Towards Climate-smart Hospitals: Methodology and Pilot of India's First Nationwide Hospital Energy Survey

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ABSTRACT

India's healthcare infrastructure is expanding and evolving amidst the growing need for enhanced Indoor Environmental Quality in hospitals, accentuated by COVID-19 and frequent heatwaves, which will have serious implications for hospitals' energy use and energy-related GHG emissions. It is imperative to make hospitals in India climate-smart using robust end-use energy data. This paper discusses the methodology and pilot of India's first-ever national hospital energy survey to characterize the energy consumption, Scope I & II emissions, fuel types, and O&M practices. The survey across end-use systems in 10 public and private hospital typologies is based on 75 data points that will be collected from 1000+ hospitals covering all five climate zones of India. The anonymized data will be released publicly, along with analytical and data visualization tools. This paper will (i) describe the survey scope, design, and methodology, (ii) provide learnings and data insights from the survey pilot, and (iii) outline the next steps towards the full-fledged survey. The learnings from and outcomes of the survey methodology and pilot will have broad applicability for harnessing the power of end-use energy data to mainstream energy efficiency in hospitals and even other commercial buildings in India and other countries.

Introduction

The imperative need for healthy, energy-efficient, and low-carbon buildings is growing alongside rising expectations of private and public sector environmental performance in light of COVID-19 and India's pledges at COP26. The hospital sector comprises a significant proportion of India's commercial building sector, both in terms of its built-up area (6%) and energy consumption (14%) (Kumar et al. 2018). The carbon footprint of the Indian healthcare sector is 39 million tonnes of CO_2e per year, which is equivalent to annual GHG emissions from 10 coal-fired power plants (Health Care Without Harm 2019).

Three emerging trends mark the energy consumption and GHG emissions of hospitals in India. Firstly, the COVID-19 pandemic has increased the country's dependence on more advanced and accessible healthcare, including a growing focus on air filtration and purification, which has significant implications on hospitals' HVAC energy consumption and GHG emissions. Secondly, warming temperatures coupled with more frequent heatwaves will entail an increasing penetration of air conditioning in hospitals to ensure thermal comfort. Thirdly, there is an urgent emphasis on improving the healthcare infrastructure in India by ensuring uninterrupted electricity in rural healthcare facilities. The Ministry of Health and Family Welfare, Government of India, is creating 150,000 Health and Wellness Centres in India under its *Ayushman Bharat* program to strengthen and expand the range of primary healthcare services (Ministry of Health and Family Welfare 2022).

As a result of these drivers, it is estimated that in 2017-2027, the total hospital stock in India will grow by 30%, from 69 million m^2 to 89 million $m^{2,}$ with a coincident increase in energy intensity by 15-20% from 153 kWh/m^2/year to 179 kWh/m^2/year. This will result in a 45% growth in electricity consumption of hospitals from 11 billion units to 16 billion (Kumar et al. 2018). In the face of these changes, there is an imperative need to create climate-smart hospitals to ensure that healthcare is provided to all in an environmentally sustainable way.

Motivation

Defining strategies and effecting energy efficiency interventions for climate-smart hospitals in India is contingent on the availability of granular end-use energy data. In order to design these interventions and assess their energy savings potential, it is imperative to accurately characterize the energy use in hospitals at the national and state level across different hospital typologies. However, there is a serious lack of reliable end-use energy data from either government sources (e.g., Ministry of Statistics and Programme Implementation and Central Electricity Authority of India), past surveys (e.g., USAID ECO-III project), or market research reports. Alliance for an Energy Efficient Economy (AEEE) and the Centre for Chronic Disease Control (CCDC) aim to close this data gap by launching India's first-ever national hospital energy survey. One of the objectives of the National Programme on Climate Change and Human Health (Ministry of Health and Family Welfare 2018) is to strengthen the healthcare system in the context of climate change. This objective provides an opportunity to not only prioritize the energy requirements of the health sector but also the necessity to decarbonize the Indian health sector. This survey is envisaged to provide the much-needed energy baseline for Indian hospitals and pave the way for future actions to strengthen the healthcare system in an ecologically sustainable manner. It will characterize the energy consumption, Scope I & II emissions, fuel types, and O&M practices of end-use systems in 10 public and private hospital typologies based on 75 data points that will be collected from 1000+ hospitals covering all 5 climate zones of India.

Survey Scope

This hospital energy survey will be administered in all 5 climate zones of India and the following political boundaries in India.

- 17 out of the 28 states of India, i.e., Assam (AS), Bihar (BR), Chhattisgarh (CG), Gujarat (GJ), Himachal Pradesh (HP), Jharkhand (JH), Karnataka (KA), Kerala (KL), Madhya Pradesh (MP), Maharashtra (MH), Odisha (OD), Punjab (PU) + Chandigarh (CH) UT, Rajasthan (RJ), Tamil Nadu (TN), Uttar Pradesh (UP), Uttarakhand (UK), and West Bengal (WB).
- Delhi UT & National Capital Region (DL)

These states and Union Territories (UTs) were chosen because they cover large swathes of the length and breadth of India (Figure 1), all 5 climate zones, several large urban centers wherein high-end energy-intensive hospitals are concentrated, and have enough public and private hospital populations to meet the requirements of the sampling methodology.

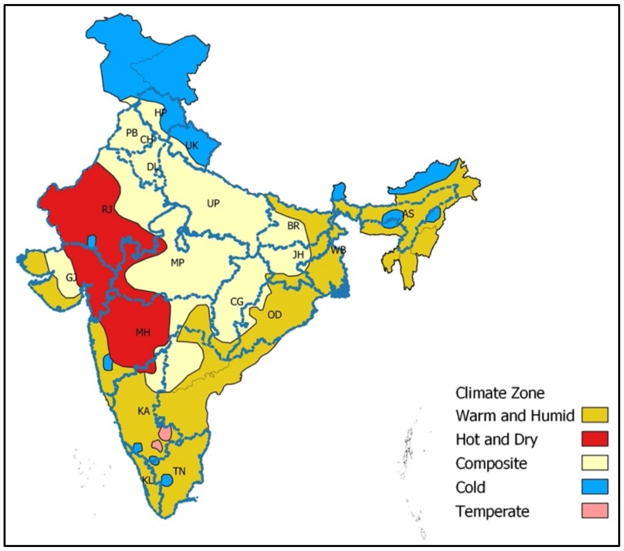

Figure 1. Geographical scope of the survey, i.e., 5 climate zones and 18 states/UTs (outlined in blue). *Source*: Bureau of Indian Standards 2016.

The survey will cover publicly- and privately-owned hospitals, i.e., centers of medical care with inpatient beds, of 10 typologies described in Table 1. This does not include pure diagnostic centers, research labs, and out-patient clinics with no inpatient beds, and some hospital typologies. The total population of public hospitals across all typologies is 171,504, of which 127,735 are electrified (Ministry of Health and Family Welfare 2019 and National Health Policy 2020). The total population of private hospitals across all typologies is 7,353 in the geographical scope described above. This private hospital population was arrived at by merging the private hospital network lists of health insurance providers, namely, ICICI Lombard, MD India Health Insurance TPA Pvt. Ltd., and hospital network list of Association of Healthcare Providers of India, and by assigning each hospital a typology based on desktop research. Secondary research did not reveal a single exhaustive list of private hospitals in India.

Table1. Hospital typologies within the project scope

Public	Sub-centre	A sub-centre is the first point of contact between the primary health care system and the community and has at most 2-4 basic beds. Sub-centres are expected to provide promotive, preventive, and few curative primary healthcare services.
	Primary Health Centre (PHC)	A PHC is the first port of call to a qualified doctor of the public sector in rural areas for curative, preventive, and promotive healthcare. It has 4-6 beds.

	Sub-centre/PHC recently converted to Health and Wellness Centre (HWC)	An HWC is a hospital that has been created under the *Ayushman Bharat* program by transforming existing SCs and PHCs in an attempt to deliver a comprehensive range of services spanning preventive, promotive, curative, rehabilitative, and palliative care.
	Community Health Centre (CHC)	A CHC is a 30-bed hospital providing specialist care in medicine, obstetrics and gynaecology, surgery, paediatrics, dental, etc.
	Sub-district/divisional Hospital (SDH)	An SDH is a 31-100 bed hospital at the secondary referral level responsible for the sub-district/sub-division of a defined geographical area containing a defined population. Specialist services are provided through them.
	District Hospital (DH)	A DH functions as a secondary level of health care which provides curative, preventive, and promotive healthcare services to the people living in urban (district headquarters town and adjoining areas) and the rural people in the district. The bed strength of a DH varies from 75 to 500 beds depending on the size, terrain, and population of the district.
	Medical college	This includes public medical colleges with inpatient beds.
Private	Single-specialty hospital	A single-specialty hospital offers one specialty, e.g., eye hospitals, cancer hospitals, nursing homes, etc.
	Super-/Multi-speciality hospital	A multi-specialty hospital offers several basic specialties, e.g., general medicine, general surgery, gynaecology, orthopaedics, paediatrics, etc. A super-specialty hospital offers several niche treatments in specialties, e.g., cardiology, gastroenterology, oncology, cardiothoracic surgery, neurosurgery, plastic surgery, etc. These are usually done by doctors who have degrees above post-graduation.
	Medical College	This includes private medical colleges with inpatient beds.

Sampling Methodology

While the sampling methodology was founded on the statistical principles of stratified sampling, its academic rigor was balanced with practical learnings gleaned from the pilot experience and based on expert consultations to align it with the survey objectives, project timeline, and resources.

Sample Size

Considering that the total population of public and private hospitals in India is approximately 179,000, as described above, the original sample size was estimated to be roughly 1,500 at a 95% confidence level and 2.5% margin of error. However, based on the long survey lead times in the pilot and the tight project timeline, the sample size was adjusted to 1,000. This new sample size was seconded by a senior energy expert with past experience in hospital energy surveys in India. The sampling error is likely to comprise only a small share of the total error, say up to 10%, while the majority of the error is likely to creep into a technical survey such as this on account of inaccurate data transfer between the surveyor and the respondent if the questions are not explained and understood well. Hence, it was decided to prioritize data quality over quantity.

Validation Group

A validation group of an additional 100 large public and private hospitals will be surveyed by building energy engineers/auditors with significant past experience in building energy operations. The validation sample survey will be closely monitored by the survey administrators to ensure highly reliable data that can be used to validate the quality of the data from the remaining 1,000 sample surveys, that were conducted by trained surveyors, with less experience in building energy operations.

Sample Stratification

Ownership. The sample size was divided in the ratio of 4:1 between publicly- and privately-owned hospitals. The larger sample of public healthcare facilities will aim to provide not just national-level trends in hospital energy consumption but also comparable state-level trends. This regional primary data will serve to guide more targeted interventions in the study states.

Climate zone. The climate zone map of India per the National Building Code 2016 of India was overlaid with the district map of India using QGIS, a free and open-source cross-platform desktop geographic information system application that supports viewing, editing, and analysis of geospatial data. This overlaying enabled assigning each district one of the 5 climate zones in India. Some districts that fall across more than a single climate zone were assigned that climate zone which is largest by area. Figure 2 shows this QGIS overlaying for the state of Maharashtra – in this, the district of Latur falls across 2 climate zones, i.e., hot and dry and composite, but it was assigned hot and dry since it a covers larger area of Latur.

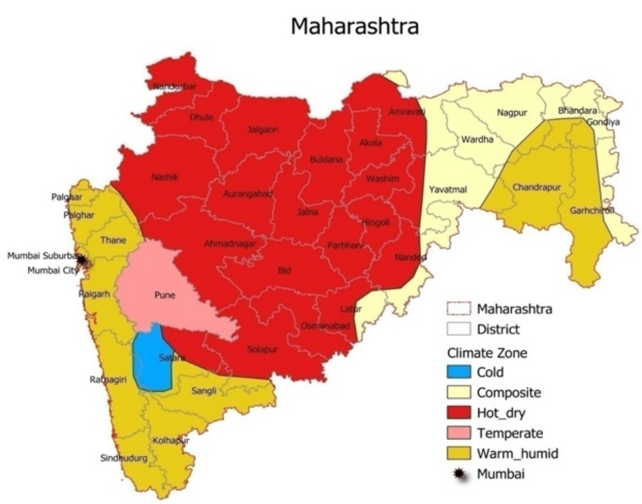

Figure 2. Layering of the climate zone and district maps of Maharashtra on QGIS.

The public and private hospitals were distributed among the 5 climate zones by number, as shown in Figure 3.

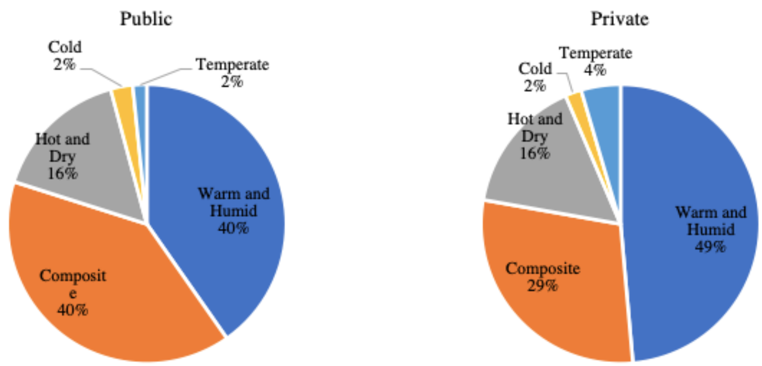

Figure 3. Climate zone distribution of public and private hospitals

Hospital typology. The public hospitals were distributed by the approximate share of their annual energy consumption based on primary data (sourced from up to 10 public hospitals) and not by hospital populations to avoid skewing the distribution towards small public hospitals, i.e., sub-centers and primary health centers, which though much larger in number compared to sub-district and district hospitals, consume far less energy on account of limited energy using medical and building services. The private hospitals were distributed purely by number since it is very difficult to account for the wide variation in the energy intensities of private hospitals. Figure 4 shows the distribution of hospitals by their typology.

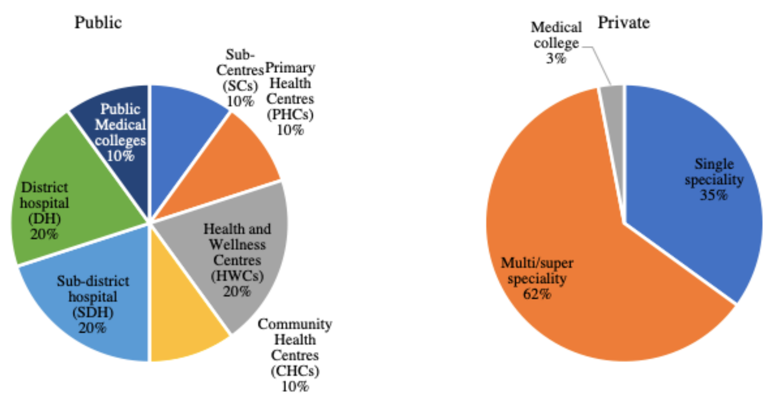

Figure 4. Typology distribution of public and private hospitals

Survey Questionnaire

The survey questionnaire, customized for the 10 public and private hospital typologies mentioned above, was carefully created to meet the survey objectives. It was designed to gauge high-level electrical (including grid-connected, onsite diesel generator, and onsite solar PV electricity) and non-electrical (including diesel, petrol, fuel/furnace oil, natural gas, liquified petroleum gas, and biomass) annual energy consumptions at the hospital-level, key business metrics and building characteristic of normalizing annual energy consumptions, end-use energy system characteristics and the practice of energy-saving measures within them. It was not designed to enable an investment-grade/walk-through energy audit.

Questionnaire Development

Literature review. The survey questionnaire was built-up from the following resources: Establishing a Commercial Buildings Energy Data Framework for India (Iyer et al. 2017), ENERGY STAR Portfolio Manager, and Exploratory Data Analysis of Indian Hospital Benchmarking Dataset: Key Findings and Recommendations published under the USAID CBERD project (Sarraf et al. 2014).

Key considerations. The following considerations were used to customize the survey questionnaire such that the survey objectives can be met reasonably within the project timeline.

- Data collection boundaries: The questionnaire was designed to limit data collection to (i) buildings in which medical services and/or patient support services are provided, excluding staff quarters, hostels, etc., (ii) FY2019-20, since this was the most recent pre-pandemic year when the hospitals operated "as usual", and FY2020-21 data too in some cases, and (iii) fully operational facilities, appliances, and equipment, excluding defunct, redundant, and standby ones.
- Comprehensiveness versus feasibility of data collection: Each question in the questionnaire was carefully thought through in terms of its contribution/value in meeting the survey objectives; low-priority questions were left out to reduce the survey time. The questions were designed to leverage, as far as possible, data/records easily available with/accessible by hospital personnel.
- Ease of response: Questions were framed with single/multi-select options to choose from as far as possible to enable ease of survey response and reduce the survey time.
- Hospital typology-wise customization: The 10 hospital typologies considered in the survey are vastly different in terms of their medical and building services. Hence the questions were customized to create more targeted questionnaires for each typology, with fewer questions presented to small hospitals in rural areas fewer than those presented to large hospitals in urban centers.

Questionnaire review and due diligence. The questionnaire underwent two major rounds of revisions, once after a rigorous review process by international domain subject matter experts (see Acknowledgement) and then once again to incorporate learnings from the field after the questionnaire was piloted in 20+ large and small, public and private hospitals.

Final Questionnaire. The final questionnaire comprises 75 questions across the following elements:

- Identifiers (e.g., hospital name, location, contact details of the primary respondent, etc.)
- Medical specialties; basic business metrics such as the number of beds
- Building characteristics, e.g., total gross floor area, green building certification
- Hospital-level annual consumption of electricity and non-electricity energy
- Characteristics of onsite solar PV system used to support hospital energy needs
- Ambient lighting of interior spaces
- HVAC
- Refrigeration for drugs, vaccines, blood, and morgues/ mortuaries
- Medical imaging equipment; their operational practices

- Centralized and standalone hot water systems, centralized steam generation
- Pumping cold and clear treated municipal and/ or groundwater
- Treatment of municipal and/or recycled water, sewage, and liquid waste
- EV charging

Data Sharing Terms

Hospitals will share their data with the survey administrators per the following:

- Results of analysis performed on the combined data will be made publicly available, and research findings will be published.
- The survey data will be publicly released after removing all personal identifiers such that the data cannot be retraced back to the hospital, i.e., information that could be used to identify the hospital or survey respondent will be removed, including addresses, contact information, and names.
- Personal identifiers of publicly-owned hospitals may be shared with State Nodal Officers for Climate Change[1] of the hospital's state (only) to enable appropriate and timely interventions.

Survey Pilot

Given the technical nature of the survey, a small team of surveyors with at least a bachelor's degree and 1 year field experience was provided comprehensive training ahead of the pilot. A pilot survey, comprising both public and private typologies, was conducted in two regions – Delhi UT & National Capital Region (DL) in the composite climate zone, and Bengaluru Urban and Rural, Karnataka (KA) in the temperate climate zone (Figure 1). 20+ hospitals were covered under the pilot survey conducted from December 2021 to January 2022. The survey generated a lot of interest among public and private hospitals keen to use the survey data to benchmark their energy performance with peers in similar climates as a definitive step towards energy management.

Data Insights

The pilot survey distributed across different types of public and private hospitals is not conclusive of the energy performance trends within the different types of healthcare facilities. However, it provides a critical understanding of the range of outcomes possible from the main survey.

Energy Performance Indicators. Carefully defined energy performance index (EPI) benchmarks for different hospital types can facilitate a quick and reliable energy performance assessment by offering a comparison with similarly-sized hospitals with comparable healthcare facilities. Two separate EPIs, annual electricity consumption per unit area (kWh/m^2.year) and

[1] State Nodal Officers for Climate Change are part of the institutional mechanism developed under National Program on Climate Change and Human Health. They are state government officials who are entrusted with the responsibility to implement NPCCHH in the states. SNOCCs are supported by district nodal officers.

annual electricity consumption per hospital bed (kWh/bed.year), were assessed for the sampled hospitals. The EPIs, both area-weighted (Figure 5) and bed-weighted (Figure 6), were assessed for both pre-pandemic FY 2019-20 and pandemic FY 2020-21. A huge variation was observed in the EPIs of the surveyed hospitals grouped by their types. The mean EPI values of the sampled hospitals for each hospital type are marked on both the EPI figures. The pre-pandemic mean area-weighted EPI for public hospitals were 3 kWh/m^2.year for HWCs, 18 kWh/m^2.year for CHCs, and 198 kWh/m^2.year for SDH. In the case of the private hospitals, the pre-pandemic mean area-weighted EPI were 40 kWh/m^2.year for single-specialty hospitals, 193 kWh/m^2.year for multi-specialty hospitals, and 229 kWh/m^2.year for super-specialty hospitals. For most public hospitals (and all HWC and SDH), there was an increase in both area-weighted and bed-weighted EPIs in FY 2020-21 compared to the pre-pandemic levels. In contrast, a drop in EPIs was observed for the private hospitals post-pandemic. The number of hospital beds is not an accurate indicator of hospital occupancy as not all beds are in use throughout the year. Thus, inpatient days will be factored in the main survey to understand the bed-weighted EPI better.

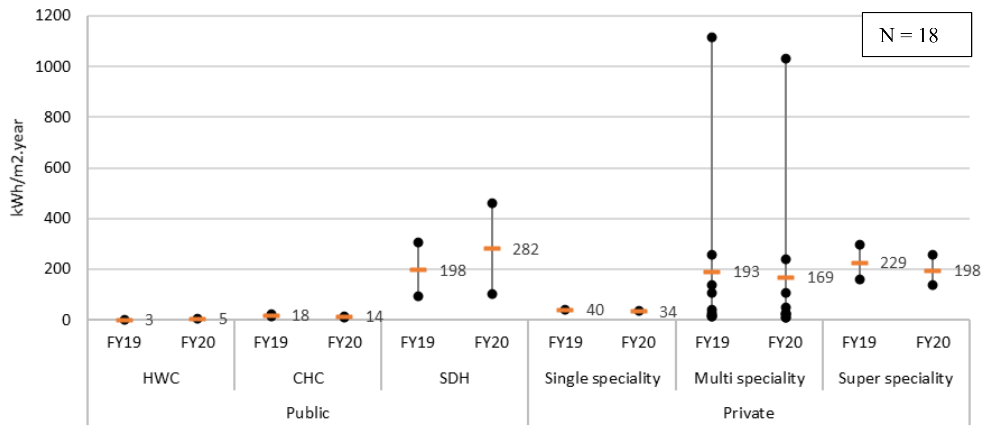

Figure 5. Hospital type-wise annual electricity consumption per unit area for the sampled hospitals

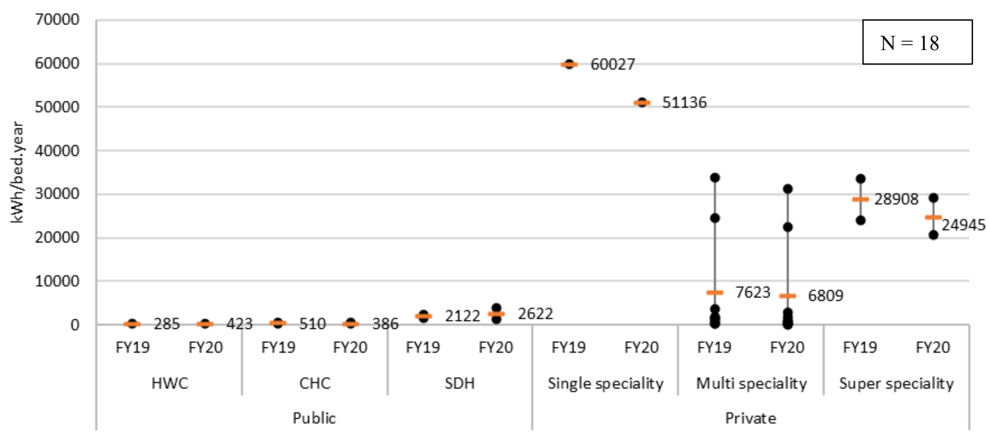

Figure 6. Hospital type-wise annual electricity consumption per bed for the sampled hospitals

Air-conditioning. Distribution data of different air-conditioner (AC) technologies can help create targeted retrofit programs. Amongst the different types of public and private hospitals surveyed, ACs were found operational in 56% of the sampled facilities. None of the smaller public healthcare facilities, including PHC, HWC, and CHC, had any air-conditioning irrespective of the climate zone. In contrast to the public hospitals, 67% of the private hospital sample had air-conditioning. Chilled water type air-conditioning was present in comparatively bigger hospitals, with a gross floor area of more than 2500 m^2 and 70 beds. Most of the operational direct expansion (DX) type ACs were 3-star (or higher) BEE (i.e., Bureau of Energy Efficiency, Ministry of Power, Government of India) star labeled. The distribution of DX units by type and status of BEE star rating is presented in Figure 7(a). The most prominent type of DX unit was the split air-conditioner comprising 71% of the overall stock. 68% of these split ACs were 3 to 5-star BEE star labeled. Variable Refrigerant Flow (VRF) ACs comprise 6% of the overall stock; only 17% of these units were 3 to 5-star BEE star labeled. The distribution of BEE star-rated DX units by hospital types is also presented in Figure 7(b). Looking at the overall stock of DX type ACs in the sampled healthcare facilities, there is a scope to replace 35% of ACs with energy-efficient BEE-star-rated ones. Non-star-rated in Figure 7 means either unlabeled or having a star rating below 3-star BEE star rating. The break-up of operational chilled water tons of refrigeration (TR) by type of chiller, refrigerant, and motor drive is presented in Figure 8. The chilled water type air-conditioning systems were present only in private hospital samples, wherein 61% of the operational TR was installed in super-specialty and the remaining 39% in multi-specialty hospitals. Half of the operational chilled water capacity comprised water-cooled centrifugal chillers, followed by 36% air-cooled screw chillers, 12% water-cooled reciprocating chillers, and just 1% air-cooled reciprocating chillers. 100% of the sampled water-cooled centrifugal chillers had HFC-based refrigerants. In contrast, 72% of the sampled air-cooled screw chillers, 49% water-cooled reciprocating chillers, and 100% air-cooled reciprocating chillers had HCFC-based refrigerants. There was an almost equal distribution of Variable Frequency Drives (VFD) in the water-cooled centrifugal, air-cooled screw, and water-cooled reciprocating chillers, with roughly 50% of the operational tonnage being VFD and remaining Constant Speed Drives (CSD) for each the three types of chillers. All air-cooled reciprocating chillers were with CSD.

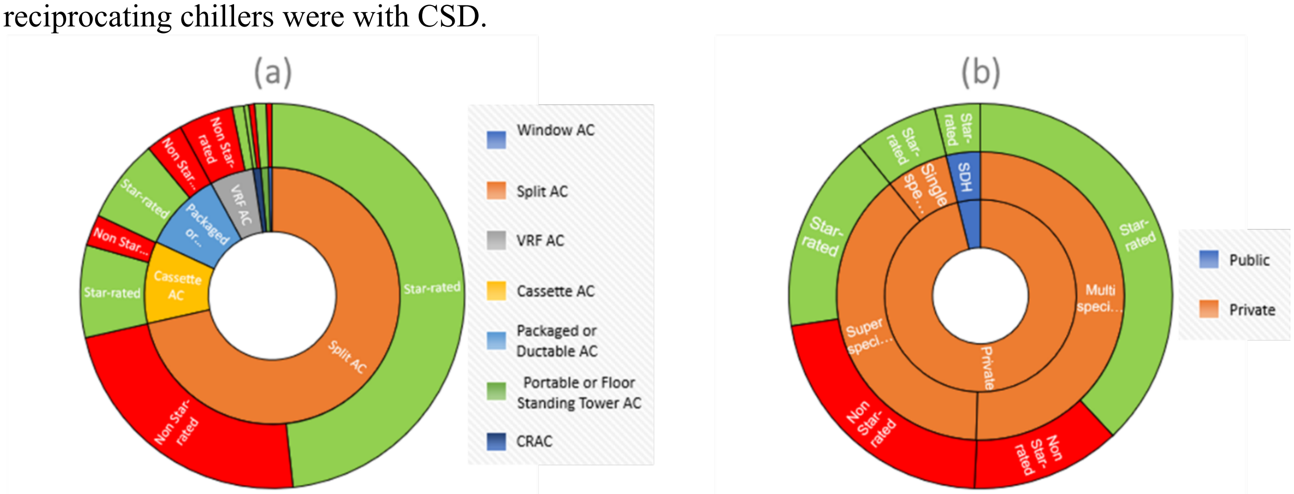

Figure 7. (a) Distribution of DX units by type and BEE star rating; (b) Distribution of BEE star rated DX units by hospital types

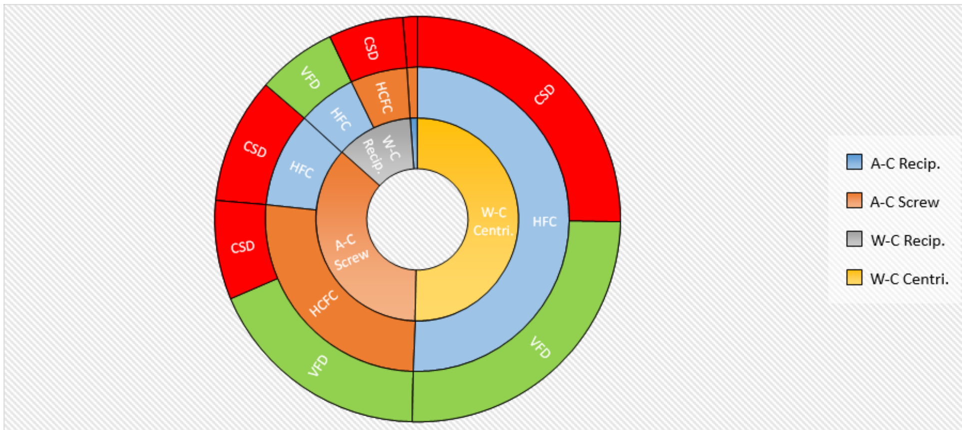

Figure 8. Break-up of operational Chilled Water TR by type of chiller, refrigerant, and motor drive

Medical imaging equipment. The sampled public hospitals had X-ray, echocardiogram, and ultrasound types of medical imaging equipment. All of them were switched "Off" when not in use (i.e., when not scanning) during business and non-business hours. In contrast, all medical imaging equipment in the private hospitals (Figure 9), apart from Cyclotron, were not always operated in "Low power mode" when not in use (i.e., not scanning) during business hours. 40-60% of all ultrasound, echocardiogram, MRI, CT scan, and X-ray machines were operated in "Power-consuming 'standby' mode" when not in use during business hours. Additionally, 30-60% of all Echocardiogram, MRI, CT scan, and X-ray machines were operated in "Power-consuming 'standby' mode" even during non-business hours, i.e., when the hospital is not providing medical care. Medical imaging equipment has significant energy saving potential by operating them in energy-saving "Low power mode" mode during working hours. Results from the main survey will be used to inform energy-efficient practices in medical imaging equipment that can be adopted by hospital personnel, of course without compromising patient care.

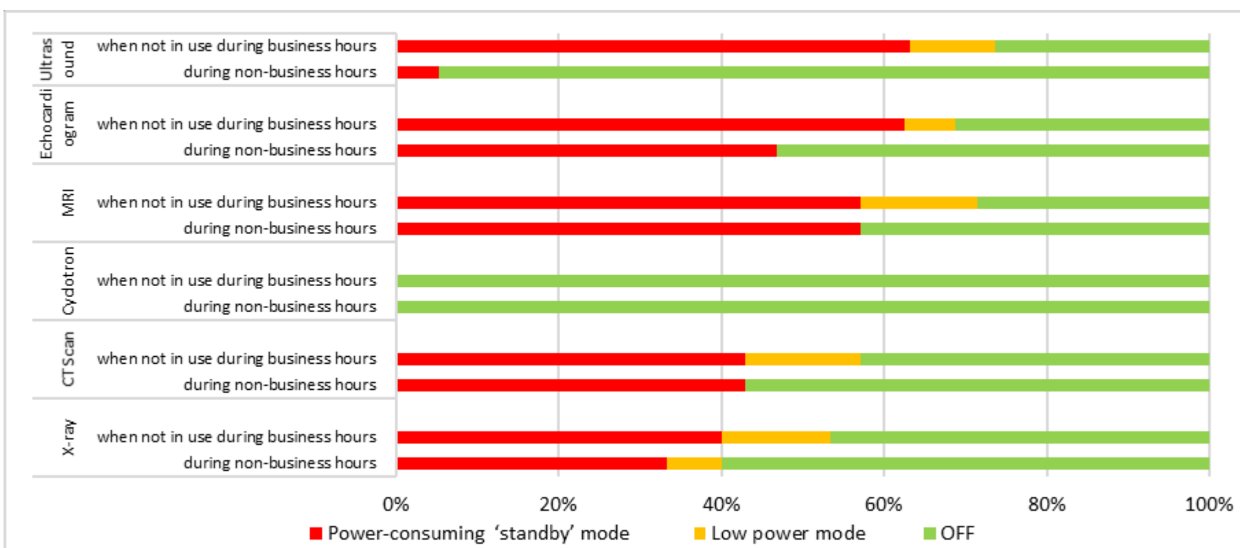

Figure 9. Distribution of power modes during business and non-business hours for private hospitals

Medical use refrigeration. CFC-based refrigerators are still prevalent in medical use refrigeration equipment in many public and private hospitals (Figure 10). Half of the sampled

CHC and SDH had CFC-based refrigerators in the public hospitals. 44% of the sampled private multi-specialty hospitals had CFC-based refrigeration units. In terms of the operational stock, the share of refrigerators still using CFC refrigerants was as high as 20% in at least one CHC and SDH. Overall, the percentage of CFC-based refrigerators in the sampled stock of medical refrigeration units in public hospitals was 8% and 1% for private hospitals. The main survey results can help prioritize the phase-out of CFC-based refrigerators and inform the design of BEE's standards and labeling (S&L) program.

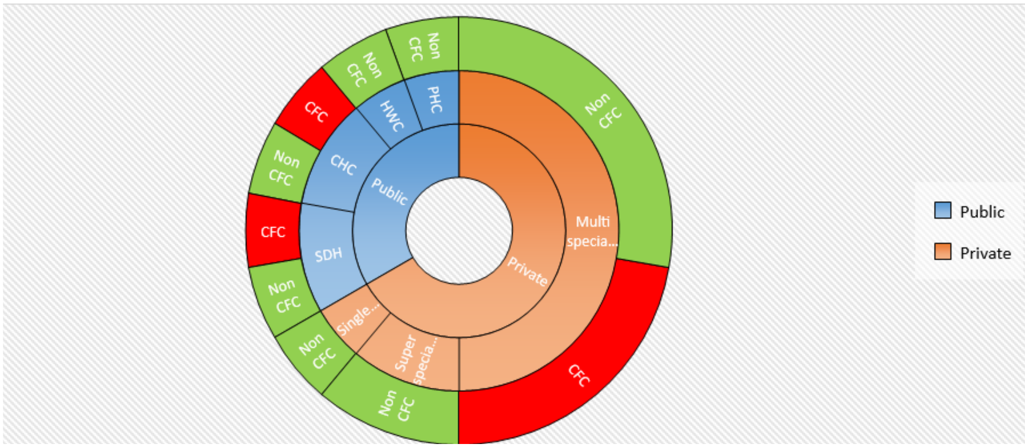

Figure 10. Distribution of sampled hospitals by the presence of CFC-based Medical Refrigeration units

Data Quality and Limitations

The sample size was skewed towards private hospitals, with the public hospitals being underrepresented. There were some reporting issues in terms of the units, for instance, values in ft^2 being reported as m^2. The raw data went through a rigorous quality check before starting the analysis. The purpose was to check for potential errors that may have occurred at the time of data entry. The quality check revealed a possibility of misinterpretation of some questions, such as refrigeration tonnage of individual units being misunderstood as the total installed tonnage of the given unit type. There were incomplete and inaccurate data points as well, particularly in the monthly electricity consumption. The potentially erroneous data points were either corrected through verification with hospital authorities or ignored or removed altogether.

Learnings and Post-pilot Revisions

Three specific challenges occurred in executing the pilot as envisaged due to the rising cases of COVID-19 in India due to the Omicron variant.

- Firstly, with most large public hospitals required to prioritize activities toward COVID response, it was difficult to engage these health facilities in the survey.
- Secondly, the varied levels of the surge in cases in both pilot states saw different levels of respondent participation across facilities. In Karnataka, smaller facilities in the public health system, as well as different typologies of private healthcare, were onboarded. In contrast, in Delhi, where the pandemic was more severe at the time, large and smaller public hospitals could not be reached.

- Thirdly, given the largely technical nature of the survey questions, the lack of facility-level engineering personnel in most public facilities affected data quality adversely.

Despite these changes, the exercise provided a lot of learnings that helped make revisions to the main survey.

Different governance structure of the healthcare facilities. Foremost among the learnings is that the project is dealing with two parallel health systems in India – private and public – both independent of each other. Recruiting healthcare facilities for such a survey entails different strategies given different governance structures. Provided the hospital management is inclined to participate in the survey, the process of engagement with the private healthcare system is relatively linear and smooth. In contrast, the process of engaging with public healthcare systems is less linear. Various government departments with varying authorities and roles are engaged to run the entire spectrum of the public healthcare system. Securing approvals to work with public health facilities, therefore, entails engagement with multiple layers of the system with corresponding delays in timelines. Conflicting priorities for health care workers can also create bottlenecks for committing time to surveys of this nature.

Public health in India is a state subject. Health is a state subject as per the Constitution of India; hence, each state has its own way of working as far as public healthcare is concerned. While the broader structure tends to follow the Indian Public Health Standards (IPHS) guidelines (Ministry of Health and Family Welfare 2012), in some states, the nomenclature of each level of care is unique. This poses challenges in following the sampling methodology outlined for the selection of facility types. Some differences in building designs and services rendered through them were also seen across the pilot study states.

Interest in understanding the post-survey outcomes. Respondents and hospital management were keen to understand post-survey outcomes and the scope for remediation strategies to optimize energy use.

Technical nature of the survey. The survey was perceived to be too technical to be administered by any market research agency. The pilot highlighted the need for in-depth training of surveyors. The surveyors needed a minimum of two visits and multiple follow-up discussions with the respondents to complete the survey. Moreover, some questions were found to be incomprehensible to the respondents, while the length of the survey could also lead to respondent fatigue and poor data quality.

These insights led to the revision of methodology and questionnaire for the main survey, specifically the sample size, the number of questions as well as the framing of questions. Key post-pilot revisions were as follows.

- Reduction in the sample size and creation of a validation group (as explained above)
- Questionnaire optimization (as explained above)
- To make the classification easier, the private hospital typologies were revisited, and the hospitals having more than one specialty like multi and super specialties were combined to form a single typology.

- The pilot exercise was useful for gaining field experience, and a Standard Operating Procedure was devised to ensure that similar mistakes are not repeated during the main survey.
- Given the technical nature of the survey, a team of 40+ surveyors with at least a bachelor's degree and 1-year on-field experience were provided comprehensive training and mock experience encompassing the aim of the study, data sharing terms, and the questionnaire.

Next Step: Main Survey

The main survey will be carried out in February-April 2022. It will be administered in a combination of 2-3 in-person and virtual meetings per hospital using its internet-enabled programmed version (programmed in Dooblo SurveyToGo) and/or its hardcopy version in those areas where internet connectivity is not reliable. The total survey time is estimated to be 2-3 hours barring follow-ups for responses that might be needed on a case-to-case basis.

The main survey will be administered to chief engineers (and the administration department for questions related to business metrics, and the biomedical department for questions related to medical refrigeration and imaging equipment) in CHC, SDH, DH, public medical colleges and all private hospitals. It will be administered to presiding doctors and/or visiting service technicians in smaller typologies such as SC and PHC.

The trained surveyors will be deployed across study states to complete the survey either through in-person meetings or through a combination of in-person and virtual follow-ups. Data quality control systems will be in place through a rigorous check at frequent intervals of all data collected through the survey portal. A subset of data will be reviewed and feedback provided to survey teams where additional inputs or missing data are encountered by the data monitoring teams. A survey tracker to ensure timely completion of facility onboarding and completion of surveys is also established. Regular check-ins of participating teams ensure the strict following of study protocols.

The survey team will use a mechanism set up by the Ministry of Health and Family Welfare under the National Program on Climate Change and Human Health to mobilize the public healthcare system, ensuring the participation of all the state/UT governments. All levels of the public healthcare system – primary, secondary, and tertiary – are represented in the survey sample. An orientation meeting was also convened prior to the pilot exercise to sensitize the state health teams to the nature and scope of the national survey and secure their support. Private hospitals will be contacted directly. The team will provide participating hospitals with the following:

- Benchmark of their hospital's energy performance with other comparable peer hospitals
- A compilation of energy-saving measures in a workshop/webinar
- Access to anonymized raw data of all public and private hospitals participating in the survey
- A training program on HVAC systems operations and maintenance at concessional fees

Use Cases of the Survey Data

The survey team will anonymize and publicly release analytical and data visualization tools similar to the GIS-based New York Energy and Water map (NYC Mayor's Office of Sustainability 2017) and Building Performance Database (US Office of Energy Efficiency and

Renewable Energy 2022). These releases will let the user split the national aggregate by hospital typology, end-use, and region. The use cases of the survey data are as follows.

- **Policymakers.** Develop and update energy benchmarks, codes, and standards for different hospital typologies and mainstream the use of renewable energy in Indian healthcare sector, in general, and rural hospitals, in particular, to improve healthcare delivery.

- **Hospital owners.** Benchmark their hospital's energy performance with peers to manage energy consumption and strengthen their ESG goals. Private hospital chains participating in the survey will be able to internally benchmark chain-wide facilities' energy performance and identify opportunities for energy efficiency interventions as the first fundamental step towards enterprise energy management.

Conclusion

In the milieu of India's heightened COP26 pledges, this survey provides a starting point to engage the health sector to achieve its decarbonization goals. Energy is an important domain for optimum health services and can seriously affect care delivery, diagnostic services, and patient outcomes in settings where absent or interrupted or sub-optimal energy consumption occurs. This baseline idea of energy consumption will provide insights into gaps in optimal energy use and opportunities for transitioning to both energy efficiency and cleaner forms of energy for all aspects of service delivery from building design, heating, and cooling to end-use of various equipment.

India's existing program with the health sector and the conduct of the survey through the program already provides an opportunity to sensitize and engage the health stakeholders from the public health systems in the dialogue for optimizing their energy use and footprints. Simultaneously, focused engagement of the private health care providers through existing networks to utilize the survey findings to implement game-changing strategies for both energy efficiency and cost-savings will steadily encourage peer hospital chains to follow suit. Overall, the insights from the survey will be leveraged to build on existing frameworks and financing opportunities at the national and sub-national levels for establishing an energy-efficient and climate-smart Indian health system.

This survey results will trigger a paradigm shift from a transactional and myopic model of energy efficiency comprising one-off interventions to a more long-term model that institutionalizes energy and emissions management practices founded on reliable data analytics across commercial and public-use buildings. This survey methodology has broad applicability for designing and implementing future efforts for closing energy data gaps for other energy-intensive building typologies such as hospital and hotel chains, ICT companies, airports, etc.

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