Towards Climate-smart Hospitals

Insights from a National Hospital Energy Consumption Survey

National Centre for Disease Control
Directorate General of Health Services
Ministry of Health and Family Welfare
Government of India

National Programme on Climate Change and Human Health

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National Hospital Energy Consumption Survey

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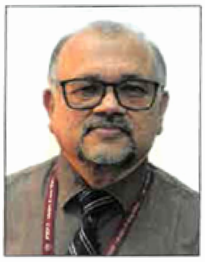

FOREWORD

It gives me immense pleasure to present the findings of the first ever national survey of hospital energy consumption in India. Under the aegis of the National Programme on Climate Change and Human Health (NPCCHH), a nation-wide exercise in 18 states with diverse climate zones was conducted in both public and private hospitals to understand the quantity and quality of energy consumption in different types of healthcare facilities.

With global and national commitment to transform health services to sustainable and environment-friendly operations, there is an immense scope to address this issue from several perspectives ranging from buildings and infrastructure, efficient use of energy and water, optimal management of biomedical and human waste, sustainable food and transport option to procurement of energy-efficient equipment. Addressing any of these domains will significantly help to reduce greenhouse gas emissions from health sector for mitigation of the Indian health sector's climate footprint.

Under NPCCHH, steady progress has been achieved in building awareness and capacity for strengthening health infrastructure and improving structural and functional resilience of the sector in face of acute climatic events. A critical component of this strengthening is provision of good, reliable, efficient and uninterrupted energy supply to healthcare facilities. This has direct impact on availability and access to healthcare services, quality of healthcare and the outcomes of care delivery on population health. Public health facilities in some regions of rural India often struggle with-poor energy supply issues while transition to reliable forms of energy has occurred in many regions. Mapping energy utilization patterns in different regions and types of healthcare facilities across Indian states provides a starting point for our programme to take a structured approach to strengthening energy efficiency in Indian health sector. Additionally, with National commitment to scale India's renewable energy capacity to 500GW by 2030, solar and other forms of clean energy provide an important and scalable option for uninterrupted energy supply to health facilities thereby optimizing health care delivery. Therefore, establishing a baseline energy assessment has a dual advantage of guiding both efficient and optimum energy provision, and utilization customized to suit the type of health facility and level of the health system.

We are grateful to our technical partners – viz. Centre for Chronic Disease Control and Alliance for Energy Efficient Economy for undertaking this Nationwide survey of a representative sample of public and private hospitals across 18 states and documenting their findings in this report. The findings provide the Indian health sector with a first look at scope for optimizing energy utilization and energy efficiency in the Indian health sector. The recommendations provided will help State health departments and State programme officials to develop strategies towards sustainable and energy-efficient health care delivery in India.

We hope the report will serve as an important resource for State governments and private healthcare providers (for policy and programme planning), for academia and think-tanks (as a source of data) and for funding agencies (with ample inputs to define resource allocation).

The National Programme on Climate Change and Human Health looks forward to implement the recommendations from this work with support from national and state-level stakeholders.

Congratulations to the technical teams for this unique endeavor!

(Atul Goel)

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Executive Summary

Motivation

The National Programme on Climate Change and Human Health (NPCCHH) envisions strengthening healthcare services to all Indian citizens, especially children, women, and marginalised populations, in the context of climate change. Launched in 2019, the program has steadily established momentum engaging all states in initiatives to establish climate-resilient and environmentally friendly healthcare facilities. With the growing vulnerability to acute climate events across India, the Indian healthcare system should be able to withstand climate change adversities and still function, for which access to uninterrupted energy is an essential prerequisite. Energy forms an important component of the Health Adaptation Plan (HAP) and proposed framework for green (environmentally sustainable) and climate -resilient or climate-smart healthcare under the NPCCHH. Under the program, states have been sensitised and encouraged to address the energy-health nexus. Access to uninterrupted sources of energy for healthcare facilities has downstream impacts on the quality of health service delivery and health outcomes. It is, hence, important to develop an understanding of the energy requirements for effective and efficient healthcare delivery, the unmet energy needs of healthcare facilities, potential for deploying alternative sources of energy to meet the energy gap, and how to reduce energy-related greenhouse gas (GHG) emissions. With this overarching objective, the NPCCHH facilitated a unique, nation-wide survey to map and understand the energy consumption patterns in Indian healthcare facilities.

The healthcare system in India is marked by distinct heterogeneity in ownership (e.g., public hospitals, insurance hospitals, municipal hospitals, railway hospitals, defence hospitals, and private hospitals), size (ranging from small clinics in rural areas to large multi-specialty hospitals), air-conditioned area, medical services, ancillary services, comfort levels, etc. As a result, the energy requirements of the healthcare facilities in the country are varied. The survey has attempted to select a representative sample of the Indian health system for this effort.

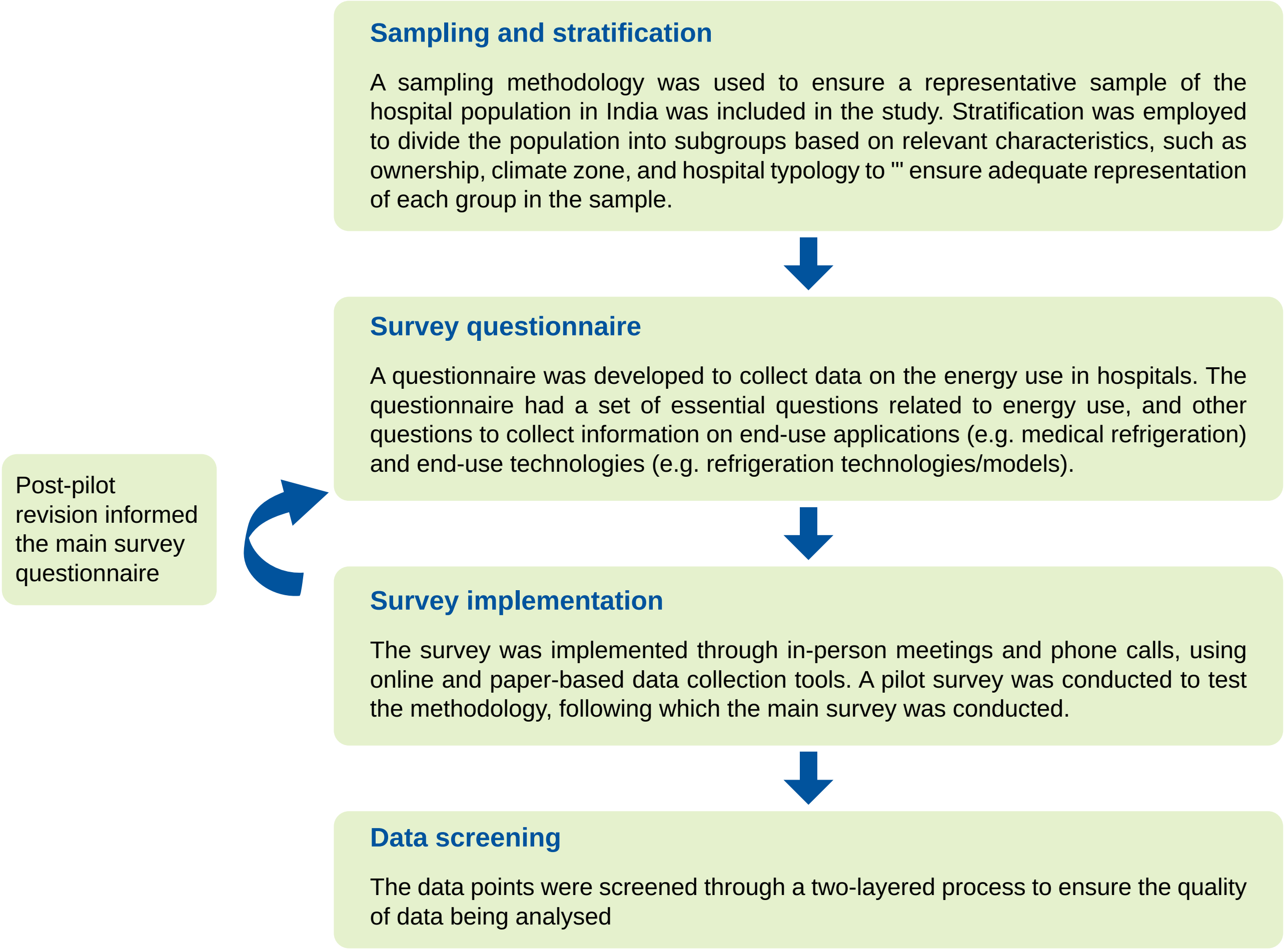
Defining strategies and deploying energy efficiency and renewable energy interventions for climate-smart hospitals is contingent on the availability of granular end-use energy data. In order to design these interventions and assess their energy savings potential, it is imperative to accurately characterise the energy use in healthcare facilities at the national and state level across different hospital typologies. This will require reliable end-use hospital energy data. So far, there have been some efforts in baselining energy consumption in commercial buildings in India, including hospitals, which is not adequate to estimate typology-wise energy performance benchmarks for healthcare facilities in India. This present study is a first-of-its-kind exercise in plugging this data gap through a hospital energy consumption survey covering many healthcare facility typologies across states and UTs.

The study was conceptualised and conducted under the aegis of the National Program on Climate Change and Human Health, Ministry of Health and Family Welfare, Government of India, with technical support from Alliance for Energy Efficient Economy (AEEE) and the Centre for Chronic Disease Control (CCDC). This study is intended to be a starting point for, among other things,

- Identifying areas of energy efficiency and renewable energy interventions in hospitals
- Formulating data-driven policies and programmes
- Identifying best practices and setting aspirational goals for hospitals towards climate-smart healthcare

Methodology

The project was launched in January 2021 and took over 2.5 years to complete. The project timelines were extended due to challenges related to the COVID-19 pandemic. It was proposed to be administered in all 5 climate zones, 18 states/Union Territories (UTs), and across 10 hospital typologies of publicly and privately-owned “hospitals”, i.e., centres of medical care with inpatient beds. The sample stratification was done in layers, based on the ownership, climate zone, and hospital typology. Public hospitals included medical college hospitals, district and sub-district hospitals, community health centres, primary health centres, health and wellness centres and sub-centers. Private hospitals included single and multi- specialty hospitals. Several key steps were involved in conducting this study, as depicted in the following figure.



Sampling and stratification

A sampling methodology was used to ensure a representative sample of the hospital population in India was included in the study. Stratification was employed to divide the population into subgroups based on relevant characteristics, such as ownership, climate zone, and hospital typology to "' ensure adequate representation of each group in the sample.

Survey questionnaire

A questionnaire was developed to collect data on the energy use in hospitals. The questionnaire had a set of essential questions related to energy use, and other questions to collect information on end-use applications (e.g. medical refrigeration) and end-use technologies (e.g. refrigeration technologies/models).

Post-pilot revision informed the main survey questionnaire

Survey implementation

The survey was implemented through in-person meetings and phone calls, using online and paper-based data collection tools. A pilot survey was conducted to test the methodology, following which the main survey was conducted.

Data screening

The data points were screened through a two-layered process to ensure the quality of data being analysed

A total of 623 hospitals (357 public and 266 private) were surveyed, which is 3.6% of the estimated hospital population in India. For comparison, the US Commercial Building Energy Consumption Survey (CBECS) 2018 selected a sample size of 16,000 buildings, which was 0.27% of the estimated 5.9 million commercial buildings in the US. A total of 341 hospitals (185 public and 156 private) qualified for final analysis after the data filtering process; the filtering process removed those hospitals from the analysis that provided either too little or seemingly incorrect data.

Summary of hospital-level survey findings

- Electricity from the grid (mainly), on-site solar PV, and on-site diesel generators comprise more than 90% of hospitals' energy supply.
- The penetration of on-site solar PV is 17% in private and 11% in public hospitals.
- Hospitals consumed ~9% of India's “commercial” electricity consumption in FY2019-20 (i.e., 9.7 TWh/year).
- The annual Scope 2 GHG emissions of hospitals in FY2019-20 were 7.7 million tonnes of CO2. (Scope 2 emissions are indirect emissions from purchased energy)
- There is a wide variation in hospital-level energy intensities (measured in Energy Performance Index (EPI) and Annual Energy Use per Bed (AEUB) between and within hospital typologies. The large EPI diversity can be attributed to factors related to energy efficiency such as the energy efficiency of end-use equipment/appliances and behavioural energy efficiency, and factors unrelated to energy efficiency such as differences in air-conditioned areas, levels of medical services provided, hours of active use, the climate zone, the degree of outsourcing of services, and patient privacy.

Summary of potential end-use interventions based on survey findings

The survey pointed to several differences in end-use uptake and utilisation pathways between the public and private healthcare facilities. While Heating, Ventilation and Air-Conditioning (HVAC) use and type depended on the size and level of healthcare in the public health system, (sub-centers and health and wellness centres mostly shown absence of HVAC) there is still immense scope to promote informed decisions in procurement of energy-efficient heating and cooling systems.

The purchase of star-rated medical-use refrigeration even in rural health facilities where storage of vaccines and drugs is required can address both the cost factor and help mitigate the hospital's energy footprint. Similarly, the transition to energy-efficient lighting, medical equipment, and water-heaters (including solar-powered heaters) can be mandated within the NPCCHH. The detailed end-use interventions are outlined below:

Heating Ventilation Air-Conditioning (HVAC): Several potential end-use interventions can be identified to improve energy efficiency in HVAC systems within hospitals. Firstly, hospitals should promote the adoption of high-efficiency BEE star-labelled Room Air Conditioners (RACs) and upgrade lower-rated RACs to 3-5 star labelled ones. Increasing awareness about BEE star ratings among administrators (and even operators) is crucial to facilitate informed decision-making. Additionally, hospitals should also consider variable frequency drives (VFD) for chillers, which enable better capacity control and result in energy savings. In terms of refrigerant use, hospitals should aim to transition from high-Global Warming Potential (GWP) refrigerants to low-GWP alternatives to reduce greenhouse gas emissions, aligning with the goals of the Montreal Protocol.

Medical-use refrigeration: Hospitals that use domestic refrigerators can mandate the purchase of 5-star-rated refrigerators in their procurement process. Additionally, for other types of medical-use refrigerators which are not yet in the Standards & Labelling (S&L) program of the Bureau of Energy Efficiency, hospitals can mandate energy efficiency as one of the criteria for selecting and procuring a suitable model. State health departments can increase the penetration of solar refrigerators in sub-centers and primary health centres in areas where the grid connectivity is unreliable.

Lighting: Adequate lighting is crucial in all establishments, especially in hospitals where the emphasis lies on health, safety, and the well-being of patients as well as healthcare professionals. The need to be well-lit as well as 24/7 operations of many healthcare facilities result in lighting being a significant part of energy use. Lighting can influence the body's circadian rhythm and impacts an individual's physical and mental well-being by affecting mood and energy levels. LED lights are found to not only be favourable from a visual comfort perspective, but also result in energy and cost savings. While hospitals in both private and public sectors have shown considerable progress in switchover to LEDs, a large remainder can still benefit from relatively simple and inexpensive lighting retrofits in hospital buildings.

Water heating systems: Energy star-rated solar water heaters are an energy-efficient option for addressing the water heating needs of hospitals. Hospitals, especially public hospitals, have a large potential for adoption of solar thermal or electric hybrid water heating systems.

Medical imaging equipment: Medical imaging equipment has significant energy saving potential by keeping it at the energy-saving "low power" mode when not in use (i.e., not scanning) during business hours. The survey supported past evidence of enormous energy savings from behavioural energy efficiency that can be adopted by hospital personnel operating medical imaging equipment without compromising patient care.

Recommendations

Overall, this unique survey demonstrated the potential to establish a baseline understanding of the Indian health sector's energy consumption both from a quantitative and qualitative perspective. While the targeted states and sample size were difficult to reach given the practical constraints encountered in securing approvals, time and resources, the survey provides a first look at the energy footprint of the Indian health sector. The results are based on primary data collected on a representative sample of healthcare facilities from all five climate zones and all typologies of healthcare across public and private health systems in India. The findings thus provide insights that can be leveraged by the NPCCHH to scale up current efforts in strengthening health care infrastructure, building climate resilience, and transitioning to uptake and use of renewable energy. Additionally, the findings on end-use interventions at all levels of healthcare provide a basis for further amplifying the efforts under the NPCCHH through the recommendations below:

- Track energy consumption in all healthcare facilities for managing energy cost and related emissions in hospitals
- Enhance energy efficiency in hospitals through Energy Service Companies (ESCOs)
- Mandate Energy Conservation Building Code (ECBC) norms for new construction and major renovation
- Mandate energy efficiency as an evaluation criterion in hospitals' procurement policies for purchasing medical devices, appliances, and equipment
- Disclose and benchmark data for energy performance target setting
- Create an integrated approach to state-level energy transition (including energy efficiency and renewable energy) in hospitals
- Increase renewable energy deployment in public healthcare infrastructure through state government-led initiatives
- Ensure effective operations and maintenance of renewable energy systems
- Enhance awareness and build capacities of health sector actors for efficient and clean energy transition
- Leverage funding through global, national, and state-level funding mechanisms

CHAPTER
ONE

Introduction

1.1 Background

The imperative need for healthy, energy-efficient, and low-carbon buildings is growing alongside rising expectations of private and public sector environmental performance. Per its new Nationally Determined Contributions (NDCs), India will, inter alia, reduce its emissions intensity of GDP by 45% by 2030 (over the 2005 baseline), and achieve 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, in the run up to its long-term goal of reaching net-zero by 2070 [1]. India's Long-Term Low Emissions Development Strategy (LT-LEDS) launched at COP27 highlights the potential to significantly reduce national power demand by improving the energy efficiency of building design, construction, and operations [2]. According to a peer-reviewed bottom-up estimate based on secondary data, in 2017, India's hospital sector comprised a significant proportion of the commercial building sector, both in terms of built-up area (6%) and energy consumption (14%) [3][1].

Three emerging trends will determine the growing energy needs of hospitals in India. Firstly, hospitals always require uninterrupted power supply to deliver quality healthcare services, to ensure adequate air filtration to prevent the spread of disease, maintain stringent indoor air quality (IAQ) levels that are strictly regulated for temperature, humidity, and quality, especially in operating rooms, emergency rooms, intensive care units (ICUs), and laboratories [4]. The COVID-19 pandemic has further underlined the need for advanced and accessible healthcare, including a growing focus on air filtration and purification, which can have significant implications on hospitals' Heating, Ventilation and Air-conditioning (HVAC) energy consumption and GHG emissions. Secondly, warming temperatures coupled with more frequent and longer heat waves will necessitate heat adaptation measures including increasing penetration of air conditioning in hospitals to ensure thermal comfort. Thirdly, there is a national emphasis on strengthening the healthcare infrastructure in India. The Ayushman Bharat Programme of the Ministry of Health & Family Welfare, Government of India, is upgrading sub-centers and Primary Health Centers (PHCs) by converting them into Health and Wellness Centers (HWCs) in a phased manner, which will provide more energy-intensive medical services compared to SCs and PHCs. The NPCCHH also has a mandate to develop environmentally sustainable and climate resilient healthcare systems across the country.

Per WHO, climate-smart healthcare

- Minimises its negative impact on the environment, restores, and improves it
- Anticipates, responds to, and recovers from climate-related shocks and stresses
- Protects the health and well-being of future generations

In the face of these emerging trends and India's new climate commitments, there is a need to make the hospitals climate-smart to ensure that healthcare is provided to all in a climate-friendly way. The idea for climate-smart healthcare stems from a report developed by the World Bank and

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[1] Kumar et al. 2019 relied on secondary research, data triangulation, and informed assumptions to arrive at meaningful and reasonable estimates in light of lack of reliable data from primary research.

Health Care Without Harm which bridges the divide between adaptation and mitigation for the health care sector [5]. It postulates the need for designing, building, operating, and investing in health systems and health care facilities that generate minimal amounts of GHGs, thereby putting health systems on a climate-smart development path. The Global Roadmap to Decarbonisation of the Health Sector developed by Health Care Without Harm emphasises on seven high-impact action areas, which include powering health care with 100% clean, renewable electricity and investing in zero emissions buildings and infrastructure [6]. Hospitals can adopt various interventions to reduce their climate footprints without compromising on patient care. Amongst the most prominent strategies are implementing measures to improve energy efficiency while meeting the energy requirements of major end-uses such as lighting, HVAC, medical imaging equipment, and so on. Energy efficiency, sometimes called the ‘first fuel’, can help hospitals cut their energy costs and reduce GHG emissions while ensuring adequate and proper healthcare delivery. Incorporation of green building principles in design, construction, and retrofitting can also help optimise energy utilisation of a hospital. Deployment of on-site energy generation including solar PV and other renewables have the potential to cut a hospital’s GHG emissions and energy costs, significantly, over time. Hence, transitioning to climate-smart hospitals would require achieving the maximum level of decarbonization through a combination of renewable energy and energy efficiency.

1.2 Motivation

The National Programme on Climate Change and Human Health [7] envisions strengthening healthcare services to all Indian citizens, and especially children, women, and marginalised populations, in the context of climate change. This means that the Indian healthcare system should be able to withstand climate change adversities and still function, for which access to uninterrupted energy is an essential prerequisite. Energy forms an important component of the Health Adaptation Plan (HAP) and proposed framework for green (environmentally sustainable) and climate resilient or climate-smart healthcare under the NPCCHH. Lack of uninterrupted and quality energy for healthcare facilities has downstream impacts on the quality of health service delivery. It is, hence, important to develop an understanding of the energy requirements for effective and efficient healthcare delivery, the unmet energy needs of healthcare facilities, potential for deploying alternative sources of energy, and the strategies to reduce energy related GHG emissions.

The healthcare system in India is marked by distinct heterogeneity in ownership and size. In terms of ownership, there are public or government hospitals, insurance hospitals, municipal hospitals, railway hospitals, defence hospitals, and private hospitals. In terms of size, the healthcare facilities range from small clinics to large multi-specialty hospitals with varied levels of air-conditioned area, medical services, ancillary services, comfort levels, etc. As a result, the energy requirements of the healthcare facilities in the country are diverse.

An accurate characterisation of energy use in hospitals/healthcare facilities across different typologies at the National and State level is imperative to define strategies for improving energy efficiency and for mapping the potential to deploy renewable energy. This will require reliable end-use hospital energy data. So far, there have been some efforts in baselining energy consumption in commercial buildings in India, including hospitals [8] [9], which is not adequate to estimate typology-wise energy performance benchmarks for hospitals in India. This unique study aims to plug the data gap through a hospital energy consumption survey covering many hospital typologies across States and UTs.

1.3 Project objectives and timeline

The study aims to understand the current energy consumption across different hospital types through a hospital energy consumption survey which could potentially help pave the way for future actions to strengthen the healthcare system in a climate-friendly manner. The main objectives of the study were:

- To map the energy footprint of the Indian healthcare system and produce a baseline assessment of energy consumption within the sector in India
- To assess the state of renewable energy deployment in healthcare and its potential to impact healthcare delivery
- To establish a strategy to drive enhanced uptake of renewables in healthcare

The study, launched in January 2021, was conceptualised and conducted under the aegis of the National Program on Climate Change and Human Health, Ministry of Health and Family Welfare, Government of India, with technical support from Alliance for Energy Efficient Economy (AEEE) and the Centre for Chronic Disease Control (CCDC). Among other things, the outcomes of this study may start or shape the discourses around -

- Identifying areas of energy efficiency and renewable energy interventions in hospitals
- Formulating data-driven policies and programmes
- Identifying best practices and setting aspirational goals for hospitals towards climate-smart healthcare

CHAPTER
TWO

Survey Scope

This survey was administered in all 5 climate zones (as specified in the National Building Codes [10]) and the following political boundaries in India: Assam (AS), Bihar (BR), Chhattisgarh (CG), Delhi (DL), Gujarat (GJ), Haryana (HR), Himachal Pradesh (HP), Jharkhand (JH), Karnataka (KA), Kerala (KL), Madhya Pradesh (MP), Maharashtra (MH), Odisha (OD), Punjab (PB), Rajasthan (RJ), Tamil Nadu (TN), Telangana (TS), Uttar Pradesh (UP), Uttarakhand (UK), West Bengal (WB), and Puducherry (PY).

These states and Union Territories (UTs) were chosen because they cover large swathes of the length and breadth of India (Figure 2.1), represent all 5 climate zones, several large urban centres wherein high-end energy-intensive hospitals are concentrated, and have enough public and private hospital populations to meet the requirements of the sampling methodology (see Section 3.1).

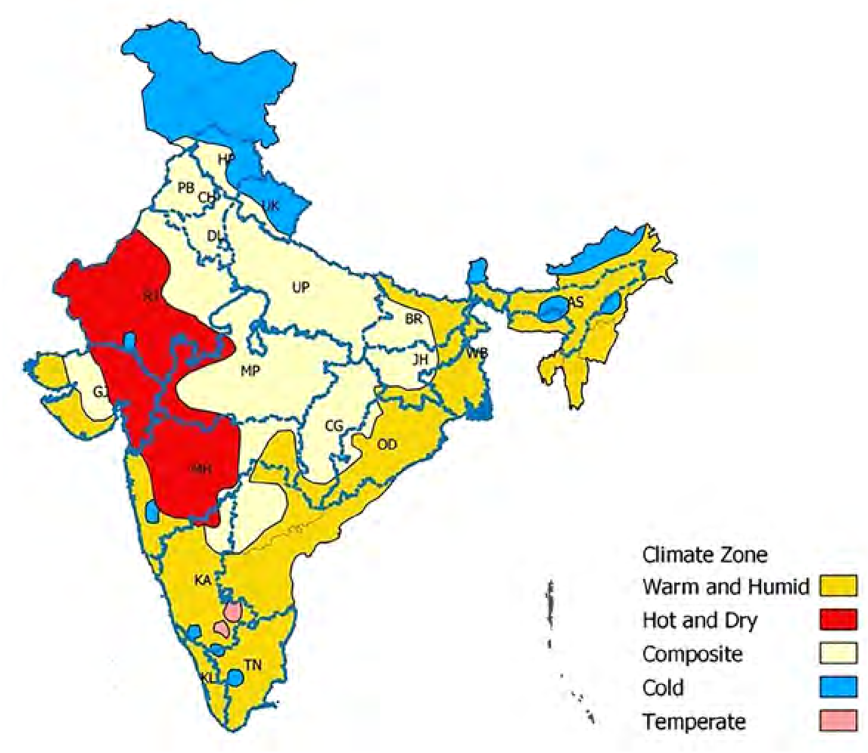


Figure 2.1: Geographical scope of the survey, i.e., 5 climate zones and 18 states/UTs (outlined in blue)

The survey covered 10 hospital typologies (described in Table 2.1) [11] of publicly and privately-owned "hospitals", i.e., centres of medical care with inpatient beds. Sub-centers without in-patient beds were also considered for the survey because they are an important part of the public health system. This definition of "hospitals" precludes pure diagnostic centres, research labs, and out-patient clinics, and some other hospital typologies such as defence, railway, municipal, ESI hospitals, hospitals governed by PSUs, etc.

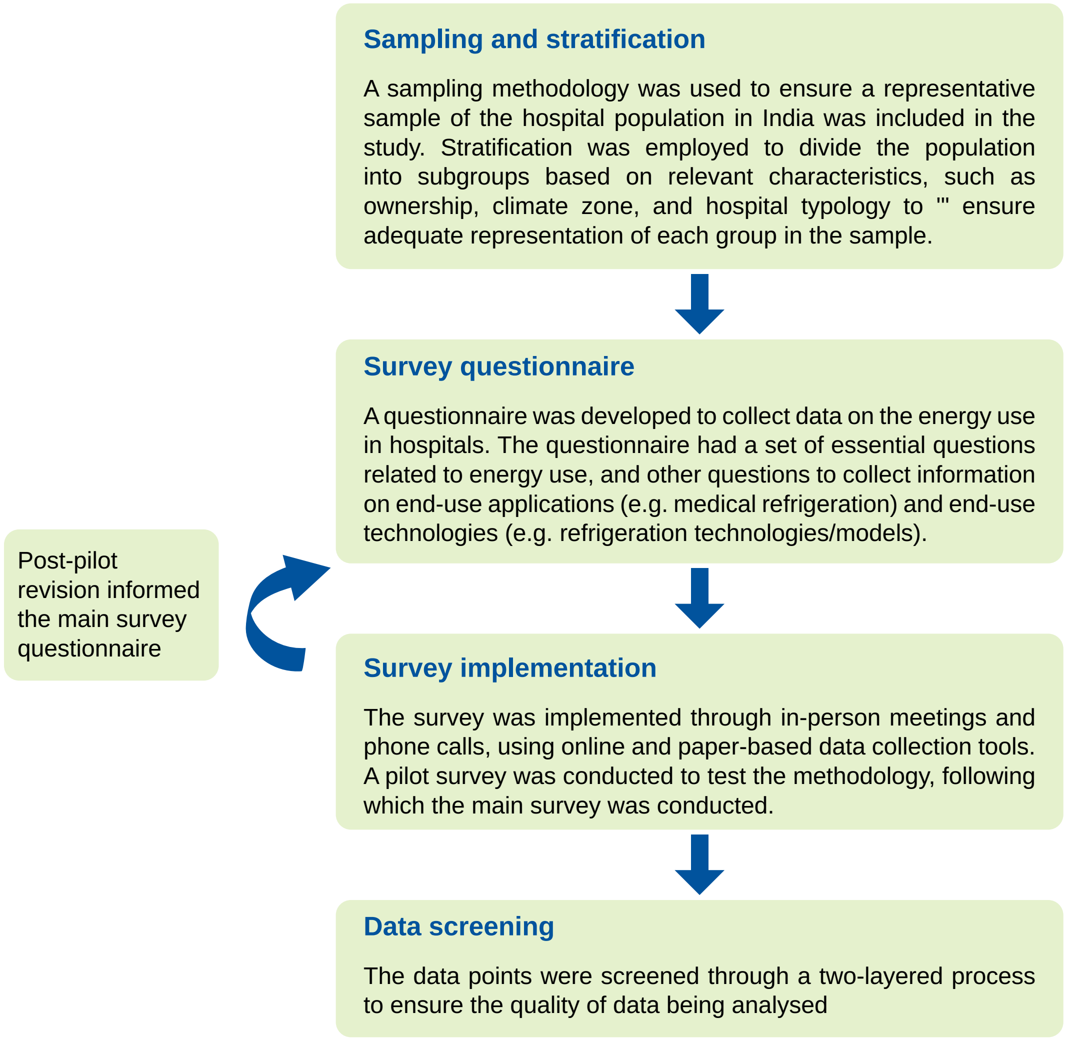
Table 2.1: Hospital typologies within the survey scope

Public hospital typologies	
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-centers 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.
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 hospital typologies	
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.

CHAPTER
THREE

Survey Methodology

Several key steps were involved in conducting this study, as depicted below in Figure 3.1.



Sampling and stratification

A sampling methodology was used to ensure a representative sample of the hospital population in India was included in the study. Stratification was employed to divide the population into subgroups based on relevant characteristics, such as ownership, climate zone, and hospital typology to "' ensure adequate representation of each group in the sample.

Survey questionnaire

A questionnaire was developed to collect data on the energy use in hospitals. The questionnaire had a set of essential questions related to energy use, and other questions to collect information on end-use applications (e.g. medical refrigeration) and end-use technologies (e.g. refrigeration technologies/models).

Post-pilot revision informed the main survey questionnaire

Survey implementation

The survey was implemented through in-person meetings and phone calls, using online and paper-based data collection tools. A pilot survey was conducted to test the methodology, following which the main survey was conducted.

Data screening

The data points were screened through a two-layered process to ensure the quality of data being analysed

Figure 3.1: Methodological steps involved in the study

3.1 Sampling and stratification

The total population of public hospitals across all typologies was 171,504, of which 127,735 were electrified in 2019 [12][2] The total population of private hospitals across all typologies is estimated to be 43,487 [13][3]. Considering that the total effective population of public and private hospitals in India is approximately 170,000, the sample size was estimated to be roughly 1,600 at a 95% confidence level and 2.5% margin of error. The sample stratification was done in layers, based on the ownership, climate zone, and hospital typology. The details of the sampling methodology can be found in this peer-reviewed paper: "Towards Climate-smart Hospitals: Methodology and Pilot of India's First Nationwide Hospital Energy Survey" [14]. While the sampling methodology was founded on the statistical principles of stratified sampling, its academic rigour 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.

3.2 Survey questionnaire

The survey utilised the AEEE Hospital Energy Survey Questionnaire [15], which was created during the course of this project. It was built-up from the following resources: Establishing a Commercial Buildings Energy Data Framework for India [16], ENERGY STAR Portfolio Manager, and Exploratory Data Analysis of Indian Hospital Benchmarking Dataset: Key Findings and Recommendations published under the USAID CBERD project [17]. The questionnaire underwent a rigorous review process by international domain subject matter experts and incorporated learnings from survey pilot[4]. After the questionnaire was piloted in 20+ large and small, public, and private hospitals, the following considerations were used to customise 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., (iii) fully operational facilities, appliances, and equipment, excluding defunct, redundant, and standby ones, and (iii) the years FY 2019-20, since this was the most recent pre-pandemic year when the hospitals operated "as usual", and FY 2020-21 data in some cases.
- **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 responding:** 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 questions were customised to create more targeted questionnaires for each typology, with fewer questions presented to small hospitals with basic healthcare services than larger multi/super specialty hospitals.

Table 3.1 shows the key sections of questionnaire, which was designed to gauge high-level electrical energy consumption (including grid-connected, onsite diesel generator, and onsite solar PV electricity) and non-electrical energy consumption (including diesel, petrol, fuel/furnace oil, natural gas, liquified petroleum gas, and biomass) at the hospital-level, key business metrics, building characteristics, end-use energy system characteristics, and the practice of energy-saving measures. It was not designed as an investment-grade or walk-through energy audit. It consisted of about 30 essential questions related to facility identity, business information, building characteristics, building-level energy use, on-site PV, HVAC, and refrigeration. It consisted of around 35 other questions to collect information on end-use applications and technologies.

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[2] This was the latest information available at the time of creating the survey sampling methodology. Newer data has become publicly available recently, which has been utilised in the post-survey data analysis.

[3] This private hospital population number was sourced from a study by Centre for Disease Dynamics, Economic & Policy and Princeton University, which estimated the number of private hospitals in each State/UT based on specific percentage break-up of hospitals (as provided in the National Sample Survey 75th Round Report). Primary research through contacting hospital networks as well as secondary desktop research did not reveal a single exhaustive list of private hospitals in India.

[4] Details of the pilot survey can be found in the peer-reviewed paper "Towards Climate-smart Hospitals: Methodology and Pilot of India's First Nationwide Hospital Energy Survey" (see References).

Additional to the responses to these questions, electricity bills (for data verification purposes) and the data provider's consent to the survey's data privacy terms were meant to be collected from hospitals.

Table 3.1: Key sections of the survey questionnaire

Essential sections	
Facility identity	This section covers hospital identifiers, which will be strictly protected per the data privacy terms. No personal data regarding individual patients, doctors, hospital staff, etc., was collected.
Business information	This section covers available facilities and basic business metrics to enable benchmarking the energy performance of comparable hospitals.
Building characteristics	This section covers basic building design and construction characteristics, which will be used to benchmark the energy performance of comparable hospitals.
Building-level energy use	This section covers building/hospital level consumption of electricity and non-electricity energy. It also includes information on Upgraded Power Supply (UPS) and Building Management System (BMS) or Enterprise Energy Management (EEM) systems
Onsite solar PV	This section captures the characteristics of onsite solar PV systems used to support hospital energy needs.
Heating, ventilation, and air conditioning (HVAC)	This section covers air-conditioning and fresh air ventilation, air circulation fans, air filtration/purification, medical/server equipment cooling, and space heating.
Medical use refrigeration	This section covers refrigeration for storing drugs, vaccines, blood, ice packs, and other medical products, and morgues/mortuaries.
Other sections	
Lighting	This section covers ambient lighting of interior spaces. It does NOT cover special lighting used for medical procedures, and lighting of exterior spaces such as basements, driveways, and parking lots.
Medical imaging equipment	This section covers medical imaging equipment that typically represent large single plug loads, and where significant energy savings might be possible through good operational practices.
Steam and hot water	This section covers centralised and standalone hot water systems for personal hygiene, kitchen/pantry use, and laundry; and centralised and standalone steam generation for sterilisation of medical instruments, laundry use, and humidifying air.
Water supply pumping	This section covers pumping cold and clear treated municipal and/or groundwater for water supply purposes. It does NOT include pumping water for specialised medical procedures and laboratory use and pumping within Water/Sewage/Effluent Treatment Plants.
Treatment Plant	This section covers (1) Water Treatment Plant (WTP): Building-level onsite treatment of municipal and/or recycled water, including reverse osmosis (RO). It does not include small standalone water purifiers. (2) Sewage Treatment Plant (STP): Building-level onsite treatment of sewage. (3) Effluent Treatment Plant (ETP): Building-level onsite treatment liquid waste from operation theatres or other such liquid waste.
Electric vehicle (EV) charging	This section covers onsite charging of electric vehicles.

3.3 Survey implementation

3.3.1 Surveyor training

On-ground surveyors were given rigorous training before being deployed in the field for the pilot and the main survey. Surveyors received an overview of the study and specific instructions for conducting the survey. A comprehensive survey toolkit and manual was provided to each surveyor. The surveyors had to conduct multiple rounds of mock interviews. Thorough feedback was provided to each surveyor at the end of each mock survey. Additionally, the technical team sat in on the first few surveys to guide the surveyors.

3.3.2 On-boarding of hospitals

Public and private hospitals were identified and onboarded for the survey per the sample stratification as closely as possible.

A top-down approach was followed to on-board public hospitals, which was facilitated by the National Center for Disease Control (NCDC). NCDC convened a meeting of the State Nodal Officers for Climate Change (SNOCCs) to explain the nature and scope of the national survey and secure their support. This was followed by written communications to each state requesting to nominate public hospitals for the survey. The State and District Nodal Officers for Climate Change facilitated the selection of facilities in respective states where surveys could be administered. Overall, over 500 leads were gathered for contacting public hospitals across 14 states.

To identify private hospitals, an exhaustive list of about 7,353 private healthcare facilities was compiled by merging the private hospital network lists of health insurance providers, namely, ICICI Lombard, MD India Health Insurance TPA Pvt. Ltd., and the hospital list of Association of Healthcare Providers of India (AHPI). The hospitals were then classified into single-specialty and super/multi-specialty based on the healthcare services provided by them. The list for private medical colleges was retrieved from the National Health Profile 2020 [18].

3.3.3 Data confidentiality

No personal data regarding individual patients, doctors, hospital staff, etc., was collected – only the contact information (i.e., name, email ID, and phone number) of the primary survey respondent was noted. The primary survey respondent agreed to the following data confidentiality terms:

“By providing DATA to the RECIPIENT, the PROVIDER understands that the RECIPIENT intends to aggregate DATA at the state and at the national levels from many PROVIDERS for analysis purposes and to enable research regarding hospital energy efficiency. Results of analysis performed on the combined DATA will be made publicly available, and research findings will be published. The DATA will be publicly released after removing all personal identifiers such that the DATA cannot be retraced back to the hospital/HCFs, i.e., information that could be used to identify either the PROVIDER or individual buildings will be removed, including building addresses, contact information, and names. Personal identifiers of privately-owned hospitals will be shared outside the RECIPIENT only after prior written consent. Personal identifiers of publicly owned hospitals may be shared with State Nodal Officers for Climate Change of the PROVIDER’s state; personal identifiers of publicly owned hospitals will be shared outside the RECIPIENT only after prior written consent.”

3.3.4 Modes of data collection

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

The survey was administered in a combination of 2-3 in-person and virtual meetings per hospital using a digital version of the questionnaire and/or its hardcopy version in those areas where internet connectivity was not reliable. Many respondents showed preference for hard copies over the digital version of the questionnaire. At the beginning of the survey, the respondents were informed of the data sharing terms and presented a consent form to sign for the collection of data.

A mix of three methods of data collection was followed:

- **Web-based:** The online survey link was shared with the respondents/departments via email. The respondents then responded to the questionnaire and submitted the survey which got uploaded on the server. Telephonic follow-ups were made to ensure a high level of participation.
- **Telephonic interviews:** A team of trained personnel conducted telephonic surveys with the concerned person/department to get feedback. Prior appointments were fixed for conducting the interviews.
- **Face-to-face intervention:** The interviewers carried a tablet with the online version of the questionnaire or a hard copy of the questionnaire to conduct the face-to-face intervention.

A survey tracker to ensure the timely completion of facility onboarding and completion of surveys was established. In some cases, the lead times for interviews were very long due to lack of availability of hospital staff for the survey. Some of these lead times took as long as a few weeks per hospital. Identification and timely communication with the appropriate respondent were a challenge in many hospitals.

3.3.5 Quality control

Data quality control systems were established through a rigorous check at frequent intervals of all data collected throughout the survey. The following measures were undertaken:

Regular check-ins of participating teams to ensure that the standard data collection process was being followed

A subset of data was reviewed, and feedback was provided to survey teams where the data monitoring teams encountered additional inputs or missing data

Several data points were back-checked with hospitals through a combination of in-person visits and telephonic communications

Feedback on the survey experience was also collected from respondents to ensure genuineness of the survey exercise

3.3.6 Sample size surveyed

A total of 623 hospitals (357 public and 266 private) were surveyed across 5 climatic zones and 10 hospital typologies, which is 3.6% of the estimated hospital population in India (see Section 3.1). For comparison, the US Commercial Building Energy Consumption Survey (CBECS) 2018 selected a sample size of 16,000 buildings, which was 0.27% of the estimated 5.9 million commercial buildings in the US [19].

Public hospitals from 14 states were surveyed. Additionally, filter criteria were used before final analysis to ensure quality control of the final data used. Therefore, despite data collection in over 600 hospitals, analysis was conducted in a smaller sample of 341 hospitals (see section 3.4). Regional-level analyses, provided to public hospitals directly, were carried out; state-level analyses were not possible due to sample sizes per state.

3.4 Data screening

A total of 341 of 623 hospitals/healthcare facilities qualified for analysis after the data filtering process, which removed those hospitals from the analysis that provided either too little or seemingly incorrect data. Appendix A shows the number of hospitals surveyed and those that qualified for analysis per state, per climate zone, and per hospital typology.

Screening criteria 1: Data sufficiency. Hospitals were removed from the analysis if they failed to provide one or more of the following information or data points. 540 hospitals passed through Filter Criteria 1 for the next level of filtering.

- Consent form[5]
- Number of beds for FY 2019-20
- Built-up area
- Electricity consumption for FY 2019-20

Screening criteria 2: Statistical data quality control. This screening was based on the interquartile range (IQR) method of outlier detection and correction [20] which was used to remove data outliers based on predefined upper and lower boundary values of the energy intensities of area of the different hospital typologies grouped by the number of operational beds. 341 hospitals passed through the Filter Criteria 2 for final analysis.

By and large, data availability, access, and quality were generally found to be better for questions in the essential sections (see Table 3.1). Usable data for some end-use sections was not sufficient to draw numerical results; however, it can still be used as anecdotal evidence to drive future work in the hospitals sector.

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[5] The consent form was only applicable for the private hospitals since they were contacted individually. Consent forms for public hospitals were not mandatory since they were approached for the survey through the state's SNOCCs.

CHAPTER
FOUR

Survey Findings

The following sections provide detailed insights based on the analysed sample of 341 hospitals. Where sufficient data is available, the findings are presented separately for public and private healthcare facilities. In some cases, for example, HVAC utilisation, the absence of HVAC in smaller public health facilities precludes presentation of typology-wise findings.

4.1 Energy sources

Electricity from the grid (mainly), on-site solar PV, and on-site diesel generators comprise more than 90% of hospitals' energy supply (Figure 4.1). Electricity sourced from off-site solar PV plants and/or through open access modes, if any, are included in grid electricity. Liquefied petroleum gas (LPG) is the most used primary fuel. Natural gas, furnace oil, and firewood are other primary fuels used in hospitals. It is worth noting that reporting and accuracy of these direct fuels can be complicated. It is also generally an indicator of how much and when fuels were *purchased* rather than how much and when the fuels were *used*.

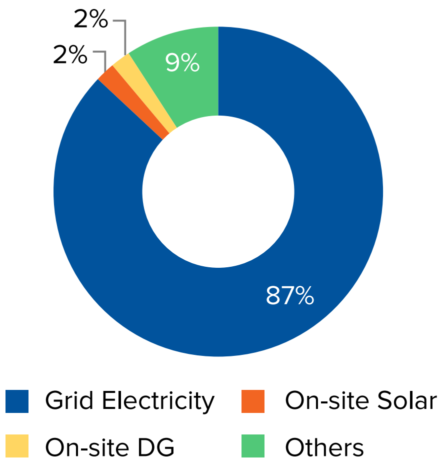

Figure 4.1: Distribution of hospitals' total primary energy use by energy source

The penetration of on-site solar PV is 17% in private and 11% in public hospitals. Public CHCs have reported the highest number of solar PV installations followed by District Hospitals and Medical Colleges. Using the analysable data from 18 public facilities, it was observed that 11 facilities used off-grid solar PV systems without battery storage for direct use in building operations. It was also observed that the hospitals / healthcare facilities are not deploying solar PV systems as a source for critical load back-up; hence rely on diesel generators during the hours of power supply failure to provide critical services.

Anecdotal observations: In both the public and private hospitals, the maintenance of solar PV plants is conducted through an annual maintenance contract issued to the solar PV plant service provider. It is observed that in public hospitals the maintenance of the solar PV plant was not effectively conducted, with the energy survey team visibly confirming the presence of the broken component of solar panels as informed by the hospital administrative staff. Some of the hospitals surveyed even indicated that the solar PV plants' components needed detailed repairing and replacement. Non-renewal of annual maintenance contracts was common in public hospitals which indicates that deploying solar energy in the public health system needs an integrated approach through governance and financing mechanisms to ensure sustained uptake and scale-up.

4.2 India-wide annual hospital electricity consumption and Scope 2 GHG emissions

The India-wide annual hospital electricity consumption and associated emissions are shown in Table 4.1. This estimation is limited to grid electricity use and Scope 2 emissions since grid electricity is by far the most dominant energy source for hospitals in India. Per these estimates and CEA's electricity sales data, hospitals consumed ~9% of India's "commercial" electricity in FY 2019-20 [27].

Table 4.1: India-wide annual hospital grid electricity consumption and Scope 2 GHG emissions in FY 2019-20

	Number of hospitals	Median annual grid electricity consumption per hospital (MWh/year)	India-wide annual grid hospital electricity consumption (MWh/year)	Scope 2 GHG emissions (tCO_2/year)
	A	B	C = A * B	D = C * 0.79
Private (0-5 beds)	2,545	3.55	9,035	7,137
Private (6-10 beds)	3,540	7.45	26,373	20,835
Private (11-30 beds)	18,655	12.0	2,23,860	1,76,849
Private (31-50 beds)	9,399	31.18	2,93,061	2,31,518
Private (51-100 beds)	5,625	66.66	3,74,963	2,96,220
Private (101-500 beds)	3,258	1,910.46	62,24,279	49,17,180
Private (>500 beds)	465	3,610.50	16,78,883	13,26,317
Private (All)	**43,487**		**88,30,452**	**69,76,057**
Sub-centre	41,311	0.3	12,393	9,791
PHC	7,565	5	37,825	29,882
HWC-SC	1,20,518	1	1,20,518	95,209
HWC-PHC	23,488	5	1,17,440	92,778
CHC	6,064	20	1,21,280	95,811
SDH	1,275	22	28,050	22,160
DH	767	240	1,84,080	1,45,423
Medical College	315	900	2,83,500	2,23,965
Public (all)	**2,01,303**		**9,05,086**	**7,15,018**
Total	**2,44,790**		**97,35,539**	**76,91,075**
			9.7 TWh/year	**7.7 million tonnes of CO2/year**

Table 4.1 was estimated using the following data points:

- The number of private hospitals in India [21] distributed by their size (number of beds) using the size distribution of private hospitals empaneled by insurance companies [22] (Column A)
- Column A: The latest number of public hospitals in India (as on 31 March 2023, sourced from Rural Health Statistics 2021-22) [23]; the number of HWCs (as on 28 May 2023, sourced from the Ayushman Bharat website) [24][6] (Column A)
- The median[7] annual electricity consumption per public and private hospital typology based on the survey data (Column B)
- GHG emission factors of 0.0741 $kgCO_2/MJ$ for diesel [25] and 0.79 $kgCO_2/kWh$ for grid electricity [26]
- The India-wide annual grid hospital electricity consumption (MWh/year) [C] is a product of the number of hospitals and the median annual grid electricity consumption per hospital(MWh/year). This was found to be 9.7 TWh/year.
- The Scope 2 GHG emission is a product of the annual grid electricity consumption [C] and GHG emission factors. This was found to be 7.7 million tonnes of CO_2/year

Greenhouse gas emissions are divided into three categories for businesses or organizations – Scope 1, Scope 2, and Scope 3 – as developed by the Greenhouse Gas protocol. Scope 2 emissions are “indirect” emissions produced by purchased energy that an organisation buys and consumes.

4.3 Hospital-level energy intensities

Energy Performance Index (EPI) is a widely used metric for measuring the energy efficiency of a building. It is the ratio of the total energy consumed by a building in a year to its gross floor area[8]. A lower EPI indicates a more energy-efficient building. Here, the electrical energy used in hospitals from the grid, on-site solar PV, and on-site diesel generators, is considered in the EPI estimation. It is worth noting that EPI uses the total electricity consumption and not the net electricity consumption, which disregards electricity used from onsite solar PV, since the use of a net metric may obscure the energy efficiency of the hospital. Non-electrical energy use is not considered in the EPI estimation. EPI is the most familiar form of energy consumption for building stakeholders and best reflects what owners can directly control and are responsible for, increasing the ability of the building owner and operator to control the outcome of the energy savings. EPI is a direct indication of energy efficiency that is easy to obtain and requires no interpretation: it is directly available from utility bills.

Figure 4.2 shows the EPI distribution within every hospital typology. The large EPI diversity even within the same hospital typology can be attributed to factors related to energy efficiency such as the energy efficiency of end-use equipment/appliances and behavioural energy efficiency, and factors unrelated to energy efficiency such as differences in air-conditioned areas, levels of medical services provided, hours of active use, the climate zone, and the degree of outsourcing of services.

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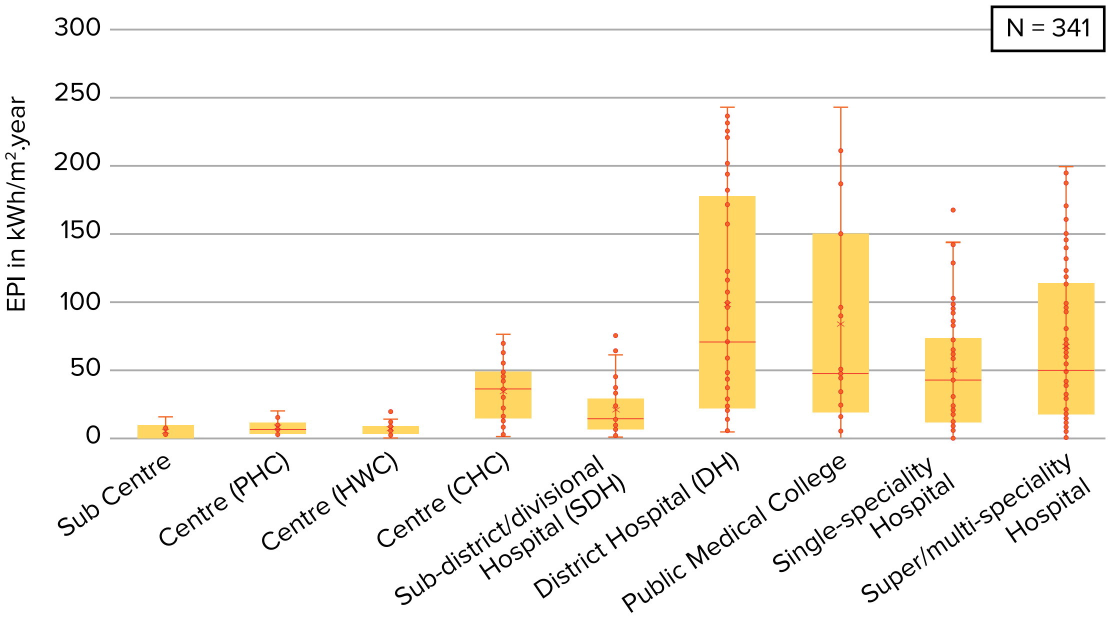
[6] The effective number of sub-centers and PHCs was calculated by subtracting the number of HWCs converted from sub-centers and PHCs from the total number of sub-centers and PHCs, respectively.

[7] Median is the preferred measure of central tendency when the distribution of data is skewed or when there are clear outliers.

[8] The definition of floor area is not consistently used across standards and policies, even in the US. Many jurisdictions in the US reference the ENERGY STAR® Portfolio Manager® (ESPM) definition of conditioned floor area, though standards such as ANSI/ASHRAE/IES Standards 90.1 and 100 and ANSI/ASHRAE Standard 105 (ASHRAE 2022, 2018, 2021) use other definitions, including gross square footage, as included here. For the purposes of this study, gross floor area is the sum of all conditioned and unconditioned floor area, excluding basements, driveways, and parking lots.



	Sub-centre	Primary Health Centre (PHC)	Health and Wellness Centre (HWC)	Community Health Centre (CHC)	Sub-district/ divisional Hospital (SDH)	District Hospital (DH)	Public Medical College	Single-specialty Hospital	Super-/ Multi-speciality Hospital
1st quartile (Q1)	2	4	4	15	7	24	27	14	18
3rd quartile (Q3)	7	11	10	48	25	172	138	74	114

Figure 4.2: Distribution of EPI within every hospital typology

Annual energy use per bed (AEUB) is another internally used measure of a hospital's energy performance. It circumvents the challenges related to obtaining the gross floor area, often confused with other types of area used in architecture and real estate parlance, needed for EPI estimation. Instead, it relies on the number of operational inpatient beds, which is easier to obtain. Here, the electrical energy used in hospitals from the grid, on-site solar PV, and on-site diesel generators, is considered in the AEUB estimation. Non-electrical energy use is not considered in the AEUB estimation.

Figure 4.3[9] shows the AEUB distribution within every hospital typology. The large AEUB diversity even within the same hospital typology can be attributed to different levels of healthcare quality and patient privacy. For example, higher quality of healthcare and greater patient privacy can lead to a lower number of beds per unit gross floor area and result in a higher AEUB.

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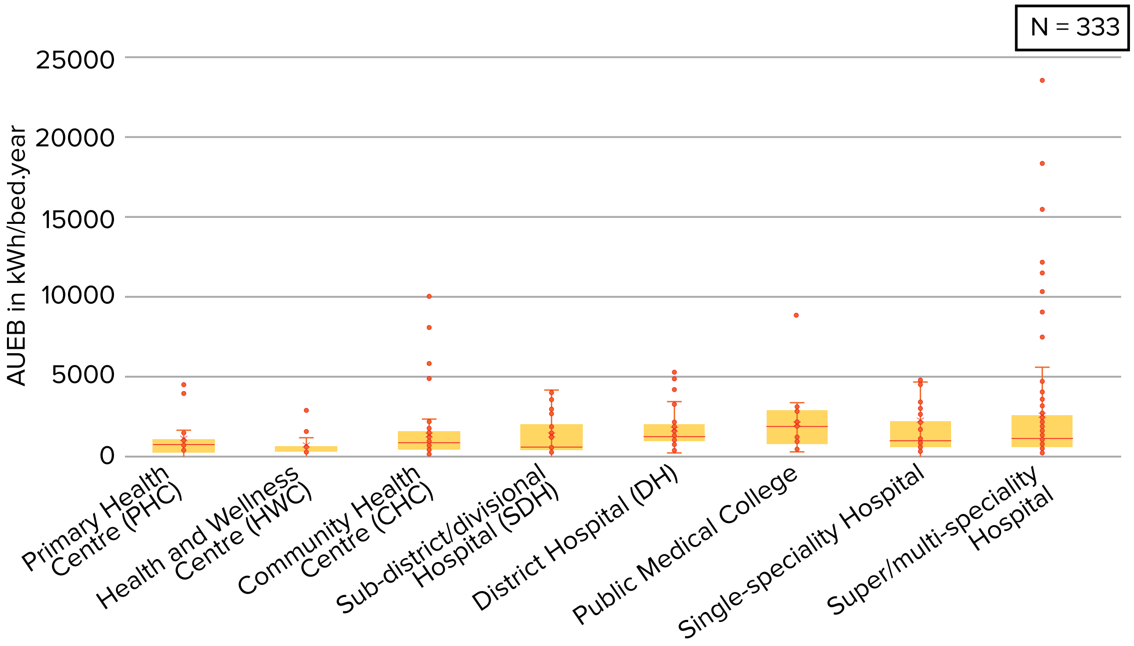
[9] Since some sub-centers did not have any operational inpatient beds, they have been removed from AEUB estimations. The total number of hospitals that were analysed for this parameter was 333.



	Primary Health Centre (PHC)	Health and Wellness Centre (HWC)	Community Health Centre (CHC)	Sub-district/ divisional Hospital (SDH)	District Hospital (DH)	Public Medical College	Single-specialty Hospital	Super-/ Multi-speciality Hospital
1st quartile (Q1)	351	200	320	82	778	756	325	488
3rd quartile (Q3)	952	1100	1518	1613	1819	2753	2158	2300

Figure 4.3: Distribution of AEUB within every hospital typology

4.4 End-use characteristics

4.4.1 Heating Ventilation and Air-Conditioning (HVAC)

4.4.1.1 HVAC system type

The survey revealed variations in HVAC system types across different hospital typologies in India. Among these systems, the Direct Expansion (DX) air conditioning system, which encompasses Window ACs, Split ACs, Packaged ACs, Variable Refrigerant Flow (VRF), and others, emerged as the most prominent HVAC type in the surveyed hospitals.

A significant majority, 60% of the surveyed hospitals, employed the DX system, while only approximately 11% utilized a chilled water system which is large central air-conditioning systems. Notably, 27% of the surveyed hospitals did not report any type of air conditioning system, leading to their categorization as “No HVAC” facilities. This was particularly observed in public health facilities.

In the public hospitals, none of the surveyed Sub-centers (SC) and Health and Wellness Centers (HWC) reported the presence of any HVAC system. Additionally, two-thirds of Primary Health Centers (PHC) did not have HVAC systems, while the remaining one-third employed the DX system. Public Medical colleges recorded the highest share of Chilled Water systems at 20%, followed by Sub-district/divisional Hospitals (SDH) and District Hospitals (DH) at 15% each, and Community Health Centers (CHC) at 3%.

Comparing hospital segments, private hospitals exhibited a lower percentage of No HVAC facilities, with 21% without any HVAC systems, compared to 44% of public hospitals. Private hospitals also had a relatively higher prevalence of chilled water HVAC systems, accounting for 14% of their installations, in contrast to the 7% observed in public hospitals.

Within the private hospitals, all surveyed Medical Colleges relied on Chilled Water HVAC systems, with one-third also utilizing DX systems. Multi-/Super-specialty and Single-specialty hospitals displayed a similar distribution of DX type HVAC systems, constituting three-fourths of the surveyed sample in each. However, Multi-/Super-specialty hospitals demonstrated a relatively higher adoption of Chilled Water HVAC systems, accounting for 17% of their installations, while Single-specialty hospitals exhibited an 8% share.

Figure 4.4 presents a comprehensive understanding of cooling access in various hospital typologies and the prevalence of specific HVAC types.

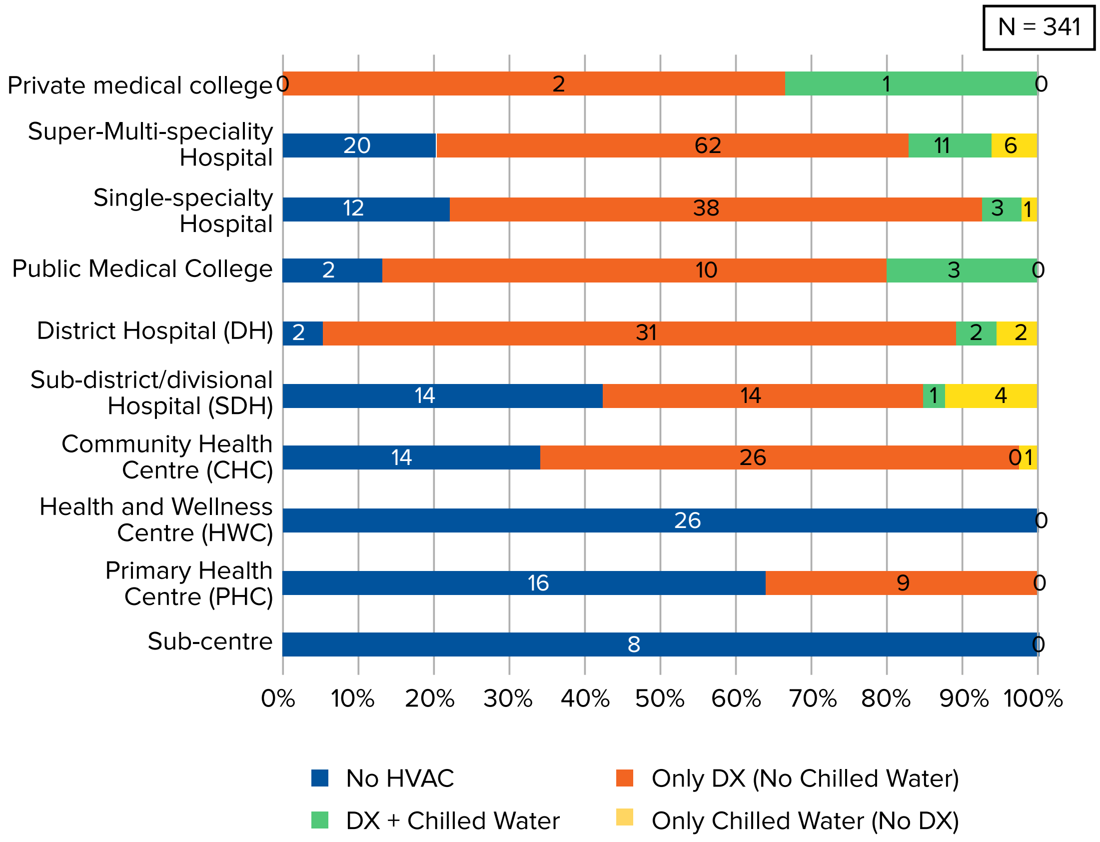


Figure 4.4: Distribution of number of hospitals with different HVAC system types by hospital typologies

The survey revealed significant variations in the share of air-conditioned areas both within and across different types of hospitals, as illustrated in Figure 4.5. Private hospitals, on average, have a higher proportion of air-conditioned areas compared to public hospitals, indicating a greater prevalence of air-conditioners in the private healthcare sector.

In public hospitals, the average air-conditioned area also varies across different facility types. In Primary Health Centers (PHCs) and Community Health Centers (CHCs), the average conditioned area is 8% each. Sub-district/divisional Hospitals (SDHs) have an average of 10% conditioned area, while Medical Colleges have 22% and District Hospitals (DHs) have 24%. Data on air-conditioned areas were not reported for Sub-Centers (SCs) and Health and Wellness Centers (HWCs). In private hospitals, the average air-conditioned area is approximately 33%-34%.

The information regarding air-conditioned areas is crucial for accurate building stock modelling and energy forecasting exercises. Currently, there is a lack of detailed data in this regard, and existing modelling efforts heavily rely on unreliable estimates. Obtaining granular data on air-conditioning usage in hospitals would significantly enhance the precision and reliability of such modelling exercises.

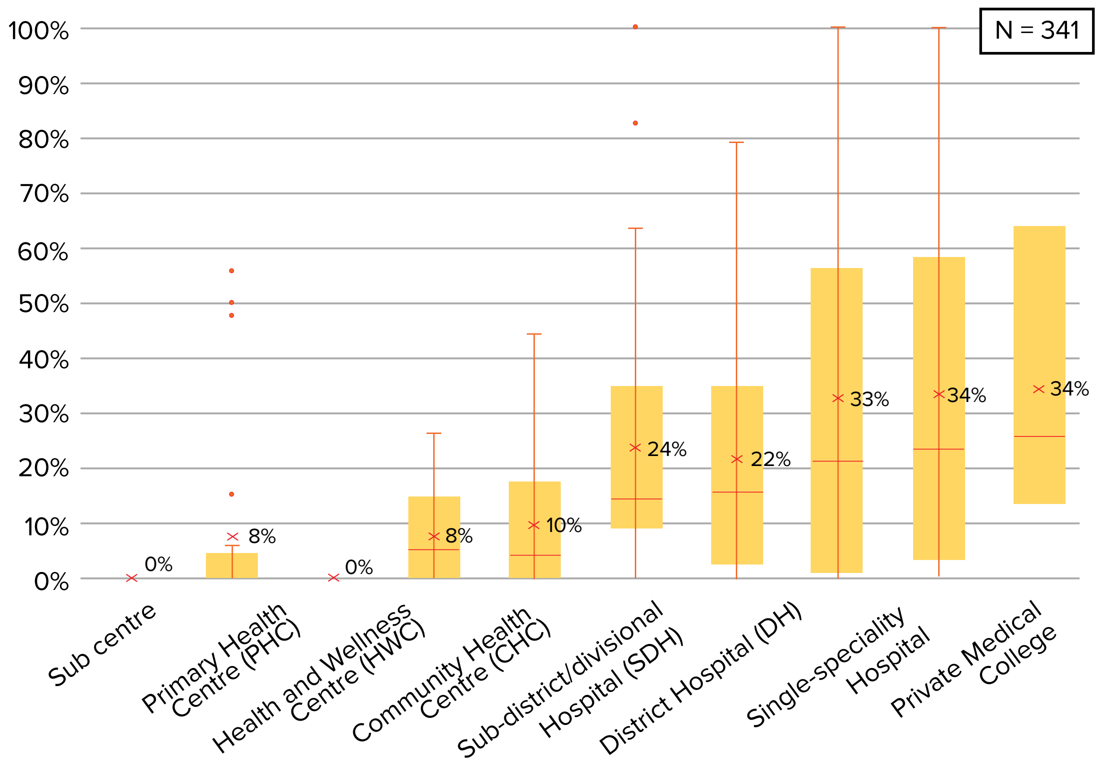


Figure 4.5: Variation in percentage air-conditioned area by hospital typologies

4.4.1.2 Efficiency of HVAC system – BEE Star Labelling of DX units

The analysis of the sample survey yields valuable insights into the prevalence and adoption of high-efficiency BEE star-labeled Room Air Conditioners (RACs) within the DX type HVAC system. Figures 4.6 and 4.7 offer a comprehensive understanding of these aspects in public and private hospitals, respectively.

In both public and private hospitals, Split ACs emerge as the dominant type of DX system in terms of total installed cooling capacity. They constitute 60% and 45% of the DX cooling capacity in the surveyed public and private hospitals, respectively. The relative share of VRF type DX systems is higher in private hospitals, accounting for 24% of the installed cooling capacity compared to 16% in public hospitals.

When analyzing the BEE star ratings in public hospitals, it is observed that 54% of the installed cooling capacity of Split ACs and 56% of Window ACs are labeled as 3-5 star. In private hospitals, 65% of Split ACs and 57% of Window ACs have a 3–5-star BEE label.

Notably, the survey revealed that information regarding BEE star ratings was unavailable for approximately 18% of the installed cooling capacity of Split ACs in public hospitals. In private hospitals, a smaller percentage of 6% for Split ACs and 5% for Window ACs were reported as ‘Not Aware’ of BEE star ratings. This absence of information, denoted as ‘Not Aware’ in the graphs, can be attributed to a general lack of awareness about the BEE star rating program.

Overall, among the surveyed RAC stock (excluding VRF and Others), 54% of the total surveyed DX cooling capacity in public hospitals falls within the 3-5-star range, 32% is below 3-5 star, and 14% is labeled as ‘Not Aware.’ In private hospitals, 59% of the surveyed RAC cooling capacity is 3-5 star, 35% is below 3-5 star, and only 6% is labeled as ‘Not Aware.’

There exists a significant opportunity to improve energy efficiency in both public and private hospitals by upgrading RACs rated below 3 stars to 3-5 star labeled RACs.

The remaining DX types, including Heat Pump, Cassette, Packaged or Ductable, Portable or Floor Standing Tower, and Computer Room AC (CRAC), collectively account for 4% and 18% of the total installed cooling capacity in surveyed public and private hospitals, respectively.

Overall, awareness and uptake of star rated RACs in public facilities can be enhanced.

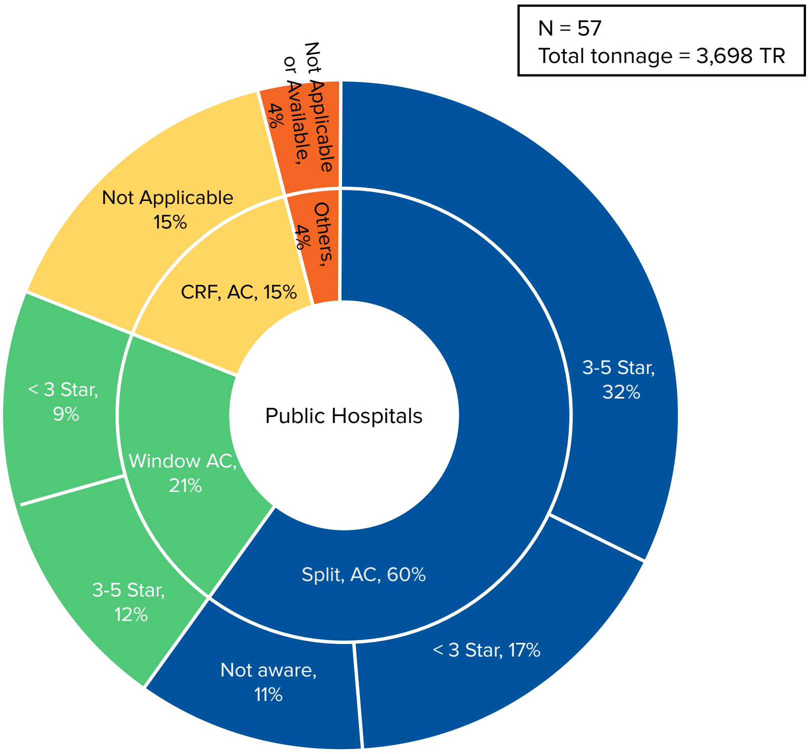


Figure 4.6: Distribution of DX units’ cooling capacity by type and BEE star labelling for public hospitals

[**Note**: 57 public hospitals provided data for DX cooling capacity, and the aggregated DX cooling capacity of these hospitals is 3,698 TR.]

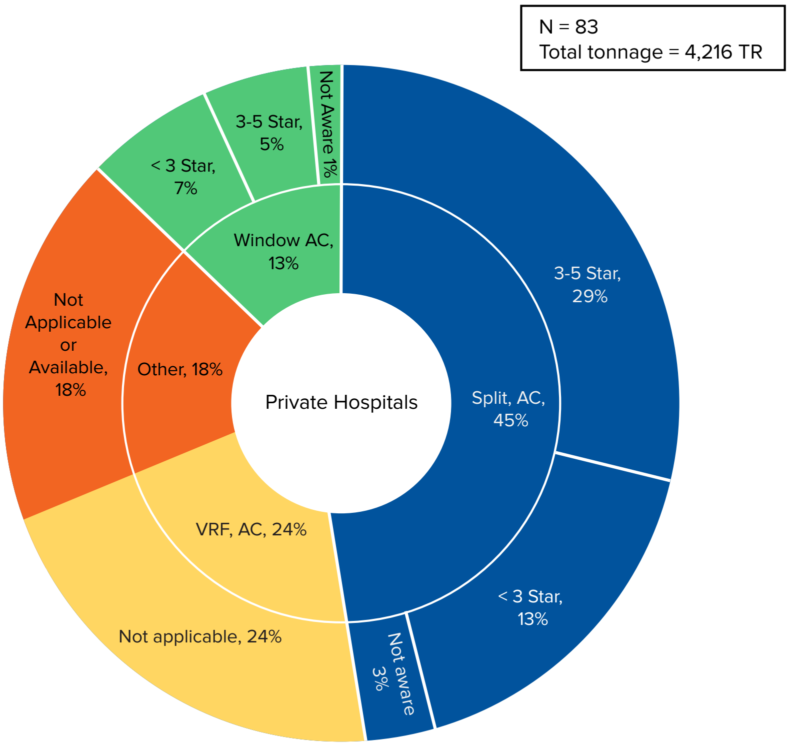


Figure 4.7: Distribution of DX units’ cooling capacity by type and BEE star labelling for private hospitals

[**Note**: 83 private hospitals provided data for DX cooling capacity, and the aggregated DX cooling capacity of these hospitals is 4,216 TR.]

4.4.1.3 Share of chilled water-cooling capacity in private hospitals[10]

Figure 4.8 provides a comprehensive overview of prevalent chilled water air conditioning systems and technologies in the surveyed private hospitals. Most of the installed chilled water-cooling capacity is attributed to screw chillers, accounting for 51%, followed by centrifugal chillers (37%), and scroll chillers (12%). Among these, all centrifugal chillers and 86% of screw chillers incorporate a water-cooled heat rejection system, known for its superior energy efficiency compared to air-cooled heat rejection systems. In contrast, scroll chillers, commonly used for smaller cooling capacity applications, are predominantly air-cooled (75%). While water-cooled chillers offer higher efficiency, the viability and sustainability of their usage may be compromised in areas facing water scarcity.

In terms of capacity control at varying load conditions, around 86% of water-cooled centrifugal chillers, 75% of water-cooled screw chillers, 71% of air-cooled screw chillers and nearly all water-cooled scroll chillers are equipped with a variable frequency drive (VFD) motor starter. This technology enables improved capacity control and significant energy savings compared to chillers with constant speed drive (CSD) capacity controls. Conversely, air-cooled scroll chillers operate with a constant speed drive (CSD), indicating non-modulated constant operation of the chilled water pumps.

Benchmark efficiencies, expressed as the Coefficient of Performance (COP), can be derived based on the type and size of the chiller systems.

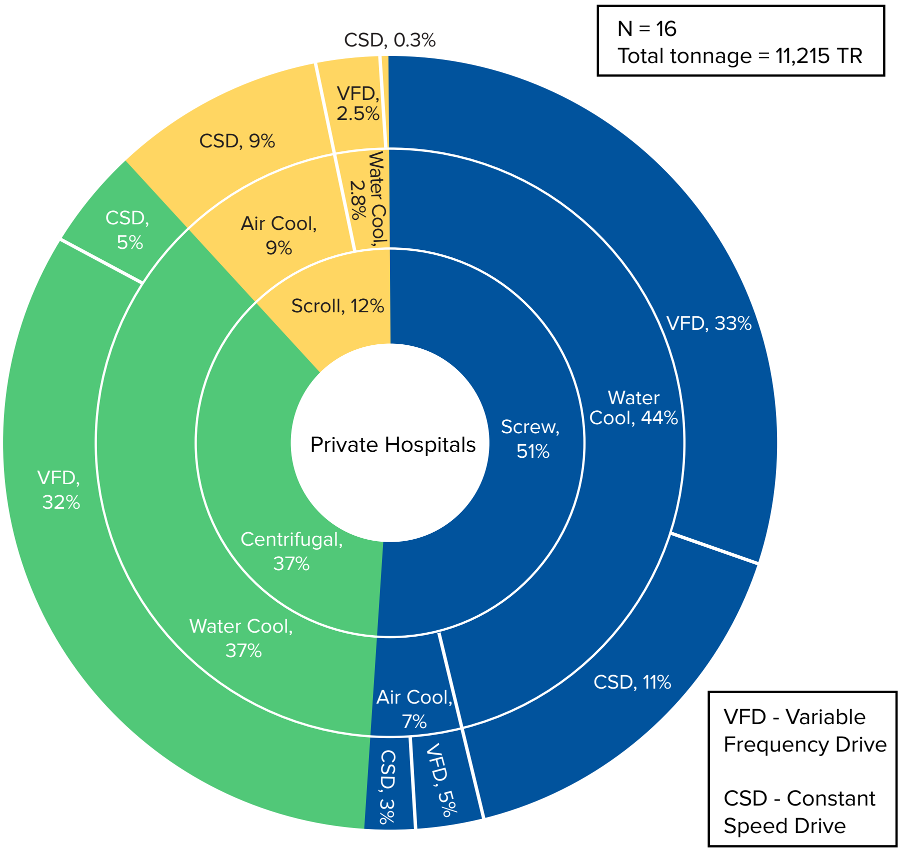


Figure 4.8: Distribution of Chillers' (chilled water type HVAC System) cooling capacity by compressor type, heat rejection mode and motor speed control type for private hospitals

[**Note**: 16 private hospitals provided data for chilled water-cooling capacity, and the aggregated chilled water cooling capacity of these hospitals is 11,215 TR.]

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[10] Chilled-water-based large central air-conditioning systems are only present in a limited number of the surveyed public facilities; therefore, this particular analysis is restricted to private hospitals.

4.4.1.4 Refrigerant use[11]

Figure 4.9 provides a comprehensive overview of the prevalent refrigerants used in the chillers of private hospitals, showcasing the distribution of the number of surveyed chillers based on refrigerant type. The usage of refrigerants in chilled water type HVAC systems contributes to environmental damage through direct greenhouse gas (GHG) emissions resulting from refrigerant leakage in the equipment. Hydrofluorocarbons (HFCs) are the most used refrigerant group, accounting for 64% of the chiller share, followed by Hydrochlorofluorocarbon (HCFC), primarily R-22 gas, with a chiller share of 21%. Currently, low-GWP (Global Warming Potential) refrigerants such as HFOs and HFO-HFC blends are in the early stages of adoption, constituting only 4% of hospital HVAC systems.

To align with the goals of the Montreal Protocol, it is essential to phase out the use of HCFC refrigerants in chiller systems. Additionally, phasing-down, i.e., a gradual reduction in the consumption and manufacturing of HFC refrigerants is necessary. These actions present an opportunity to replace existing systems with low-GWP refrigerants. However, it is crucial to consider the improvement of energy efficiency in air conditioning equipment during this transition.

The transition from high-GWP refrigerants to low-GWP alternatives, as outlined in the Kigali Amendment to the Montreal Protocol, can be achieved through two approaches. The first approach involves replacing the HVAC system with low-GWP refrigerants at the end of its life cycle. The second approach entails replacing the current refrigerant used in the HVAC system with a suitable alternative during its life cycle.

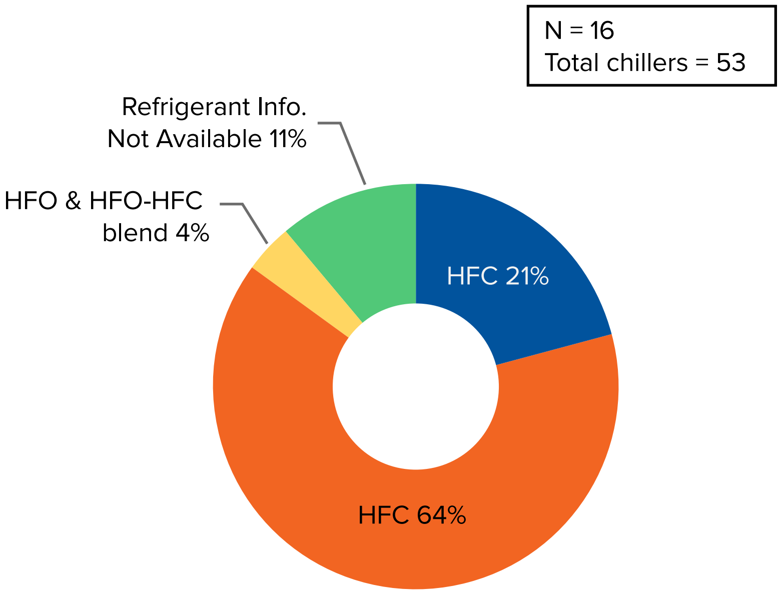

Figure 4.9: Distribution of number of surveyed chillers based on refrigerant type for private hospitals

[**Note**: 16 private hospitals provided data on the type of refrigerant used, and the total number of chillers in these hospitals is 53.]

4.4.2 Medical-use refrigeration

Hospitals use refrigeration units to store vaccines, medicines, blood, lab samples, reagents, and other uses such as the mortuary.

As can be seen from Figure 4.10, 47% of the refrigeration units in the surveyed hospitals are domestic refrigerators. Domestic refrigerators constitute 45% of all refrigeration units in the surveyed private hospitals and 50% in the surveyed public hospitals. Domestic refrigerators are included in the BEE's mandatory S&L for energy efficiency. Since refrigeration

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[11] Chilled-water-based large central air-conditioning systems are only present in a limited number of the surveyed public facilities; therefore, this particular analysis is restricted to private hospitals.

units run 24x7, hospitals can procure the most energy-efficient model (5-star rating) for applications where a domestic refrigerator will serve the purpose.

It is encouraging to see the use of solar refrigerators among the surveyed hospitals. Of the total refrigeration units in the surveyed hospitals, solar direct drive refrigerators constitute 1%. *Solar refrigerators are a climate-smart solution for small health centres in remote or rural areas where grid connectivity is unreliable, as they can reduce the reliance on diesel generators for powering refrigerators*.

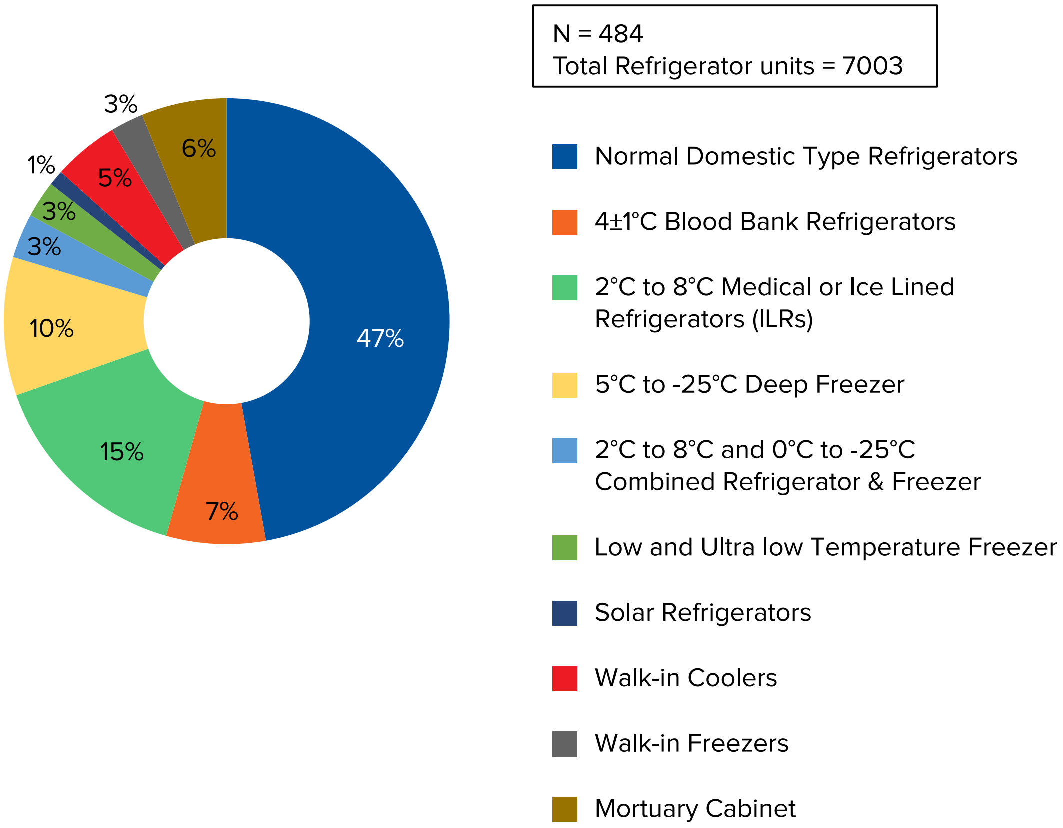

Figure 4.10: Distribution of medical refrigeration units by type of unit

[**Note**: 484 of the 623 surveyed hospitals provided data on the type of medical refrigeration units, and the total number of units in these hospitals is 7003.]

4.4.3 Lighting

The building interior lighting of the surveyed hospitals was analysed to understand the penetration of Light-emitting diode (LED) light fixtures. LED lighting has proven useful for hospital lighting applications. Per Pan American Health Organization's study on LED Lighting in Hospitals [28], improvements in LED technology enables hospitals to fulfil diverse lighting requirements by addressing the three main parameters of lighting level, colour rendering index, and colour temperature. Lighting levels have also been found to affect patient health and mood. Optimum lighting also impacts service delivery, especially in critical care, operating and labour rooms. Thus, the ability to control lighting levels to positively affect patients' well-being, meeting the lighting requirements of hospitals, whilst also limiting energy consumption is one of the major challenges faced in hospital lighting- all of which is addressed by LED lighting.

As shown in Figure 4.11 and 4.12, 30% of the public hospitals and 50% private hospitals had a high (>80%) penetration of LED light fixtures. This signifies a shift towards more energy efficient lighting choices in both public and private hospitals. Meanwhile, lighting can be made more efficient in 17% of the public hospitals and 14% of private hospitals, which had a low penetration of LED fixture (< 20%).

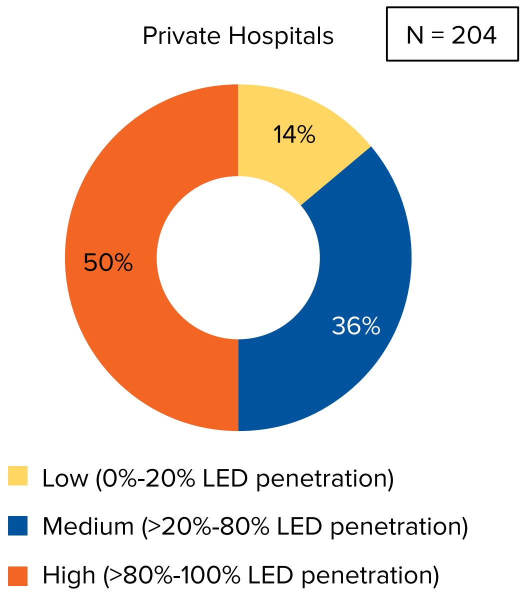

Figure 4.11: Distribution of LED penetration for interior lighting in private hospitals

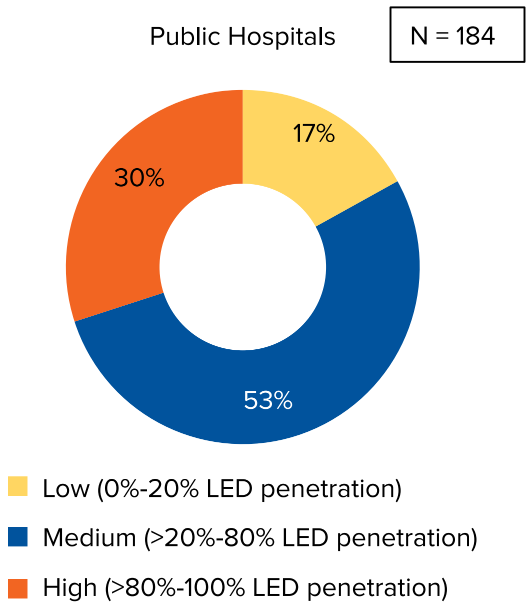

Figure 4.12: Distribution of LED penetration for interior lighting in public hospitals

[**Note**: 184 of the 357 public and 204 of the 266 private surveyed hospitals provided data on the LED penetration for interior lighting.]

4.4.4 Water heating systems

Standalone electric geysers are most used for water heating purposes in both the private and public hospitals. As seen in Figure 4.13 and 4.14, the penetration of solar thermal or solar thermal-electric hybrid water heating systems in the public and private hospitals remains low, more so in public hospitals.

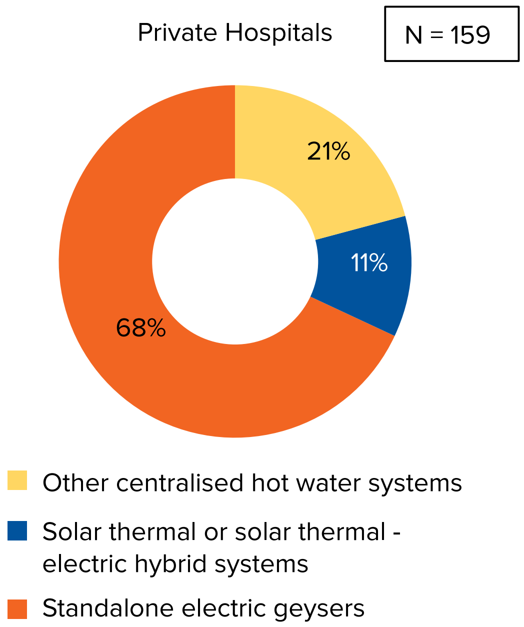

Figure 4.13: Distribution of hot water systems in private hospitals

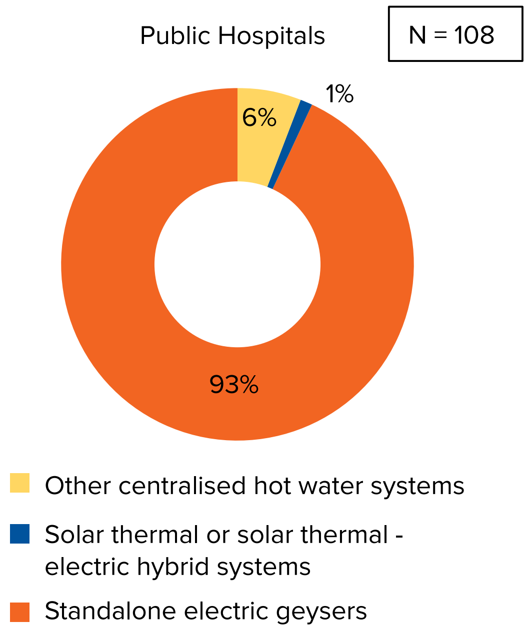

Figure 4.14: Distribution of hot water systems in public hospitals

[**Note**: 108 of the 357 public and 159 of the 266 private surveyed hospitals provided data on the hot water systems used in the facility.]

The Energy Conservation Building Code mandates the use of solar water heaters in hospitals with centralised systems that cover at least one fifth of the hot water design capacity. Central ministries such as the MNRE have also been promoting the use of solar water heaters along with some states such as Uttar Pradesh and Haryana, which also recommend solar water heaters for application in hospitals. Further, in a step towards enhancing the efficiency of solar water heaters, BEE also introduced a voluntary star labelling program for solar water heaters in December 2019. However, there is still significant scope for promoting uptake of solar thermal or electric hybrid water heating systems in hospitals.

4.5 Summary of potential end-use interventions based on survey findings

The survey findings provide insights for sensitisation, uptake and enhanced informed adoption of end-use interventions for both public and private healthcare facilities.

- **HVAC:** Several potential end-use interventions can be identified to improve energy efficiency in HVAC systems within hospitals. Firstly, hospitals should promote the adoption of high-efficiency BEE star-labelled Room Air Conditioners (RACs) and upgrade lower-rated RACs to 3-5 star labelled ones. Increasing awareness about BEE star ratings among administrators (and even operators) is crucial to facilitate informed decision-making. Additionally, hospitals should also consider variable frequency drives (VFD) for chillers, which enable better capacity control and result in energy savings. In terms of refrigerant use, hospitals should aim to transition from high-GWP refrigerants to low-GWP alternatives to reduce greenhouse gas emissions, aligning with the goals of the Montreal Protocol.
- **Medical-use refrigeration:** Hospitals that use domestic refrigerators can mandate the purchase of 5-star-rated refrigerators in their procurement process. Additionally, for other types of medical-use refrigerators which are not yet in the S&L program, hospitals can mandate energy efficiency as one of the criteria for selecting a suitable model. State health departments can increase the penetration of solar refrigerators in sub-centers and primary health centres in areas where the grid connectivity is unreliable.
- **Lighting:** Adequate lighting is crucial in all establishments, but especially in hospitals, where the emphasis lies on health, safety, and the well-being of patients as well as healthcare professionals. The need to be well-lit as well as 24/7 operations of many healthcare facilities result in lighting being a significant part of energy use. Lighting can influence the body’s circadian rhythm and impacts an individual’s physical and mental well-being by affecting mood, and energy levels. LED lights are found to not only be favourable from a visual comfort perspective, but also result in energy and cost savings. While hospitals in both private and public sectors have shown considerable progress in switchover to LEDs, a large remainder can still benefit from relatively simple and inexpensive lighting retrofits in hospital buildings.
- **Water heating systems:** Energy star-rated solar water heaters are an energy-efficient option for addressing the water heating needs of hospitals. Hospitals, especially public hospitals, have a large potential for adoption of solar thermal or electric hybrid water heating systems.
- **Medical imaging equipment:** Medical imaging equipment has significant energy saving potential by keeping it at the energy-saving “low power” mode when not in use (i.e., not scanning) during business hours. The survey supported past evidence of enormous energy savings from behavioural energy efficiency that can be adopted by hospital personnel operating medical imaging equipment without compromising patient care [29].

4.6 Limitations

Due to resource and time constraints and the long survey lead times, the intended sample size could not be fully met during the course of this project. The survey could not be implemented in public hospitals across all the states/UTs as originally intended (see Section 2) due to varying levels of cooperation received in different states/UTs. Overall this unique survey demonstrates the potential to establish a baseline understanding of the Indian health sector’s energy consumption both from a quantitative and qualitative perspective. While the targeted states and sample size were difficult to reach given the practical constraints encountered in securing approvals, time and resources, the survey provides a first look at the energy footprint of the Indian health sector. It is recommended that this study is followed up with smaller targeted data collection efforts wherever the sample size is found to be insufficient to draw results conclusively. However, it should be borne in mind that sampling error comprises only a small share of the total error, while the majority of the error that is likely to occur in a technical survey such as this is on account of inaccurate data transfer between the surveyor and the respondent if the questions are not explained and understood well.

CHAPTER
FIVE

Recommendations

The results are based on primary data collected on a representative sample of healthcare facilities from all five climate zones and all typologies of healthcare across public and private health systems in India. The findings thus provide insights that can be supported in scaling up current efforts in strengthening health care infrastructure, building climate resilience and transitioning to uptake and use of renewable energy. Additionally, recommendations from the end-use interventions assessments at all levels of healthcare can provide a basis for further expanding activities under green and climate resilient health care facilities component under the National Programme on Climate Change and Human Health in India.

Recommendation #1: Track energy consumption in all healthcare facilities for managing energy cost and related emissions in hospitals

To effectively manage energy costs and emissions in hospitals (Scope 1 and Scope 2), tracking energy use is a necessary first step. Hospitals should track various forms of energy consumption, including electricity, diesel, liquefied petroleum gas (LPG), and more. This involves measuring absolute energy consumption for the entire hospital and calculating energy intensity metrics such as kWh/bed or kWh/patient. By comparing energy performance and costs on a quarterly or yearly basis, hospitals can identify trends and areas for improvement.

Tracking energy consumption includes measuring, monitoring, and reporting of the key parameters regularly. The reporting could be both internal and external. Internal reporting to senior management helps raise awareness about energy usage patterns, identify areas of improvement, and allocate resources for energy conservation measures. External reporting to regulatory bodies such as the Bureau of Energy Efficiency (BEE) and the Ministry of Health and Family Welfare (MoHFW), if mandated or even voluntarily, demonstrates a hospital's commitment to sustainability and provides an opportunity for recognition and compliance with energy conservation regulations. Under NPCCHH, energy audits have been proposed. This intervention needs to be strengthened to mandate regular energy audits to track energy usage and effective energy planning.

Energy reporting should encompass not only energy consumption but also general, infrastructure, and occupancy-related information. This includes the type of hospital, the number of beds, gross floor area (GFA), total conditioned area, outpatient department (OPD) patient footfall, and in-patient days. Energy data should cover grid electricity consumption, onsite electricity generation through solar PV, onsite electricity generation by diesel generator sets, other onsite renewable energy generation, and fuel consumption for all other onsite energy purposes. It is equally important to include energy-related expenditures in the reporting, enabling effective analysis and decision-making regarding energy efficiency measures and financial planning.

Recommendation #2: Enhance energy efficiency in hospitals through Energy Service Companies (ESCOs)

A substantial number of surveyed public and private hospitals showed considerable potential for upgrading and retrofitting their existing HVAC systems, along with other energy end uses. ESCOs through Energy Savings Performance Contracting (ESPC) can help achieve significant energy savings and reduce the carbon footprint and costs associated with hospital energy usage. ESCOs provide a comprehensive package of energy services, including energy audits, project design, financing, installation & commissioning of energy-efficient solutions, operation, and maintenance. They guarantee energy savings and are typically compensated based on a portion of the achieved savings.

It is recommended that hospitals in India should prioritise retrofitting and upgrading various end-use systems, such as HVAC and building controls by engaging ESCOs. ESCOs operating within and across hospital networks can leverage demand aggregation to enable bulk procurement, resulting in substantial cost reductions. The Government of India's Energy Efficiency Services Limited (EESL) has successfully implemented the energy-efficient lighting replacement program known as UJALA. Through this program, EESL has demonstrated the effectiveness of the ESCO model in streamlining and standardising procurement, execution, and measurement and verification (M&V) processes in India. To facilitate widespread ESCO adoption, certain requirements must be addressed. Key requirements for ESCO adoption include ensuring access to financing options, establishing standardised solutions, enforcing supportive policies at the institutional level, creating organisational mechanisms for efficient dispute resolution, and the presence of credible market facilitators. NPCCHH could explore the feasibility of supporting the ESCO model through engagement with EESL.

Recommendation #3: Mandate Energy Conservation Building Code (ECBC) norms for new construction and major renovation

The Energy Conservation Building Code (ECBC) has been notified in 18 states and is in the process of being notified in the remaining states and UTs. ECBC is mandated for all new buildings with a minimum connected load of 100kW or a lower threshold as notified by the state. Going a step further, incorporating ECBC norms and green building guidelines for smaller hospitals and for renovations to existing hospitals in the NPCCHH guidelines for green and climate resilient healthcare facilities will ensure that these new structures are designed and constructed to optimise energy use and minimise environmental impact.

Recommendation #4: Mandate energy efficiency as an evaluation criterion in hospitals' procurement policies for purchasing medical devices, appliances, and equipment

Hospitals can update their procurement policies to mandate the purchase of energy-efficient equipment for new buildings and when replacing old/defunct equipment. Fourteen (14) building appliances, including lights, ceiling fans, refrigerators, air conditioners and water heaters, are included in BEE's S&L program under the mandatory scheme and twenty (20) appliances/equipment, including pumps, motors and chillers, are included in BEE's S&L program under the voluntary scheme. Hospitals should update their procurement policies to mandate the purchase of BEE S&L 4- or 5-star-rated appliances and equipment. Since medical equipment and devices are not yet included in any S&L program, hospitals can update their procurement policies to include energy efficiency in their evaluation criteria for medical equipment from different vendors. This can be facilitated through the sustainable procurement component of the NPCCHH framework for climate resilient healthcare facilities.

Recommendation #5: Disclose and benchmark data for energy performance target setting

To improve energy efficiency in hospitals, it is crucial to leverage data disclosure and benchmarking policies. This approach provides a rich source of data for target setting, as it represents the measured energy use of buildings and covers almost all buildings within the chosen scope. To implement this recommendation effectively, the BEE and the NPCCHH, NCDC-MoHFW should collaborate closely and undertake the following actions:

- **Standardise Data Measurement, Monitoring, and Reporting:** BEE and NPCCHH, NCDC-MoHFW should work together to establish standardised protocols for data measurement, monitoring, and reporting by hospitals. This includes defining which categories of hospitals will report their energy performance and specifying the frequency of reporting. Standardising these processes will establish uniformity and facilitate comparability in energy performance data across various types of hospitals in both the public and private sectors.
- **Develop Data Collection Templates:** To streamline data collection and reporting, BEE and NPCCHH, NCDC-MoHFW should develop comprehensive data collection templates customised to suit the specific requirements of different hospital types. These templates should capture relevant information about energy consumption and hospital occupancy. By providing standardised templates, hospitals can easily report their energy performance in a consistent and structured manner. Furthermore, the State Designated Agencies (SDAs) associated with BEE and NCDC- MoHFW through the NPCCCH program and state secretariats can play a crucial role in coordinating with hospitals in the states.
- **Benchmark Hospital Energy Performance:** BEE and NPCCHH, NCDC-MoHFW should undertake efforts to benchmark the energy performance of different hospital typologies. This involves analysing the reported energy data and establishing performance benchmarks that reflect the energy efficiency levels achievable in the hospital sector. By benchmarking energy performance, hospitals can compare their own performance against established standards, identify areas for improvement, and set targets accordingly. The benchmarks can also feed into BEE's existing scheme for star rating of hospital buildings.
- **Inclusion of Large Hospitals in Perform, Achieve and Trade (PAT) Program:** Building upon the success of the PAT program, BEE should consider including large public and private hospitals in the next PAT cycle. This integration would enable hospitals to participate in the program and align their building performance targets with benchmarking data. By gradually increasing the stringency of building performance targets, hospitals can be encouraged to adopt energy-efficient practices and technologies, further driving energy savings and reducing carbon emissions.

Recommendation #6: Create an integrated approach to energy transition (including energy efficiency and renewable energy) in hospitals

The state Health Departments as nodal agencies must be empowered to convene relevant stakeholders across different departments to ensure a coordinated approach to energy transition in the health sector. This essentially includes the state energy cell/, state designated agency, public health engineering department, hospital administrator/s, state environment cell representatives, city/village planning department officials, manufacturers/suppliers as appropriate and state financing agencies. The central coordinating agency or task force under NPCCHH could oversee the integrated approach amongst stakeholders to chart a roadmap for implementation through the following :(i) plan to improve energy efficiency of the buildings (ii) plans to develop guidelines for procuring energy efficient end-use equipment/appliances (iii) plans to increase deployment of renewable energy following thorough assessment of energy needs and (iv) institutional mechanism to maintain the energy installations for efficient operations.

At the national level, BEE, the Ministry of New and Renewable Energy (MNRE) and the Ministry of Health and Family Welfare can combine their knowledge and resources to promote energy efficiency and renewable energy in health facilities through cross-sectoral programs and schemes. At the state level, SDAs, REDAs and state health departments can leverage their expertise and knowledge to define and implement state-specific schemes to reduce the energy footprint and carbon footprint of health facilities in the state. Additionally, the state health department can work with the SDA and REDA to integrate energy efficiency and renewable energy in schemes for improving and expanding healthcare infrastructure in the state. Overall, the NPCCHH can oversee this integrated approach through the provision of a guidance document and roadmap for state-level implementation of energy transition.

Recommendation #7: Increase renewable energy deployment in public healthcare infrastructure through state government-led initiatives

Renewable energy must be deployed on small and remote public facilities (SC, PHC & CHC) which are un-electrified or lack quality power supply with the objective to strengthen healthcare delivery; emissions mitigation will be a co-benefit of such an intervention. On larger facilities (SDH, DH & Medical College) with better grid-based power supply, renewable energy could be deployed to mitigate emissions from energy consumption; such interventions can also serve as power backup for critical electric loads during hours of power failure, thus, reducing dependency on diesel generators. Although some state governments have initiated the process of solarisation, assessing the energy needed to deliver the mandated level of service in each health centre will help to plan for energy efficient equipment/appliances as well as adequate renewable energy capacity.

Recommendation #8: Ensure effective operations and maintenance of renewable energy systems

Integrating climate change in the health departments' planning and budgeting, the State Governments must allocate resources to meet capital and operational expenditure of renewable energy systems. These expenditures must be incorporated as regular items in the state health budget. The National Programme for Climate Change and Human Health for example, has integrated energy for healthcare in the health mission budget. The state and central agencies deploying renewable energy in health centres should ensure that the tender includes specifications for capacity building, a minimum 5-year annual maintenance contract (AMC), and the presence of local service personnel from the vendor.

Recommendation #9: Enhance awareness and build capacities

To drive the widespread adoption of energy efficiency and renewable energy in hospitals, it is essential to prioritise both enhancing awareness and building capacities among hospital administrators, facility managers, and staff. These programs could educate hospital staff on energy management, energy-efficient equipment and practices, energy-conscious behaviour and renewable energy solutions. Additionally, capacity building programs for policymakers and government officials will enable them to develop government programs and schemes to advance energy efficiency and renewable energy in hospitals and healthcare facilities. BEE, SDAs and REDAs, in collaboration with NPCCHH, MoHFW and state health departments, can develop capacity building programs for policymakers, government officials, hospital administrators and facility managers, and other relevant stakeholders in the hospital sector.

Recommendation #10: Leverage funding through global, national, and state-level funding mechanisms

State health departments must explore all funding pathways besides leveraging their own budgets and unlocking new mechanisms. The following funding opportunities are available for state governments to increase renewable energy deployment in public healthcare:

- The financial mechanisms established under the United Nations Framework Convention on Climate Change (UNFCCC) such as the Green Climate Fund, which aims to mobilise funding at scale to invest in low-emission and climate resilient development
- Funds available at the district-level for executing convergence programmes
- Bilateral / Multilateral funding agencies
- Local and regional funding mechanisms including examples like Arogya Raksha Samiti (ARS), philanthropies, CSR and international diplomatic channels/embassies.

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Appendices

APPENDIX A: Number of hospitals surveyed, qualified for analysis per state, per climate zone, and per hospital typology

Table A.1: State-wise sample size achieved

State	Public			Private			All		
	Surveyed	Qualified for analysis	% qualified for analysis	Surveyed	Qualified for analysis	% qualified for analysis	Surveyed	Qualified for analysis	% qualified for analysis
Assam	18	11	61%	7	2	29%	25	13	52%
Bihar	-	-	-	4	1	25%	4	1	25%
Chhattisgarh				4	3	75%	4	3	75%
Delhi	-	-	-	14	8	57%	14	8	57%
Gujarat	19	12	63%	13	10	77%	32	22	69%
Haryana	-	-	-	1	0	0%	1	0	0%
Himachal Pradesh	57	26	46%	4	4	100%	61	30	49%
Jharkhand	18	2	11%	5	3	60%	23	5	22%
Karnataka	34	7	21%	21	2	10%	55	9	16%
Kerala	34	19	56%	11	4	36%	45	23	51%
Madhya Pradesh	-	-	-	20	11	55%	20	11	55%
Maharashtra	6	6	100%	58	40	69%	64	46	72%
Odisha	17	8	47%	8	5	63%	25	13	52%
Puducherry	-	-	-	1	1	100%	1	1	100%
Punjab	25	17	68%	7	5	71%	32	22	69%
Rajasthan	1	0	0%	9	6	67%	10	6	60%
Tamil Nadu	34	19	56%	34	18	53%	68	37	54%
Telangana	-	-	-	5	4	80%	5	4	80%
Uttar Pradesh	50	34	68%	29	22	76%	79	56	71%
Uttarakhand	1	1	100%	1	0	0%	2	1	50%
West Bengal	43	23	53%	10	7	70%	53	30	57%
Total	**357**	**185**	**52%**	**266**	**156**	**59%**	**623**	**341**	**55%**

Table A.2: Climate zone-wise sample size achieved

Climate Zone	Public			Private			All		
	Surveyed	Qualified for analysis	% qualified for analysis	Surveyed	Qualified for analysis	% qualified for analysis	Surveyed	Qualified for analysis	% qualified for analysis
Cold	5	2	40%	8	6	75%	13	8	62%
Composite	150	83	55%	91	63	69%	241	146	61%
Hot and Dry	25	17	68%	36	28	78%	61	45	74%
Temperate	24	11	46%	23	4	17%	47	15	32%
Warm and humid	153	72	47%	108	55	51%	261	127	49%
Total	**357**	**185**	**52%**	**266**	**156**	**59%**	**623**	**341**	**55%**

Table A.3: Hospital typology-wise sample size achieved

Hospital typology	Surveyed	Qualified for analysis	% qualified for analysis
Public			
Sub-centre	26	8	31%
Primary Health Centre (PHC)	44	25	57%
Health and Wellness Centre (HWC)	62	26	42%
Community Health Centre (CHC)	84	41	49%
Sub- district/divisional Hospital (SDH)	59	33	56%
District Hospital (DH)	55	37	67%
Medical College	27	15	56%
Public total	**357**	**185**	**52%**
Private			
Single-speciality Hospital	70	54	77%
Super-/ multi-speciality Hospital	176	99	56%
Medical college	20	3	15%
Private Total	**266**	**156**	**59%**

APPENDIX B: Case studies

Public hospitals

KGMU, Lucknow

King George's Medical University is a 4000-bedded tertiary care public hospital in Lucknow, India. The hospital was established in 1905 and is currently managed by the State Government of Uttar Pradesh. In 2017, KGMU installed an on-campus solar power plant and solar parabolas with the aim to reduce their power cost and ecological footprint under Uttar Pradesh Non-Conventional Energy Development Agency (UPNEDA). UPNEDA is a government created Non-Conventional Energy Development Agency that was formerly established in April 1983 under the department of additional energy sources as an autonomous institution. The agency has been functioning as a nodal body for implementation of various solar schemes in the state.

- 400kW Solar power plant installed at the hospital that saves around Rs 32 Lakhs per year in the electricity bill. Automatic Power Factor Control Panel, an electric device, is installed with the new system to minimise energy consumption by 35- 40% from conventional sources.
- Thirty solar parabolas are installed at one of the hospital buildings to cook food for 3000 patients admitted at the hospital.
- A team of electrical engineers deployed along with assistants to maintain and coordinate the efficient functioning of solar power plants and solar parabolas.
- Energy efficient lighting is used by replacing sodium lights with LED lights.

Read more: https://greenhospitalsindia.com/wp-content/uploads/2022/05/GGHH-Case-Study-KGMU.pdf

Williamnagar Civil Hospital, Meghalaya

Williamnagar civil hospital is a 100 bedded public hospital established in 2007. It is the only hospital in East Garo Hills district of Meghalaya, catering to a population of about 25,000.

Considering the rising covid cases, current fluctuations and power cuts, the district collector of Williamnagar approached SELCO Foundation for working on renewable energy supply. In 2020, when COVID-19 cases were on the rise, Williamnagar Civil Hospital was converted into a Covid care centre. The blocks that were used as a Covid care centre and isolation ward were installed with solar panels that power basic loads like lighting as well as critical equipment for covid care.

Specifically, the equipment running off of solar power include - existing LED bulbs and tube lights, fans, charging points, refrigerators, deep freezer, suction apparatus, oxygen concentrators, semi auto analyser, and needle cutter. Solar energy is used as a backup, whenever there are power cuts. The solar power systems installed in the covid care centre and isolation ward have capacities of 3.96kW (12 solar panels) and 2.97kW (9 solar panels) respectively. In the case of unavailability of sun, the battery provides a backup of up to two days. The staff at the hospital has been trained for the maintenance of solar panels.

Read more: https://greenhospitalsindia.com/wp-content/uploads/2023/03/Williamnagar-civil-hospital.pdf

Sub-centers, Meghalaya

The state of Meghalaya faces frequent power cuts which has affected the delivery of healthcare services. These disruptions in power can last as long as eight hours per day and can be worse during the monsoon period as the power supply lines go through the forest.

The government of Meghalaya, in partnership with SELCO Foundation, under National Health Mission has installed solar panels on 100 sub-centers in eleven districts, along with energy efficient equipment. The list of equipment that runs on solar energy includes – tube lights, fans, charging points, radiant warmer, suction apparatus, spotlight, and vaccine refrigerator. The solar power system is off grid, i.e., there is no dependency on the grid. The battery that accompanies this system provides a backup of up to three days, in case of unavailability of sun due to weather conditions. For sub-centers, they have segregated the solar power system for luminaries, equipment, and staff quarters.

Since the installation, the Auxiliary Nurse Midwives have experienced significant improvement in the functioning of sub-centers, especially in the way there is no interruption during the delivery of pregnant women. The sub-centers run entirely on solar energy. SELCO Foundation has trained the staff at sub-centers on how to maintain the solar panels which includes cleaning it and refilling the distilled water in batteries.

Read more: https://greenhospitalsindia.com/wp-content/uploads/2023/03/Meghalaya-Subcenters.pdf

Private hospitals

KIMS, Hyderabad

KIMS Hospital, Hyderabad, is a 1000-bed super-speciality hospital, which is part of the KIMS Hospitals chain that operates 12 multi-speciality hospitals in Telangana, Andhra Pradesh & Maharashtra and has an aggregate bed capacity of 4000+ beds.

In July 2018, KIMS Hospital, Hyderabad, started implementing an energy efficiency project in collaboration with SmartJoules. To date, the project has improved energy efficiency by 22%, resulting in savings of INR 10.8 crores. The interventions implemented are:

- Design interventions **for air conditioning, hot water and steam systems, pumping and laundry. These included consolidating the cooling load, electrifying hot water and steam systems and improving controls.**
- Equipment interventions **such as energy-efficient pumps for HVAC, energy-efficient lighting, fans, kitchen burners and laundry dryers.**
- Operations interventions **such as tracking and analysing energy consumption and improving maintenance practices.**

The energy and cost savings at KIMS Hospital, Hyderabad, clearly endorse the effectiveness of tracking and analysing energy consumption, and implementing energy conservation measures.

Read more at: https://www.smartjoules.co.in/case-study/kims/

Bhagat Hospital, New Delhi

Bhagat Hospital, a private multi-specialty hospital in Delhi with 85 beds, has been operational since 2009. With a strong commitment to environmental sustainability, the hospital has implemented a range of energy efficiency and renewable energy measures. This case study highlights the key initiatives undertaken by Bhagat Hospital to become a climate-smart healthcare facility.

- Energy-efficient Building Design and Materials: Bhagat Hospital implemented several strategies to minimise heat gains through the building envelope, resulting in reduced cooling load for air-conditioning and overall energy consumption. These measures include the utilisation of insulated windows and innovative shading techniques. By externally shading the walls with a panel made of suitable plywood and heat-retardant Polyvinyl Chloride (PVC) sheeting, an air cavity with a thickness of 1 inch is created, effectively reducing heat ingress. The PVC sheet, which can be easily cleaned with soap and water, also contributes to maintenance cost savings by eliminating the need for frequent repainting. Furthermore, door closers have been installed on all doors to prevent unwanted heat transfers.
- Energy Management and Data Analytics Platform: The hospital implemented an energy management and data analytics platform connected to the LT side of the transformer. This platform allows real-time monitoring of energy parameters, trend analysis, load imbalance identification, and power quality monitoring, ensuring efficient energy utilisation.
- 5-Star Rated Air Conditioning: Bhagat Hospital made a conscious decision to procure and replace air-conditioning units with BEE 5-star rated models.

- Lighting Optimization: Bhagat Hospital undertook a comprehensive analysis of lighting loads in different areas. Based on the findings, a lighting schedule was designed to optimise energy consumption. LED lighting fixtures were adopted throughout the facility, both indoors and outdoors, resulting in significant energy savings. The project costs were recovered within two months due to the achieved energy savings. Additionally, automatic lighting controls, including motion sensors, were installed in specific areas of the hospital to further optimise the lighting load.
- Energy Conservation in Medical Equipment: To conserve energy consumption related to medical equipment, the hospital implemented guidelines and conducted awareness training for medical equipment technicians.
- Timer Switch for Toilet Exhaust Fans: Bhagat Hospital implemented automatic timers in the operation of exhaust fans. These timers were designed to set a specific duration for the exhaust fans, ensuring they only operated when necessary. This approach effectively reduced energy wastage and decreased the overall air conditioning load as well.
- Solar Water Heating System: Bhagat Hospital installed solar water heating systems to provide hot water to patient rooms, reducing reliance on conventional energy sources.
- Solar PV System: Bhagat Hospital implemented a rooftop grid-tied solar photovoltaic system in two phases, totalling 50 kWp.

Bhagat Hospital exemplifies an energy-efficient and environmentally conscious healthcare facility. By implementing energy management systems, optimising lighting, prioritising energy-efficient equipment, and adopting renewable energy sources the hospital has successfully reduced its carbon footprint while maintaining high-quality patient care.

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