Decoding India's residential building stock characteristics to enable effective energy efficiency policies and programs

Sandeep Kachhawa
Senior Research Associate
Alliance for an Energy Efficient Economy
Saira Tower, 4th Floor
N-161A,Yusuf Sarai
New Delhi
India
sandeep@aeee.in

Satish Kumar
President and Executive Director
Alliance for an Energy Efficient Economy
Saira Tower, 4th Floor
N-161A,Yusuf Sarai
New Delhi
India
satish@aeee.in

Mohini Singh
The author was Senior Research Associate
at Alliance for an Energy Efficient Economy
mohinisingh9@gmail.com

Keywords
building stock, residential buildings, energy data, big data, India

Abstract
Data is a precursor to the formulation of data-driven and evidence-based policies and promote strategic interventions for overall transformation. For the building sector, energy efficiency related policy making hinge on the availability of data on building characteristics such as type of occupancy, built floor area, and associated energy consumption. While the overall electricity consumption is accounted at the national and state level, there is lack of information about floor area and penetration of energy-intensive appliances such as air conditioners due to the fragmented character of the sector and absence of data disclosure regulations. Several sub-sectoral level efforts have manifested into formulating strategies addressing thermal comfort, embodied and operational energy for high, medium and low income housing groups. However, a holistic approach is required to unleash the full potential of energy efficiency and support India's national and international commitments on climate change.

The study proffers a hybrid approach to decode the residential building stock in India with two-fold objectives: (a) to inform meaningful insights about the current residential stock and its likely growth in the near and medium term; and, (b) to promote thermal comfort for all by exploring cost-effective and energy-efficient space cooling strategies for various income groups to address India's escalating cooling electricity needs. The sector characterisation exercise informs that the residential sector (~15 billion m^2 floor area) consumes ~280 TWh electricity with just 8 % room air-conditioner penetration in 2017. This data accounting is a first-of-its-kind exercise to bridge the residential sector electricity consumption related data gaps by devising methodologies and illuminating key sources of data. The authors believe that the exercise will be of long-term assistance to researchers, policy makers and business community to conduct market sizing exercises in future that remain central to promoting data-driven policy measures.

Introduction
India is on the cusp of rapid urbanisation and development and is witnessing one of the fastest construction growths worldwide (Navigant Research, 2018). This construction growth is not unforeseen especially considering the perpetual housing shortage that has long been a challenge for the Government of India (Kumar, et al., 2018). The thriving residential & commercial building sector in India accounted for 34 % of the total electricity consumption, 1066 TWh, in 2016–17 with the residential sector alone consuming one-fourth of the total national demand (MOSPI, 2018). With the growing housing demand and continuously increasing appliance penetration, the residential sector electricity consumption is expected to further double in the coming decade (CEA, 2017), posing huge stress on the already burdened electricity grids. Amongst various reasons, increasing use of room air-conditioners (RAC) is an important driver contributing to this rapid increase in electricity use in residential buildings. Government of India (GoI) under an important initiative titled, *Pradhan Mantri Awas Yojana (PMAY)*, is supporting affordable housing through various interventions such as slum redevelopment, credit linked subsidies, affordable housing projects in partnership with other agencies, and subsidies for beneficiary-led construction. However, there is no

emphasis on ensuring basic thermal comfort and the energy consumption implications of building design and construction under the scheme (Kumar, et al., 2018). Another important GoI initiative, the Eco-Niwas Samhita 2018 (energy conservation building code for residential buildings) focusses on building design & construction to enhance energy efficiency and improve thermal comfort for building occupants, but the lack of information on upcoming housing demand, disaggregated at economic stratum, impedes formulation of effective implementation strategies. The unavailability of residential sector classification has hindered the policy actions to holistically address the sector. Clearly, the current and upcoming residential stock estimations and RAC penetration (or absence of RAC thereof) have a significant bearing on formulation & effective implementation of policies and programs.

ROLE OF DATA IN EFFECTIVE POLICY MAKING AND IMPLEMENTATION

Data is crucial for scientific research and policy planning and plays a fundamental role in the development and advancement of any economy. It assists in making global/ national/ regional predictions on population, climate change, unemployment, food security, environment and natural resources security etc. In India, the Ministry of Statistics and Programme Implementation (MoSPI) gathers, analyses and disseminates a vast array of information on a regular basis at the national level. Its socio-economic statistics is a canonical example and an important component in the development of the country (MoSPI, n.d.). For instance, the literacy statistics study conducted and released by MoSPI directed formulation of evidence-based policies and various interventions over the period of time. The Ministry of Human Resource Development (MHRD), having access to high-quality MoSPI literacy rate data, launched various successful policy reforms to address literacy rates in India. Having said that, good quality, credible and representative data, if made available to the various professionals such as researchers, consultants etc. will unleash the power of human intellect leading to multiple benefits accruing to the society and to the nation. On the other hand, poor data collection, analysis, and dissemination practices will hinder and challenge policy development, implementation and intervention, impeding India's development.

In the building sector, quantification of energy consumption remains fairly nascent and primitive in several economies including India. However, developed economies like U.S., Europe, Singapore etc. have been practicing data-driven research/ estimation/ models/ policies for quite some time and strongly promote freely available data. Building energy data collection and management programs like Commercial Buildings Energy Consumption Survey (CBECS) & California Commercial End-Use Survey (CEUS) from U.S., Tabula 17, Episcope and Mure from Europe and Building Energy Submission System (BESS) from Singapore are successful international examples where comprehensive data on relevant energy use parameters are collected, analysed with technical and statistical rigour, and disseminated (Iyer, et al., 2016).

Indian data collection and disclosure laws, on the contrary, do not always provide a clear mandate leading to ambiguity and ambivalence on the part of Indian ministries when it comes to distributing and sharing data. This can handicap the necessary systematic and rigorous data collection efforts, data processing and dissemination. In many cases, the data collection initiative, while funded by taxpayers' money, overlook the right of the people to access collected data, only shares outcome of the analyses, which could be biased or even flawed. Several efforts have been made to rectify this situation, mandating data disclosure requirements. For example, MoSPI and the Central Electricity Authority (CEA) have been disseminating data to the general public, that they have the mandate to collect through regulatory powers vested in their authority. Though the majority of government institutions have sufficient legal authority to collect energy data and share it among different departments for administrative reasons, the right to disseminate to the general public is not clearly articulated(Dukkipati, et al., 2014).

CONTRIBUTIONS OF THE PAPER

The fragmented character of the residential sector in India poses several challenges. The study is based on a detailed investigation of existing literature along with structured interviews with experts and professionals is an attempt to bridge the existing data gaps and promote data-driven evidence-based policies in the sector. While the authors undertook extensive discussions in-house and with experts to ensure the methodology adopted and analysis presented represents the sector appropriately; however, lack of well-established research methodology and disparity in data availability, has been a major limitation and therefore the outputs are presented with uncertainty estimates.

The estimates for room air-conditioner stock and its penetration, analysed in this paper, present the current and upcoming active cooling demand landscape for the residential sector, thus directing towards a detailed investigation to promote low-cost and sustainable cooling solutions while envisaging "Thermal comfort for All". Based on the methodology presented, extensive sub-national efforts are recommended, presenting the sector characteristics at sub-national and national level along with the respective climate zone which will be helpful in outlining effective strategies for Thermal Comfort for All.

Characterising the residential building sector

India is experiencing rapid growth in population along with rising purchasing power leading to growth in floor space, electricity consumption and appliance penetration, specifically air-conditioners. Recognising the need for sector-specific policy formulation and effective implementation, the residential stock characterisation exercise is an attempt to comprehend the sector with granular and disaggregated information on household wise floor area, electricity consumption and air-conditioner penetration for the current and future scenario. The estimation exercise relies on a hybrid approach, the top-down approach to disaggregate the number of households; whereas a bottom-up approach to identify the floor area, electricity consumption and air-conditioner penetration from a unit level to household income groups.

THE METHODOLOGY

The overall methodology relied on the hybrid-approach and included data assembly from relevant GoI reports, data analysis and categorisation into groups of buildings of comparable segments and data modelling to arrive at the total floor area, electricity consumption and air-conditioner penetration (Kumar, et al., 2018). Further, it includes segmentation, calculations and assumptions, and validation. The estimation involves

a continuous process from data assembly to validation and each step includes extensive discussions with experts and educated assumptions were substituted for the absence of data.

Data Assembly

To comprehend and characterise the fragmented sector, the first step was to identify and analyse the existing body of work outlining the residential sector and its sub-segments. An exhaustive secondary data collection was carried along with analyses of various surveys by ministries in the Government of India, research papers, relevant reports published by the public or private sector and published in-house audit reports which informed the paper findings. The key data sources targeted include data published by MoSPI, National Survey Statistics Office (NSSO), NITI Aayog – India Energy Security Scenarios (IESS), and National Council of Applied Economic Research (NCAER). The following datasets were targeted (1) Existing classification of the sector published by the government or industry reports and (2) Residential building design codes/ case-studies/ audit- reports informing the area, energy consumption and air-conditioner penetration.

For example, in 2017, approximately 272 million households were estimated in India which will rise to 328 and 386 million in 2027 and 2037 respectively (NITI Aayog, 2015). The Census 2011 of India breaks down the number of households in the following segments: non-exclusive room, one room, two rooms, three rooms, four rooms and five rooms and above (Census of India, 2011). Approximately 60 %–70 % of all the households fall in one room and two room categories. According to the NCAER 2010 estimates, 56.3 %, 29.6 %, 12.9 % and 1.3 % of the households fall under the Economically Weaker Section (EWS), Low Income Group (LIG), Medium Income Group (MIG) and High Income Group (HIG) respectively (NCAER-CMCR, 2010). National Building Code and various housing policies/missions/ reports provide a range of built area (similar to floor area) for EWS, LIG, MIG & HIG (NBC, 2016), (MoHUPA, 2012) (MoHUPA, 2016) (MoHUPA, 2012a). Floor area for each household segment is estimated based on the aforementioned data and multiple discussions held with sector experts. The available data is extrapolated to arrive at the current and future floor area within each income group. MIG segment covers approximately 38 % of the total floor area followed by LIG, EWS and HIG at 23 %, 31 % and 8 % respectively in 2017 and it is assumed that the similar trend follows for next ten years. Residential built-area CAGR (Compound Annual Growth Rate) from NITI Aayog – IESS is also referred to align the medium and long-term built-area for the residential sector. Further, various researches – (Rawal & Shukla, 2014) (Sachar, et al., 2018) (MoEFCC, 2018) (NITI Aayog, n.d.) (Kumar , et al., 2018) (NSSO, 2010) (Chunekar, et al., 2016) – informed the EPI and air-conditioner penetration within various income groups.

Segmentation and Characterisation

The data assembly stage which also included data scrutiny provided multiple data sets which informed the sector segmentation along with the character of each segment. While the segmentation included identification of the number of EWS, LIG, MIG and HIG households, extrapolated from the number of rooms; characterisation included defining units for each EWS, LIG, MIG and HIG household in terms of electricity consumption, floor area and air-conditioner demand at the most granular level. In the case of data unavailability informed assumptions discussed in the following section were derived from data assembly state, followed by experts' opinions and exhaustive in- house discussion.

Calculation and Assumptions

The following outputs were envisaged from the exercise (1) Total residential sector floor area along with each segment floor area, (2) Electricity consumption at the national level by residential sector, along with electricity consumption by each segment (3) Number of households with air-conditioners and; (4) Total number of air-conditioners. Each of the aforementioned was estimated for the year 2017–2018, 2022–23 and 2027–28. The ranges of the final estimates were produced at the segment level and aggregated to produce the said outputs at the national level. The algebraic formula used to comprehend the electricity consumption from EPI is:

Energy performance index (EPI)
= Electricity consumed (kWh) per unit floor area (m^2)/year

The following assumptions were considered during the exercise:

1. Breakdown of the number of households into number of rooms and into EWS, LIG, MIG and HIG segment will remain the same from the date of data publication till 2027–2028. For example, it is assumed that 60 %–70 % of all the households fall in one room and two room categories and 56.3 %, 29.6 %, 12.9 % and 1.3 % of the households fall under EWS, LIG, MIG & HIG respectively.
2. The majority of households with 'non-exclusive room', 'one room' and 'two rooms' will belong to EWS category in urban and rural areas. Similarly, the majority of households with 'two rooms' and 'three rooms' setups will belong to LIG category; majority of 'three rooms', 'four rooms' and 'five rooms' and partial 'six rooms and above' will belong to MIG category; and, remaining 'six rooms and above' will belong to HIG category. For example, in the year 2017–18, the estimated households in urban and rural area as per IESS 2047 are 90 and 182 million respectively. Extrapolating the similar information along with Census 2011 and NCEAR 2010 data, the households under EWS, LIG, MIG and HIG category are illustrated in Table 1.
3. The minimum area per room as per NBC 2015 is 7.5 m^2. The built-up area for EWS and LIG category, which includes households with one-two rooms or three rooms in case of rural area-three rooms, is based on the NBC and information provided by other housing policies/ missions reports. For example, PMAY indicate the carpet area for EWS and LIG housing in the range of 30 m^2 and 60 m^2 respectively. For the MIG and HIG category, several housing societies plans are referred, and for each household category, a range of floor area is considered which is then averaged. Further, it is assumed that the area per household will remain same till 2027–28. (Kumar, et al., 2018) (NBC, 2016) (Rawal & Shukla, 2014) (Khosla & Bhardwaj, 2017) (Housing.com, n.d.).
4. The EPI of the households belonging to various income groups is referred from multiple studies and in house energy audits (Rawal & Shukla, 2014) (Khosla & Bhardwaj, 2017) (GRIHA, n.d.).

5. To delineate the number of households with room air-conditioner and the average number of air-conditioners per household, several published research – (AEEE, 2018) (Sachar, et al., 2018) (Chunekar, et al., 2016) and market intelligence reports (BSRIA, 2016) are referred. Current penetration as 7–9 % with 60 to70 % of the stock installed in the residential sector is derived from AEEE analysis using the sources referenced. Further, the estimations were validated using short expert surveys from building design and construction industry professionals.

Validation

To ensure the reliability of numbers, the estimation exercise included a process where attempt was made to validate each number/ assumption at each stage of the methodology. Data sets with discrepancies including the data sets from the data assembly stage and from assumptions stage were omitted. For example, the derived aggregated floor area for 2017–18 was validated from NITI Aayog's IESS data on total residential sector floor area (NITI Aayog, n.d.). The current room air-conditioner penetration is validated from published research (AEEE, 2018) and market intelligence reports indicating current penetration as 7–9 % with approximately 60 % of the stock installed in the residential sector. The validation process and the analysis of selected data sets also supported informed assumptions to bridge the data gaps.

Outputs

In 2017–18 the residential sector accounted for a floor space of 15.3 billion m^2 increasing at a CAGR of ~3.6 % from 2017–18 to 2027–28 with a higher growth rate from 2017–18 to 2022 23 due to the ongoing missions and programs of GoI such as PMAY, which aims to address the housing demand by 2022. The estimated floor area is illustrated in Table 3. Considering IESS population data, the per capita floor space in 2017–18 is 11.9 m^2 (NITI Aayog, 2015).

The current residential stock electricity consumption of ~280 TWh is expected to grow by 66 % under the business-as-usual scenario to 465 TWh by 2022-23 and by 112 % to 595 TWh by 2027–28 as illustrated segment-wise in Figure 1. It is assumed that the actual electricity consumption may vary approximately by 5 % to 10 % for the following two reasons; (1) No electricity consumption in case of vacant flats (11 % is the vacant stock); and, (2) Higher electricity consumption for floor space categorised as residential but used for commercial activity.

The overall room air-conditioner penetration in the sector will rise from 8 % in 2017–18 to 12 % and 21 % by 2022–23 & 2027–28 respectively, with the urban residential stock having approximately 44 % room air-conditioner penetration in 2027–28. Figure 2 & 3 depict the estimated number of households with and without room air-conditioner and estimated stock of room air-conditioner respectively. As per NSSO, there were approximately 1.2 room air conditioners per household in 2011 (NSSO, 2010). The present analysis indicates approximately 1.25 room air conditioners per household in 2017–18 which will rise to 1.5 and 2 room air conditioners per household in 2027–28 and 2037–38 respectively. It was anticipated that from 2001 till 2017, the majority of room air conditioner penetration was occurring within households without air conditioner i.e. households bought their first air conditioner; however, based on AEEE research supported with various market intelligence reports (BSRIA, 2016) and our interactions with various stakeholders, it is likely that in the next 10 years significant penetration will take place in households already having air conditioners i.e. households will opt for second/ third air conditioners. The above analysis presents the business-as-usual scenario,

Table 1. Total households disaggregated by income level (million).

	2017–18		2022–23		2027–28	
	Rural	Urban	Rural	Urban	Rural	Urban
EWS	121.32	31.68	131.30	38.02	139.44	45.06
LIG	39.93	40.53	39.70	49.34	37.76	59.28
MIG	20.23	14.91	21.70	17.18	22.55	19.57
HIG	0.52	2.97	0.31	3.56	0.15	4.22
Total	182.00	90.09	193.00	108.11	199.90	128.13

Table 2. Percentage of households with room air-conditioners (A); and the average number of room air-conditioner per household (B).

	2017–18				2022–23				2027–28			
	Rural		Urban		Rural		Urban		Rural		Urban	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
EWS	0 %	0	0 %	0	0 %	0	0%	0 to 1*	0 %	0	5–45 %	1
LIG	0 %	0	15–25 %	1	0–7 %	0 to 1*	20–40 %	1	5–15 %	1	35–70 %	1
MIG	5–30 %	1	35–85 %	1	10–35 %	1	45–90 %	1 to 2*	15–60 %	1 to 2*	60–100 %	2 to 3*
HIG	25–30 %	1	75–85%	2	30–35 %	2	80–90 %	3	80–90 %	2	95–100 %	4

*Note: * The average RAC per household is considered from the indicated range, based on the number of rooms within each household category.*

Table 3. Residential sector floor area (million m²).

Million m²	2017–18		2022–23		2027–28	
	Min	Max	Min	Max	Min	Max
EWS	2,987	3,964	3,330	4,416	3,659	4,848
LIG	4,256	5,321	5,774	7,481	6,441	8,321
MIG	5,197	6,551	7,252	8,907	7,957	9,782
HIG	1,021	1,370	1,146	1,533	1,267	1,690
Total	13,461	17,205	17,502	22,336	19,324	24,640
Average	15,333		19,919		21.982	

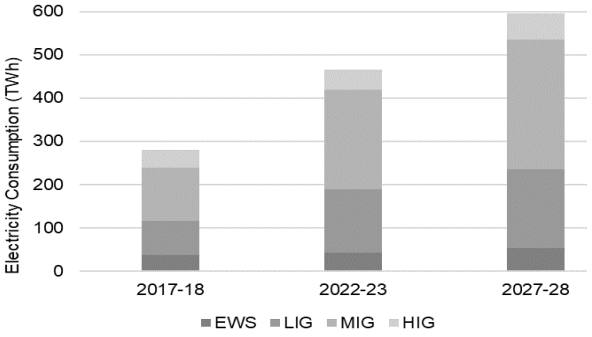

Figure 1. Electricity consumption by residential sector.

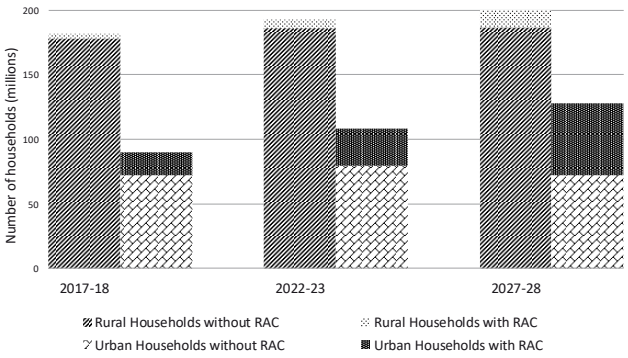

Figure 2. Households with room air-conditioner.

taking cognisance of the fact that with growth in floor space coupled with rising temperatures and purchasing power, India is going to witness a rapid rise in air-conditioner penetration. In spite of this rapid uptake of air-conditioners in the existing and upcoming stock, a significant number of households will not be able to afford air-conditioners. Hence it is critical to mainstream low-cost cooling technologies and incorporate energy efficient building design, materials, and construction technologies in the upcoming building stock to ensure thermal comfort for all. Proactively addressing the cooling demand through energy efficient building design may delay the penetration of air-conditioners in some households in the EWS & LIG segments and lesser penetration, with reduced active cooling demand, for households in MIG & HIG segments.

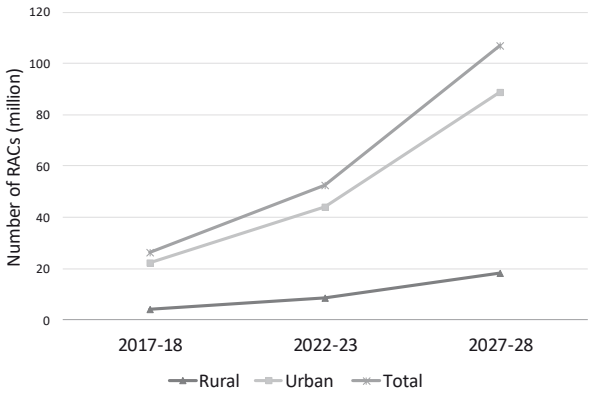

Figure 3. Room air-conditioner stock.

Potential impacts

The paper, for the first time in India, provides detailed information on the residential sector floor area, electricity consumption, number of households with room air-conditioner and room air-conditioner penetration at the national level and segment level for the current year and makes projections for 2022–23 and 2027–28 based on a detailed investigation of the existing literature. The sector characterisation will provide a closer link between energy efficiency policies and other flagship programs of GoI such as prioritised implementation of Eco-Niwas Samhita 2018 (Energy Conservation Building Code for Residential buildings) launched by BEE, through government missions such as PMAY, Smart Cities for various household segments. This exercise will also support the Standards and Labelling (S&L) program of BEE through prioritization of residential sector appliances for either inclusion or ratcheting up of minimum efficiency levels.

Space cooling in the building sector represents the bulk of India's overall cooling demand. The residential sector offers the highest potential for addressing the growing active cooling demand through promotion and adoption of Lean, Mean and Green strategies, enabling a resource efficient and low carbon future, providing thermal comfort for all. Lean, Mean and Green, a hierarchical approach underscores low-cost, energy-efficient and sustainable construction by first targeting the building design and construction, followed by installation of energy-efficient appliances/systems coupled with smart controls and finally the deployment renewable energy to meet the electricity demand (AEEE, 2017).

Under PMAY-U, GoI targets to deliver approximately 10 million affordable housing units by 2022. While the majority of sub-national governments are still developing the affordable housing

policies along with amendments of other policies/ codes such as green buildings incentive policies or building rules and regulations, this exercise provides meaningful insights to target occupant comfort oriented, climate responsive development though effective policy making. Mandating data disclosure for the residential building stock (even if limited to upcoming stock) can potentially pave the way for sustainable and environmentally conscious development aligned with India's national and international commitments.

References

AEEE, 2017. *Thermal Comfort for All,* New Delhi: s.n.

AEEE, 2018. *Demand Analysis of Cooling by Sector in India in 2027,* New Delhi: Alliance for an Energy Efficient Economy.

BSRIA, 2016. World Air Conditioning 2016, India, s.l.: BSRIA.

CEA, 2017. *All India Electricity Statistics, General Review 2017,* s.l.: Central Electricity Authority, Ministry of Power.

CEA, 2017. *Nineteenth Electric Power Survey of India,* s.l.: Central Electricity Authority, Ministry of Power.

Census of India, 2011. *Houses, Household Amenities and Assets Data 2001 2011 Visualizing Through Maps.* [Online] Available at: http://censusindia.gov.in/2011-Common/NSDI/Houses_Household.pdf [Accessed December 2018].

Chunekar, A., Varshney, S. & Dixit, S., 2016. Residential Electricity Consumption in India: What do we know?, s.l.: Prayas.

Dukkipati, S., Iyer, R. K. & Sreenivas, A., 2014. *An Assessment of Energy Data Management in India.* [Online] Available at: http://www.prayaspune.org/peg/publications/item/280.html [Accessed September 2016].

EDS, 2011. *Addressing Climate Change with Low Cost Green Housing.* [Online] Available at: http://siteresources.worldbank.org/FINANCIALSECTOR/Resources/Low_Cost_Green_Housing_Project_Report.pdf [Accessed Novermber 2017].

EIA, 2016. *EIA Overview.* [Online] Available at: http://www.eia.gov/pressroom/presentations/sieminski_09282016.pdf [Accessed November 2016].

GRIHA, n.d. *GRIHA Case Studies.* [Online] Available at: http://www.grihaindia.org/case-study [Accessed December 2018].

Housing.com, n.d. *Amrapali Leisure Valley.* [Online] Available at: https://housing.com/in/buy/projects/page/1497-amrapali-leisure-valley-by-amrapali-group-in-amrapali-leisure-valley [Accessed December 2018].

Iyer, M. et al., 2016. Establishing a Commercial Buildings Energy Data Framework for India: A Comprehensive Look at Data Collection Approaches, Use Cases and Institutions. [Online] Available at: https://eta.lbl.gov/sites/all/files/publications/lbnl-1006427.pdf [Accessed January 2018].

Khosla , R. & Bhardwaj, A., 2017. *Plugging In – Appliances used in Affordable Housing.* [Online] Available at: http://www.cprindia.org/news/6559 [Accessed 2018].

Kumar , S. et al., 2018. Projecting National Energy Saving Estimate from the Adoption of High Performance Windows Glazing in 2030, New Delhi: Alliance for an Energy Efficienct Economy.

Kumar, S. et al., 2018. Mainstreaming thermal comfort for all and resource efficiency in affordable housing: Status review of PMAY-U mission to understand barriers and drivers, New Delhi: Alliance for an Energy Efficient Economy.

Kumar, S., Singh, M. & Kachhawa, S., 2018. *Building Stock Modelling,* New Delhi: Alliance for an Energy Efficient Economy.

Kumar, S., Yadav, N., Singh, M. & Kachhawa, S., 2018. Estimating India's commercial building stock to address the energy data challenge. *Building Research & Information,* pp. 24–37.

MoEFCC, 2018. India Cooling Action Plan - Draft, New Delhi: MoEFCC.

MoHUPA, 2012a. Task force on Promoting Affordable Housing, s.l.: s.n.

MoHUPA, 2012. *Guidelines for Affordable Housing in Partnership.* [Online] Available at: https://smartnet.niua.org/sites/default/files/resources/AHP-Guidelines.pdf [Accessed April 2018].

MoHUPA, 2016. *Housing for All (Urban) Scheme Guidelines,* New Delhi: Ministry of Housing & Urban Poverty Alleviation.

MOSPI, 2018. *Energy Statistics,* New Delhi: Central Statistics Office, MOSPI.

MoSPI, n.d.. *http://mospi.nic.in/Mospi_New/upload/ses_9.html.* [Online] Available at: http://mospi.nic.in/Mospi_New/upload/ses_9.html [Accessed October 2016].

Navigant Research, 2018. *Global Building Stock Database,* s.l.: Navigant Research.

NBC, 2016. *National Building Code 2016 (Volume 2),* New Delhi: Bureau of Indian Standards (BIS).

NCAER-CMCR, 2010. *How India Earns, Spends and Saves,* s.l.: SAGE Publications .

NITI Aayog, 2015. *India Energy Security Scenarios 2047, web tool.* [Online] Available at: http://indiaenergy.gov.in/iess/default.php.

NITI Aayog, n.d. *India Energy Security Scenarios, 2047, User Guide: Residential Lighting and Appliances.* [Online] Available at: http://indiaenergy.gov.in/iess/docs/Residential-Lighting_Appliances-documentation.pdf [Accessed December 2018].

NSSO, 2010. *Household Consumer Expenditure Survey of India, 66th Round,* s.l.: National Sample Survey Organisation, India.

Rawal, R. & Shukla, Y., 2014. *Residential Buildings in India: Energy Use Projections and Savings Potentials.* [Online] Available at: http://www.gbpn.org/sites/default/files/08.%20INDIA%20Baseline_TR_low.pdf [Accessed 06 2017].

Sachar, S., Goenka, A. & Kumar , S., 2018. Sachar, S., Goenka, A., Kumar, S. (2018). Leveraging an Understanding of RAC Usage in the Residential Sector to Support India's Climate Change Commitment. Asilomar, California, US, s.n.