect to climate zone and latitude, i.e., all districts were assigned climatic zone as per the climatic zone map of India and latitude (≥23.5°N or <23.5°N).
- Newly added, name-changed, and combined/split districts of the Census of India 2001 were synced with the Census of India 2011 data. Further, all districts were subdivided into rural, urban, and total categories.

A.1.2 Estimation of population

- Population data of urban, rural, and total area of a district were extracted from the Census of India 2001 and 2011.
- The forecast of the total population of the country until 2050 was kept the same as of India Energy Security Scenario (IESS) model of NITI AYOG (Thambi et al., 2018).
- District's total population is forecasted until 2050 at a rate of country's total change in population.
- Percentage of urbanization was calculated for 2001 and 2011. Percentage of urbanization was linearly forecasted until 2050.
- Urban population of each district was calculated by multiplying the percentage of urbanization with the total population.
- Rural population of each district was calculated by subtracting the urban population from the total population.
- The year 2020 was taken as the base year for all future analysis.

A.1.3 Estimation of household size and household numbers

- Household number data of urban, rural, and total area of a district was extracted from the Census of India 2001 and 2011.
- Household sizes for 2001 and 2011 were calculated by dividing the population by the household number, specific to each district.
- Household size was linearly forecasted until 2050. However, the minimum value of 3 and maximum value of 10 was capped in the forecast (United Nations, 2017).
- Number of households after 2011 until 2050 was calculated by dividing the population by the household size.

A.1.4 Estimation of built-up area per household

- For 2011, NSSO 2006/07 data were used, which gives the built-up area per household for rural and urban areas at the state level. Data at the state level were assumed to be uniformly distributed at the district level.
- It was assumed that the household size required for a fulfilling life condition would be achieved in 2050. This is defined for urban and rural areas as per the formula below.

For a household with two or more people, the minimum living area standard is given by:
For rural areas, the household area = 25 m^2 × no. of people + 25 m^2
For urban areas, the household area = 20 m^2 × no. of people + 15 m^2

- For the intermediate years, the built-up area per household for rural and urban areas was linearly forecasted between 2011 and 2050.
- Built-up area per household in a district's total area is calculated by the built-up area per household's weighted average for urban and rural areas. The weighted average of the number of households was considered.

A.1.5 Estimation of built-up area

- Residential built-up area for urban, rural, and total area was calculated by multiplying the built-up area per household with the number of households.
- The above data were calculated for all districts from 2001 to 2050.

A.1.6 Segregating total built-up area

- The total built-up area is segregated into existing and newly constructed areas.
- The life of a building is assumed to be 50 years; it is also assumed that the built-up area existing in 2020 will be demolished at a uniform rate every year until 2070 and will be replaced by new buildings. As per this, starting from 2020, 60% of the residential buildings will get demolished by 2050.
- All buildings demolished and reconstructed after 2020 are considered as new buildings while the remaining buildings are considered as existing buildings.
- All buildings constructed after 2020 are considered as new buildings.
- Between 2020 and 2050, there will be various construction projects that are going to be demolished and reconstructed as well as newly constructed.
- Different strategies were considered for improving the building envelope properties of existing and new buildings.

A.2 Estimation of cooling demand requirement

A.2.1 ENS Simulation Model

- The ENS Simulation model is used as reference and has following key characteristics:

Table 11 Simulation Model Characteristics

Envelope	Brick Wall
Glass Type	Single Clear glass
Overhang	0.3 metre
Window Openable area	50%
Wind Exposure	Sheltered

- The ENS model is prepared after extensive consultation with all stakeholders, architects and experts including building material suppliers and developers. Residential project surveys took place to identify the existing WWR in houses.

A.2.2 Estimation of total space cooling energy requirement

- Total cooling demand per m^2 of air-conditioned space, is calculated using the energy simulations on ENS model with EMSyS installed on windows and with no EMSyS installed on windows. Total cooling demand per m^2 of air-conditioned space is calculated for predominate climate zones (warm-humid, hot-dry, composite). It is calculated for 3 different WWR (0.15, 0.25, 0.35).
- Total cooling demand per m2 of air-conditioned space for the district, is then adjusted with the EMSyS penetration at national level for urban residential housings for different scenarios. The EMSyS adoption percentage is assumed to be distributed uniformly at all districts.

A.3 EMSyS Fabric Estimation:

It is calculated considering Envelop to Built-up area ratio (=1.155) from the ECBC-R Analysis.

Table 12 EMSyS fabric requirement under different scenarios

	2030	2040	2050
BAU Scenario (m^2/y)	48,164	78,01,999	1,86,00,099
Scenario 1 (m^2/y)	35,79,70,653	37,66,61,393	43,41,65,986

Envelop area is calculated using built-up area corresponding to each district till 2050. The WWR is considered to calculate the window area. The EMSyS fabric required at the time of installation in front of a window is further calculated by multiplying a factor of 1.6 to window area. In practical, the EMSyS fabric area will be slightly higher than the window area. The factor of 1.6 is calculated from the site monitoring experience. The EMSyS fabric in m2 is calculated for both the scenarios and shown below. The current market study suggests that the installed EMSyS fabric by 2022 in m^2 in urban residential buildings is close to 1,20,000. It is interesting to note that the industry has to produce ~ 150 times the current capacity by 2050 in BAU scenario and ~ 3600 times in Scenario 1.

A.4 EMSyS and ENS Code

The ENS code (2018) compliance has one of the key provisions to minimize the heat gain in cooling-dominated climate through the building envelope (excluding roof). It defines a maximum Residential Envelope Transmittance Value (RETV)[36] for cooling-dominated climate (composite climate, hot-dry climate, warm-humid climate, and temperate climate).

RETV gives a quantitative measure of heat gains through the building envelope (excluding roof).

$$\mathbf{RETV = A * (1-WWR) * U_w * \omega_i + B * (WWR) * U_f * \omega_i + C * (WWR) * (SHGC)_{effective} * \omega_i}$$

The third term in the RETV equation is directly linked to heat gains through windows.

[36] Residential envelope transmittance value (RETV) (W/m^2) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units.

Therefore, External Shading Systems are useful in reducing the heat gain through windows and further in code compliance. Furthermore, there is an interesting analysis which shows the possibility of use of high WWR when EMSyS is installed.

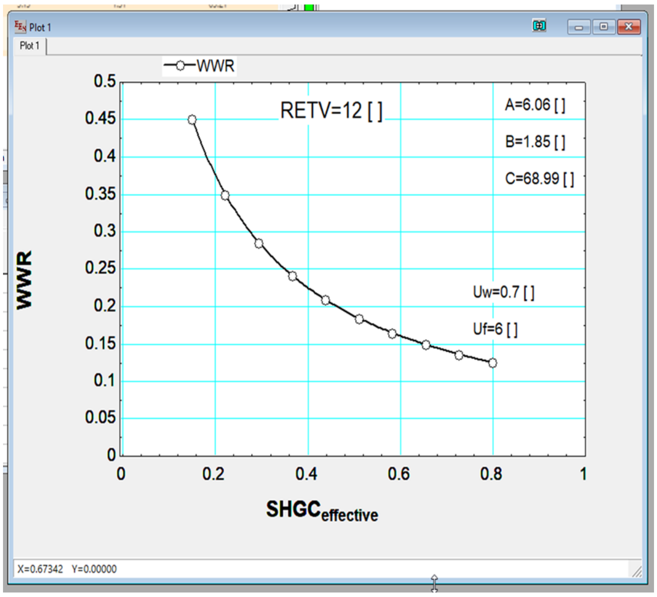

Figure 46 Relation between WWR and SHGC for a given RETV

The graph above gives an idea of combination of window to wall ratio (WWR) and effective solar heat gain coefficient ($SHGC_{effective}$) which can help in meeting an RETV of 12 W/m^2, keeping a business as usual values for all the other envelope parameters. What is suggests is that, if the WWR is low, e.g., 0.15, then an $SHGC_{effective}$ of ~0.65 may give an RETV of 12 W/m2, and this can be achieved by single clear glass with basic shading. However, if the WWR is higher, e.g., 0.35, then an $SHGC_{effective}$ of ~0.2 would be needed, which can be achieved by good shading like EMSyS.

About Bureau of Energy Efficiency

Bureau of Energy Efficiency (BEE) is statutory body under the Ministry of Power, Government of India. It assists in developing policies and strategies with the primary objective of reducing the energy intensity of the Indian economy. BEE coordinates with designated consumers, designated agencies, and other organizations to identify and utilize the existing resources and infrastructure in performing the functions assigned to it under the Energy Conservation Act.

Indo-Swiss Building Energy Efficiency Project

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 implementation 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. The Project Management and Technical Unit (PMTU) is responsible for programme implementation, which includes selected technical work, management tasks programme, and programme outreach.

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