U N I V E R S I D A D E   D E   C O I M B R A

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"Quantitative Assessment of Advanced Energy Efficiency Retrofitting for Indian Hospitals"

A thesis submitted in partial fulfillment for the degree,

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Abstract

In India, hospitals are the most complex of building types and energy intensive due to their typically functionality and services. Standard working procedures of most hospitals requires substantial energy use for various equipment's and clinical processes, which in turn accompanies substantial greenhouse gas emissions.

The country has embarked its journey on health care system transformation to meet its growing needs and to meet the world's average of 3.5 beds for every 1000 population. The government introduced important reforms and re-emphasized its vision to create access to a minimum set of health care services for all, due to which the country is experiencing an unprecedented growth in the number of hospital buildings.

With growing concerns about the increasing building stock, energy security and global environment, energy efficiency is obtaining greater attention in India. Energy audit studies in several hospitals of India have shown energy savings potential of 20-50% in electricity end uses such as lighting, cooling, ventilation etc.

This potential has mainly remained untapped for a number of reasons, one of which is a lack of information and awareness. To achieve the highly untapped potential of energy efficiency and to reduce the energy demand of increasing number of hospitals, an adequate assessment of different alternatives is needed.

In an attempt to overcome the gap of energy efficiency and to reduce the barriers, this thesis highlights a path forward for the Indian hospital buildings to be much less energy and carbon intensive, while investing in energy efficient appliances and retrofitting the minimum number of components. A bottom-up energy model BUENAS is used in this study for assessing energy demand, savings and carbon dioxide mitigations.

The growth projections of hospitals and framework for retrofitting appliances is based on the historical data from National Health Profile and Indian public health standards and later economic analysis is made to ensure feasibility of the measures. The main findings and observations of this thesis show that, when best available technology is used, a reduction of 35% energy demand in urban hospitals and 45% in rural hospitals can be achieved.

And the economic analysis shows that an outstanding six out of eight measures are economically feasible with a higher rate of returns on the investment in both urban and rural hospitals.

Keywords: energy efficiency, economics, emissions, India, retrofitting hospitals.

Resumo

Devido à diversidade dos serviços e cuidados de saúde prestados, os hospitais são edifícios complexos no que respeita à utilização de energia. Os procedimentos de trabalho típicos da maioria dos hospitais requerem uma quantidade apreciável de energia em vários equipamentos e processos clínicos, a que está associada as emissões de gases de efeito estufa.

A Índia iniciou uma intensa jornada de transformação do sistema de cuidados de saúde, tendo como objectivo melhorar os indicadores nesta área, como por exemplo o número médio de camas por 1000 habitantes que é de 3,5 – muito abaixo da média mundial-, e também para dar resposta à crescente procura por este tipo de serviços. O governo introduziu reformas importantes e voltou a sublinhar a sua visão de criar o acesso a um conjunto mínimo de serviços de cuidados de saúde para todos, devido ao qual o país está experienciando um crescimento sem precedentes no número de edifícios hospitalares.

Com as preocupações crescentes com o aumento do consumo de energia, em parte devido ao crescimento do parque imobiliário, com a própria segurança energética do país e com o ambiente, a eficiência energética é cada vez mais vista como uma estratégia capaz de responder a essas preocupações e tem tido na Índia uma atenção cada vez maior.

Estudos de auditoria energética em vários hospitais da Índia têm mostrado que existe um potencial de economia de energia entre 20% e 50% na utilização de eletricidade, sendo exemplos de usos finais que podem contribuir para essas poupanças a iluminação, a refrigeração, a ventilação etc. Este potencial tem permanecido inexplorado devido a uma série de razões, uma das quais é a falta de informação e sensibilização. Para atingir o potencial altamente inexplorado da eficiência energética e para reduzir o consumo de energia do crescente númeor de hospitais, é necessária uma avaliação adequada de diferentes alternativas.

Numa tentativa de superar a lacuna da eficiência energética e para reduzir as barreiras a uma maior disseminação de boas práticas de eficiência energética, esta tese destaca um caminho a seguir para os edifícios hospitalares da Índia de modo a serem menos intensivos em termos de energia e carbono, investindo em aparelhos energeticamente eficientes e adaptando o número mínimo de componentes. Para a análise levada a cabo neste trabalho, foi usado um modelo *bottom-up* - BUENAS - para avaliar o consumo de energia, a poupança, e a mitigação do dióxido de carbono que a opção por diferentes alternativas tecnológicas em termos de usos finais acarretam.

As projecções de crescimento do número de hospitais e a base para o retrofitting de equipamentos de utilização final de electricidade baseiam-se nos dados históricos do National Health Profile e no Indian Public Health Standards. É posteriormente realizada uma análise económica para avaliar a viabilidade económica das medidas. As principais conclusões e observações desta tese mostram que, quando a melhor tecnologia disponível é utilizada, pode ser conseguida uma redução do consumo de energia de 35% em hospitais urbanos e de 45% em hospitais rurais. Finalmente, a análise económica mostra que seis em oito medidas são economicamente viáveis, com uma taxa de retorno sobre o investimento muito interessante, tanto em hospitais urbanos, como rurais.

Palavras-chave: eficiência energética, *retrofitting*, emissões, Índia, consumo de energia em hospitais.

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Abbreviations and Acronyms

BEE - Bureau of Energy Efficiency (India)

BAU - Business-As-Usual

BAT - Best-Available-Technology

BUENAS - Bottom-Up Energy Analysis System

CHC - Community Health Centre’s

CBHI - Central Bureau of Health Intelligence

DPP - Discounted Payback Period

GDP - Gross Domestic Product

GHG - Greenhouse Gas

GWh - Gigawatt-hour

IPHS - Indian Public Health Standards

IRR - Internal Rate of Return

LED - Light Emitting Diode

kWh - kilowatt-hour

NHP - National Health Profile (India)

NUHM - National Urban Health Mission (India)

NRHM - National Rural Health Mission (India)

NPV - Net Present Value

PHC - Primary Health Centre’s

RPA – Rated Power of Appliance

SHC - Sub Health Centre’s

TFL - Tubular Fluorescent Lamp

TV - Television

Chapter I

Introduction

1.1. Background and Motivation

Buildings correspond to the largest energy-consuming sector in the economy of developed and developing countries, with over one-third of the total final energy and almost half of global electricity consumption. As a result, they are also accountable for about one-third of global carbon emissions. With growing population, and given improvements in economic development and living standards, energy consumption in the buildings sector is set to increase sharply, placing additional pressure on the energy system. Energy trends in the buildings sector can differ significantly from country to country depending on a number of factors varying from climate, population, income, economic development and building sizes.

In India buildings account for 35% of total energy consumption and an average growth rate of 8% per annum is observed in energy consumption of buildings. The building sector in India generally includes both residential and commercial buildings. Commercial sector in India includes offices, hospitals, hotels, retail establishments etc. A study by United States Agency for International Development and India’s Bureau of Energy Efficiency estimates that there will be a rapid increase in the overall built-up area, as nearly 66% of the commercial space yet to be constructed by 2030.

As energy efficiency continues to draw attention as a significant resource for economic and social development across all economies, understanding its real value has become increasingly important. In the growing energy needs of the country, energy efficiency can play a major role in improving its energy security. The buildings sector uses a wide range of technologies, several cost-effective options are already available in the buildings sector that can significantly reduce both energy consumption and emission.

Energy audit studies conducted by *ECO-III* project [17] in several office buildings, hotels, hospitals of India have indicated energy savings potential of 20-50% in electricity end uses such as lighting, cooling, ventilation etc. This potential has largely remained untapped for a number of reasons, one of which is a lack of information and awareness.

In order to achieve the untapped potential of energy efficiency in India's commercial buildings, energy efficient technologies are needed to be effectively implemented. Energy efficiency is the region in which there is both a need and demand for better data in commercial energy consumption. Better data about energy consumption can empower consumers and policy makers to more efficiently facilitate reductions in energy consumption. It is essential to have access to baseline data in order to gauge the effectiveness of energy efficiency. Many consumers desire to reduce energy consumption and consequent greenhouse gases but lack the knowledge, resources and capital to do so.

In an attempt to overcome the gap of energy efficiency and to reduce the barriers, this thesis highlights a path forward for the hospital buildings in the commercial sector of India to be much less energy and carbon intensive, while investing in energy efficient appliances and retrofitting the minimum number of components. The results alleviate the need for retrofitting of Indian hospitals, with benefits for the environment and for energy security. Several novel improvements are presented in this thesis to support the current state of knowledge on hospital buildings energy consumption of India's commercial sector that will benefit users, policy makers, and stakeholders to acquire information to empower them to reduce energy consumption.

1.2. Aim

To achieve the highly untapped potential of energy efficiency and to reduce the energy demand of increasing number of hospitals, an adequate assessment of different alternatives is needed. Thus, the aim of the study is to assess the energy demand, energy savings & reduced greenhouse gas emissions by increasing the energy efficiency of India's hospitals by retrofitting of appliances. The further part of the study also includes the economics.

1.3. Research Question & Objective

Hospital buildings of all sizes can benefit from efficient appliances for increased energy efficiency, reduced maintenance costs, and improved environments. The main objective of this thesis research is to serve as a baseline data source and to support the current state of knowledge on India's hospital buildings energy consumption that will benefit users, policy makers, and stake holders to achieve the untapped potential of energy efficiency in India's hospital buildings.

This work shall provide answers to the following two main research questions:

- How will the energy demand and corresponding CO2 emissions in Indian hospitals increase if the use of traditional equipment is continued?

- How much could the strict implementation of currently best available technologies (BATs) in the hospitals reduce energy demand and corresponding CO2 emissions?

1.4. Thesis Outline

The present thesis is arranged in five main chapters:

. In Chapter 1, the scene is set for the thesis by describing the context, background and motivation (1.1) and the aim (1.2), defining the research question and objectives (1.3) and by outlining the main content of the thesis (1.4).

. In Chapter 2, the conceptual framework describes the main considerations on which the thesis is built upon and also explains the overview of health care in India (2.1), followed by characterization of India's hospitals (2.2). The Chapter also introduces the concepts of retrofitting and energy efficiency in hospital buildings along with few case studies on hospital energy efficiency retrofitting (2.3), outlook of technologies that are used in buildings (2.4) and barriers of energy efficiency (2.5).

. In Chapter 3, methodological issues of the research are addressed by presenting, the model overview used in this study for assessing energy demand, savings and carbon dioxide mitigations (3.1), the growth projections of hospitals and framework for retrofitting appliances (3.2) and the economic analysis to ensure economic feasibility of measures (3.3).

. In Chapter 4, the main findings and observations are presented separately for each aspect of energy demand (4.1), energy savings (4.2), carbon dioxide mitigations (4.3) and economic analysis of each component which describes the economic feasibility of measure (4.4).

. In Chapter 5, concluding remarks are formulated based on the results obtained and recommendations for hospitals energy efficiency are made (5.1). The thesis closes with an outlook on needs for further research (5.2).

Chapter II

Literature Review

Health Security and Environmental Cluster of World Health Organisation has written recently in the American Journal of Preventive Medicine, “The health sector is one of the most trusted and respected sections of society, and it is also one of the largest employers and consumers of energy” [15].

Standard working procedures for most hospitals requires substantial energy use – for water heating, for maintaining indoor air quality, lighting, ventilation and several clinical processes – with accompanying substantial greenhouse gas emissions. Hospitals can implement many measures to improve energy efficiency while sustaining the energy requirements of these important energy-consuming end-uses [20].

The health sector can play an important part in mitigating the effects of global climate change by taking steps to limit its own significant climate footprint. In Brazil, for example, hospitals account for 10.6% of the country’s total commercial energy consumption [22].

In the United States of America, healthcare buildings are the second most energy-intensive commercial sector buildings; the health sector spends US$ 8.8 billion on energy every year to meet patient needs, and hospitals use about double the total energy per square foot as traditional office space [23]. The National Health Service (NHS) in England has estimated its carbon footprint at more than 18 million tonnes of CO2 each year – 25% of total public sector emissions [24].

The typical hospital building is designed for long-term use and, in practice, is often used for longer periods than its builders ever intended. The actual lifetime is normally over 50 years. During this period, the building is retrofitted and renovated many times. Reasons for this include the shorter life of technical equipment, the development of new types of equipment and health care facilities, new regulations, new energy-saving technologies and the ageing of the building itself [4].

2.1. Health Care in India

India is a home to 18% of the world's population with approximately 1.277 billion people (2015) with an expected growth of 1.2% by the year 2020, it is the second most populated and seventh largest country in the world [1]. India's economy is the world's third-largest with a GDP of 7.26% in the year 2015 as stated by World Bank.

The country's energy consumption has almost doubled since the year 2000, the total energy consumption of the country is 864.7 billion kWh in 2012 [2]. The major energy consuming sectors are industrial, agricultural, residential, commercial and transportation. Buildings account for 35% total electricity consumption, the second highest consumer after industries, building sector comprises of commercial and residential buildings [3]. Commercial building sector in India includes offices, hospitals, hotels, retail establishments etc.

Healthcare has turned into one of India's leading sectors - both in terms of revenue and employment. The major constitutes of healthcare include hospitals, clinical trials, outsourcing, telemedicine and medical tourism. Healthcare distribution of India is characterised into two major constituents - public and private. Until early 1980, the hospitals run or operated by the government and charitable organizations are the main providers of health care. However, after 1980 the healthcare sector has been attracting private capital in setting up hospitals and nursing homes. The Government or the Public healthcare system comprise of secondary and tertiary care organisations in major cities and focuses on delivering basic healthcare services in the form of primary health centre's (PHCs) in rural areas. The private sector delivers the majority of secondary, tertiary and quaternary care institutions with a major attention in metros, tier I and tier II cities [5].

According to a study conducted by World Health Organization (WHO), India currently has only 0.7 beds per every 1000 inhabitants, which is one fifth of world's average of 3.5 beds per every 1000 inhabitants [6]. The government of India has implemented several policies for improving the healthcare situation in the country. During the last few years, there has been a great change in accessibility of health care sector of the country. As per National health profile(NHP) of India estimates during the year 2000-2006 there has been an increase of 67.6% of hospital buildings in the country and it is expected to keep growing until the year 2030 to meets its population's healthcare demands [7].

2.2. Characterization of India’s Hospitals

The Indian health system includes public and private hospitals; private healthcare sector is responsible for the majority of healthcare in India. Private sector healthcare services range from those provided by large corporate hospitals, small hospitals, nursing homes, clinics and dispensaries [9].

The public health sector consists of the central government, state government, municipal & local level bodies which are categorized as Primary Health Centre’s (PHCs), Community Health Centre’s (CHC) and Sub-Health Centre’s (SHC). Private administration plays a substantial role in Indian health sector. According to National Family Health Survey, the private health sector remains the primary source of healthcare for 70% households in urban areas and 63% households in rural areas [10]. More than 60 % of the population lives in the rural India and the estimated government hospital bed scenarios in rural areas are SHC – One bed for every 5000 populations, PHC – One bed for every 30000 populations, CHC – One bed for every 80-120 thousand population [11] [12]. There is a large gap in the healthcare system between urban and rural areas. The inequity among regions is due to a lack of healthcare resources and infrastructure in the rural region. Compounding the issue, most of the population resides in the rural part of the country [21].

The World Bank estimates show that currently India has only 860 beds per million which are only one-fifth of world’s average of 3960 beds. It also showed that the country need 80,000 additional beds every year to meet the world average and the growing population needs [6]. In order to meet the growing needs and to create access to a minimum set of health care services to the people, the government of India has started its journey towards the health care system transformation [13]. In the last decade several projects have been started such as National Rural Health Mission (NRHM)-2005 and National Urban Health Mission (NUHM)-2013 [14] which includes one of the agenda as improving health care infrastructure to ensure better health services for rural and urban populations. According to Statistics of National Health Profile, there are 11,493 hospitals with 576793 beds in the country during 2011 which has been increased to 19,817 hospitals with 675779 beds in 2013 [7] [8].

Table 2.2.1 - Total Number of Hospitals:

YEAR	GOVERNMENT		PRIVATE*	
	RURAL	URBAN	RURAL	URBAN
2010	**6795**	**3748**	***2718***	***33732***
2011	**7347**	**4146**	***2939***	***37314***
2012	**18967**	**4949**	***7587***	***44541***
2013	**15398**	**4419**	***6159***	***39771***

*Private Hospital Based on Historical Data [7] [8] [12] [16].

As a sector, hospitals and health care facilities contribute for an uneven amount of energy use and emissions. Hospitals use around 2.5 times of more energy as a similar-sized commercial building. They consume energy in different forms and ways on a very large scale. They are generally large building complexes with a proper and careful internal climate control. High power equipment is used and normally a high level of heat is generated internally which demands higher cooling or ventilation. In case of older or inefficient equipment being used, more energy is consumed in terms of more electricity required, labor intensive and maintenance, etc. [22]

The range of electricity consumption of major electricity end users in Indian hospitals constitutes of HVAC (44%), lighting (31%), water pumping (7.2%), and other services (17.8%) [17]. A substantial number of Indian hospitals are unaware of the potential areas of savings that relate to energy consumption at healthcare institutions.

According to DSCL energy service company, the hospitals, as large consumers of energy, have high bills for electricity and fuels, although they may represent a small proportion of the hospital’s total operating cost. Review of the power and fuel expenses reported by 46 for-profit hospitals (CMIE PROWESS Database) for the last four years indicate that energy expenses range between 3-8% of total expenses. Even then these constitute a significant component, estimated as 15-20% of the hospitals operating and maintenance cost [4].

A study carried out by Energy conservation building code (ECBC) of India shows that hospitals in India have a potential to achieve 42% energy savings by improving energy efficiency [19]. Estimated electricity consumption in Indian hospitals including Primary Health Centre’s (PHCs), Community Health Centre’s (CHC) and Sub-Health Centre’s (SHC) in 2008 is about 769-1538 million kWh [17].

2.3. Retrofitting & Energy Efficiency in Buildings

Building energy retrofits and application of clean energy efficient measures to existing buildings can present some significant opportunities to save money, energy and reduce climate change. Upgrading and replacing inefficient energy using equipment's in buildings offers a substantial way to reduce energy demand and to increase energy savings. Appliance retrofitting has gained a lot of importance in today's building industry for achieving energy efficiency. The energy savings can be achieved by replacing old building systems with new energy saving technologies and products [36]. In order analyse the energy efficiency and achievable energy savings many studies have used the methods of energy consumption per bed and energy consumption per Square foot, but in this particular study energy consumption/appliance is practiced. Here are some case studies which has proven significant advantages of retrofitting.

2.3.1. Case Study - 1

Hospital Description

St. Mary's Hospital is located in Leonardtown, Maryland, which is a 103-bed hospital that also provides state-of-the-art emergency care. In order to reduce its energy use and costs, the hospital assessed its lighting. An energy audit of the hospital lighting systems concluded that the outdated T12 fluorescent lamps and T8s with magnetic ballasts were draining energy, and suggested the hospital to retrofit them with more efficient lighting technologies [37].

Retrofitting Measures

- T12 fluorescent lamps with magnetic ballasts were upgraded to 28 W T8 fluorescents with electronic ballasts;
- For already existing T8 lamps, magnetic ballasts were replaced with electronic ballasts.

Results Obtained

- Project payback period of 4.35 years is observed;
- After the payback period, the hospital’s yearly energy savings of $20,759 was added to its operating budget;
- Reduction in Maintenance costs was observed due to longer life of lamps.

2.3.2. Case Study - 2

Hospital Description

Rush Oak Park is located in Oak Park, Illinois, which is a 526,569 square-foot community hospital with 246 beds. The hospital is located outside of Chicago. In order to reduce its energy use and costs, the hospital adopted few measures of energy efficiency [38].

The adopted retrofitting measures were presented below:

- Replaced 90 percent of incandescent bulbs;
- T8 bulbs and electronic ballasts are chosen to replace T12 fluorescent lamps and nonelectric ballasts;
- Educated staff to operate chillers before the peak hours;
- Issued guidelines to turn off nonessential lighting after visiting hours;
- Building control systems were adopted to shut down air-handling units in non-patient areas after working hours.

Results Obtained

- Around 30 percent of energy savings are observed through adaptation ofT8 bulbs;
- Electricity savings were used to cover the cost of new electronic ballasts;

- Improved exterior lumens by 50 percent while reducing energy consumption by 26 percent;
- An amount of $340,000 is saved in nine months of the fiscal year 2010;
- Achieved Environmental Protection Agency's ENERGY STAR® label by ranking amongst the top 25 percent most energy-efficient hospitals.

2.4. Technologies Outlook in Buildings Sector

In the following, a general overview of most usual technologies used in buildings, as well as available more energy-efficient alternatives, is presented.

Water Heater

Water heater is a major energy consumption in residential and as well commercial sectors. Room for tapping the potential of energy efficiency in water heater. Conventional storage water heaters to instantaneous water heaters are majorly used in buildings. Storage water heaters have hot water readily stored in a tank at any time, instantaneous water heaters produce hot water on demand using a gas burner or electric heating coil [39]. Thus, instantaneous water heaters tend to have higher energy efficiencies by eliminating standby heat losses associated with a tank and often substantially reducing pipe losses [40]. Gas water heaters have normally lower rated energy efficiencies than electric ones, due to the combustion efficiency of gas and higher tank losses, but are more energy-efficient looking at the source efficiency, which takes into account all consumed primary energy [41].

Major technologies for water heating to reduce energy consumption are condensing water heaters for gas heating, heat-pump water heaters for electric heating and solar thermal water heaters. Condensing water heaters improve the energy efficiency of storage and instantaneous gas water heaters by about 10-30% capturing the latent heat of the combustion gas before it exits [42].

Lighting

Lighting is also a major energy consumer, representing roughly 19% of global electricity use in the commercial sector [43]. There are significant technical potentials to reduce energy consumption from electric lighting with high efficient lamps, light control systems and improved building designs [40].

Much higher improvements are possible with gas discharge lamps, typically fluorescent lamps (FL), and solid-state light-emitting diodes (LED). FLs are low-pressure gas discharge light sources, producing light mainly by fluorescent powders which get activated by ultraviolet radiation created by discharge in mercury [44]. In the building sector both, linear fluorescent lamps (LFL) and CFLs, are used with last one gaining increasing popularity due to an experienced sharp price drop in the past and their similar form to ILs [45]. In recent years, many governments have passed measures to replace conventional ILs with CFLs, as they only require around one-quarter to one-third of electricity to produce the same amount of visible light [40]. A major market barrier for CFLs is their higher initial costs in comparison to ILs [46]. although they are normally more economical on a life cycle basis, due to lower energy consumption and longer lifetimes [45]. Other market barriers are consumer awareness and distrust of consumers in the technology, as CFLs had at the beginning of their commercialization some quality and suitability issues to overcome [46].

Television

Today, liquid crystal display (LCD) televisions dominate the global market accounting for about 80% of sales in 2010 [40]. They are gradually replacing conventional cathode ray tube (CRT) technologies at an accelerated rate although these maintain popular in some emerging markets [47]. Another market transition, which takes place, is from cold cathode fluorescent lamp (CCFL) backlit LCD televisions to higher efficient light-emitting diode (LED) backlit LCD televisions [47]. The development is driven by a movement from analogue to digital televisions as well as energy-efficiency standards and an advancing LED technology (Park, et al., 2011). Plasma televisions have small portions of sales and are mainly present in the market for large screen sizes [40].

Screen sizes and time of use have considerable impacts on annual electricity consumption from televisions. For instance, a growth in screen size diagonal of 40% equates roughly double the screen size area, and 60% increase in electricity consumption in on-mode [48]. However, in recent years, the growth in screen size slowed down to around 3% for LCD and 2% for plasma in the period 2007 to 2009 [49]. Other technology trends just started towards 3D-televisions and smart televisions, increasing power consumption and changing user behaviour [50].

Refrigeration

Refrigerated appliances can be categorized into three groups: refrigerator/freezer combinations, refrigerators only and with freezer compartments and freezers only [51]. Technologies across the different categories are very similar in working, which are typically on an electrically driven vapour compression refrigeration cycle [40].

Several low-cost technologies for refrigerated appliances are available to improve their energy efficiency. Depending on how far energy efficiency policies already advanced in countries, the Lawrence Berkeley National Laboratory (LBNL) [52]. assessed a cost-effective potential for energy reductions from refrigerators of 4-71%. Options to improve the design of refrigerated appliances include thicker insulation, increased surface area for evaporators and condensers, higher efficiency compressors, thermostatic controls, use of vacuum insulation panels (VIPs) and optimized capillary tube characteristics [53].

Air Condition

Room or window air conditioners cool rooms rather than the complete building. If the cooling is provided only where they're needed, room air conditioners are less expensive to operate than central units, despite the fact their efficiency is generally smaller than that of central air conditioners [54].

The percentage of sales that drive into the residential and non-residential sectors varies significantly between countries. Generally, about 36% of sales are into housing and remaining are into commercial buildings. Not surprisingly, moveable units are more common in the residential sector and multi-split units in non-residential buildings [55].

Other Electric Appliances

Other electric appliances with a significant share of energy demand in buildings include Water pumps, Ceiling fan, and Computers. Improvement in RPA (Rated Power of Appliance) respect to possible energy reductions for other electric appliances is difficult as they cover a range number of appliance types. Therefore, for simplification, energy consumption per rural or urban hospitals of other electric appliances including water pumps, ceiling fan and computers is set constant. The energy intensity of each end use component is considered as RPA (Rated Power of Appliance) in this study.

2.5. Barriers to Energy Efficiency

Improving energy efficiency is often realized as the quick and cost-effective way of approach to achieve global greenhouse gas emission targets [56]. There is significant technical potential for improving energy efficiency in buildings, the improvements normally include the adoption of established technologies whose performance is well proven and which involve relatively little technical risk. However, it has long been recognized that various barriers obstruct the adoption of such technologies, for instance, lack of information, shortage of trained personnel and limited access to capital.

Although there is a universal consent that an energy efficiency gap exists, and that policy options to overcome this gap need to be recognized and acted upon. Imperfect Information/ Lack of information on energy efficiency opportunities might lead to cost-effective opportunities being missed [57]. A study has identified 38 barriers to implementing energy efficiency measures when building and refurbishing buildings. Barriers are greatly different from each other, that origin from different areas and complexity levels in the buildings sector [58].

In developing countries like India, attaining energy efficiency in buildings could play a significant role in building a greener economy. However, there are numerous ‘barriers’ that exists in order to adopt energy efficiency measures. Many studies have discussed qualitatively the reasons for not adopting energy-efficient technologies in India [60] [61]. These include energy pricing policies like low electricity prices for households and agriculture, other government policies like tariffs, high start-up costs, scarce opportunities for funding investments, uncertainties about the benefits of investments, and lack of information and awareness.

In order to achieve Energy efficiency, there is both a need and demand to come across the barrier of scarcity of data in commercial building energy consumption. It is essential to have access to baseline data in order to gauge the effectiveness of energy efficiency [59].

This thesis is an attempt to fill the gap of scarcity in data by providing better data about energy consumption in hospital buildings of India, which can empower consumers and policy makers to more efficiently facilitate reductions in energy consumption.

Chapter III

Methodology

A bottom-up approach is adopted in this study to assess the energy demand projection, the primary goal for adopting bottom-up approach is to assess the energy savings and greenhouse gas emissions reduction by energy efficient retrofitting of hospitals in India. The BUENAS energy projection model equations were used in this study to assess energy demand, energy savings and reduced greenhouse gas emissions.

3.1. Model Overview

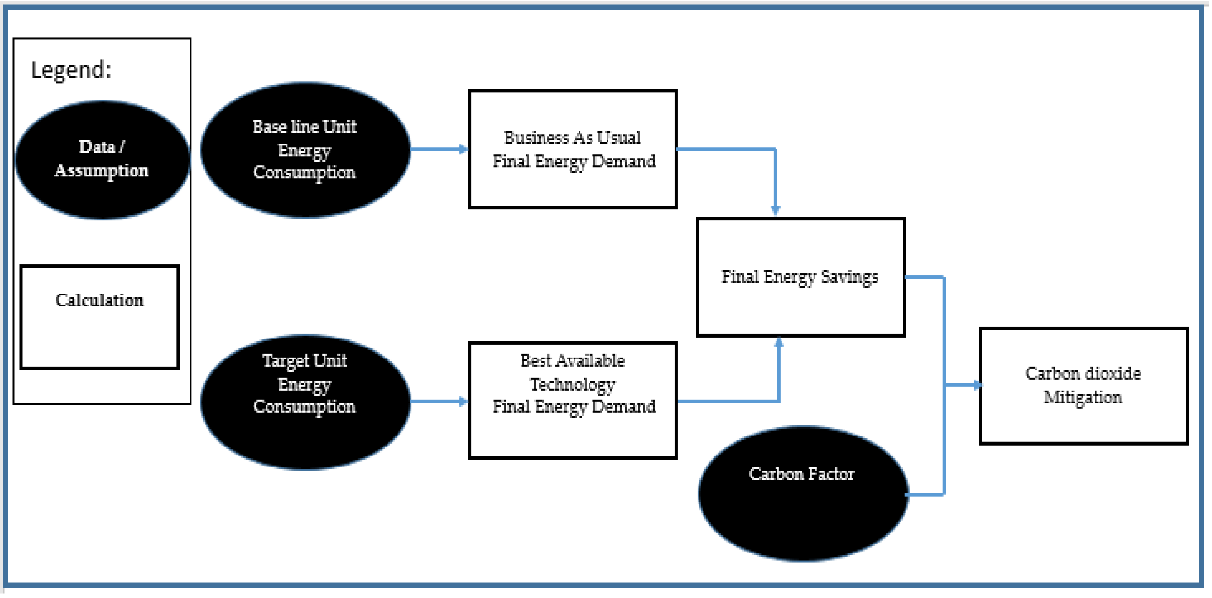


Fig. 3.1. - Flowchart of BUENAS Calculation.

BUENAS (Bottom-Up Energy Analysis System) is an end use energy demand projection model that is built by Lawrence Berkeley National Laboratory (LBNL), USA [26]. It is a tool to model energy demand by various types of energy consuming equipment and aggregate the outcomes to the end use, sector or national level. The primary objective of BUENAS is to deliver the most accurate and thorough possible assessment of energy savings and greenhouse gas emissions reductions from adopting energy efficiency measures [27].

The legend of ***Fig. 3.1.*** includes:

. ***Data or assumption*** **-** These are direct inputs to the model and in cases where no data are available, assumptions are sometimes made.

. ***Calculation*** **-** These are calculations made using the equations 1 to 5 as mentioned below.

The model determines energy demand as a product of activity and energy intensity levels (Equation 1).

Equation 1 - Basic equation for assessing energy demand:

$$\boxed{\textbf{Energy Demand = Activity * Intensity}}$$

In this equation, Activity refers to total number of components, e.g., the number of refrigerators or ceiling fans used in the hospital buildings. Intensity is guided by the usage and capacity of each component, such as the size of a water heater or the hours of use of a room air conditioner.

BUENAS calculates energy savings, according to the difference in energy demand of the two scenarios which are business as usual scenario and best available technology scenario [28]. The equation 2 and 3 were used in this study to assess energy demand for the two scenarios:

Equation 2 - Equation for assessing energy demand in Business-As-Usual scenario:

$$\boxed{\mathbf{E_{BAU}=\sum [(NOH\ (P))\ *(RPA)*(OTA)*(TNC)]}}$$

Equation 3 - Equation for assessing energy demand in Best-Available-Technology scenario:

$$\boxed{\mathbf{E_{BAT}= \sum [(NOH\ (P))\ *(RPA\ (BEE\eta)\ *(OTA)*(RNC)]}}$$

Where, EBAU is Business as usual energy demand, EBAT is Best available technology energy demand, NOH(P) is Number of Hospitals projection, RPA is Rated Power of Appliance, RPA (BEE η) is Rated Power of Appliance by Bureau of Energy Efficiency labelled products, OTA is Operational time per annum, TNC is Total number of Component, RNC is Retrofitting number of Component.

The energy savings were calculated according to the difference in energy demand scenarios. The equation 4 represents the energy savings.

Equation 4 - Equation for assessing energy demand in Best-Available-Technology scenario:

$$\boxed{\Delta \mathbf{E(y) = EBAT - EBAU}}$$

Where, $\Delta E_{(y)}$ is Final Energy Savings in year y by using best available technology. In addition, BUENAS allows the assessment of emission mitigation calculates carbon dioxide mitigation from final energy savings. It focuses on CO2 emissions, which are accountable for 90% of the GHG emissions in the energy sector [29]. The equation 5 represents the emission carbon dioxide mitigation in year y,

Equation 5 - Equation for assessing CO2 Emission Mitigation:

$$\boxed{\Delta \mathbf{CO2}_{(y)} = \Delta \mathbf{E}_{(y)} \times \mathbf{fc}_{(y)}}$$

Where, ΔCO2(y) = CO2 mitigation in year y

ΔE(y) = Final Energy Savings in year y

fc = carbon conversion factor (kg/kWh) in year y, 0.82 for India is used in this study.

3.1.2. Scenario Descriptions

Business-as-usual (BAU) Scenario

The scenario describes a pathway for hospital buildings energy demand, reflecting the current trends of appliances used in hospitals. It takes into consideration only those appliances which are used in general and recognized as traditional equipment. In contrast, the scenario offers a picture of the rising energy demand and emissions if the traditional equipment use continues.

Best Available Technology (BAT) Scenario

The scenario describes the potential reduction of energy demand in Indian hospitals to by adopting best available technology. The best available technology chosen here is the 5 star labeled appliances by BEE.

Component	***BAU***	***BAT***	***Source***
TFL	T12,60W,3000 lm	T5,36W,3200 lm	[63] [64] [65]
Refrigerator	215 lit,800W	215lit, 330W	[75] [76]
Air condition	1.5 ton, 2400W	1.5ton, 1677W	[66] [67] [68]
Water pumps	1HP,1460	1HP,730	[69] [70] [71]
Computer	250W (120W CPU+ 150W Monitor)	150W (70W CPU+ 80W Monitor)	[80] [81]
Ceiling Fan	230 Cum/min,75W	220 Cum/min,55W	[77] [78]
Water Geyser	25lts,2400W	25lts,2000W	[72] [73] [74]
Television	21inch,LCD,150W	21inch,LCD,80W	[79] [80]

Table 3.1.2. - Description of component technical properties.

3.2. Growth Projection and Framework for Retrofitting Equipment/Appliances

The data regarding total no of hospitals and growth projections were made based on the data obtained from the National Health Profile of India. National health profile of India is an annual report published by the central bureau of health intelligence under Ministry of health, India. It provides comprehensive information for planners, policy makers, health administrators and researchers in the health sector of the country [7] [8] [12] [16]. The growth projections are estimated for both private and government owned hospitals in rural and urban areas using table 3.2.1,3.2.2 The total projected number of hospitals were presented in annex-1,2, and 3.

Hospitals	Private	Government
Rural	60	40
Urban	90	10

Table 3.2.1 - Private & Government Hospital Ratios in Urban & Rural India.
Source: [7] [8] [13].

The minimum number of components for hospitals are chosen from the Indian public health standards and are presented in annex-4,5. IPHS are a set of uniform standards framed under the National Health mission by Ministry of Health and Family Welfare, Govt. of India to improve the quality of healthcare delivery in the country. These IPHS guidelines act as the main driver for continuous improvement in quality and serve as the benchmark for evaluating the functional status of health facilities [30] [31] [32].

Bureau of Energy Efficiency (BEE) is a key player for carrying energy efficiency in India which is established under the Energy Conservation Act, 2001. The selection of retrofitting components was chosen from the star labelling program by the bureau of energy efficiency, India. The 5 star rated components by the star labelling program are chosen for this study as the best available technology [33].

In total 21 equipment/appliances are covered under the scheme of star labelling of which only 8 equipment's are chosen for the study, which are used in hospitals. The chosen equipment's and their power consumption is presented in table 3.2.3.

Equipment Wattage		
Retrofitting component	**Traditional watts**	**Replacement with Energy efficient (EE) watts**
Tubular fluorescent lamps (TFL)	60	36
Refrigerator	800	330
Water pumps	1460	730
Computer	250	150
Ceiling Fan	75	55
Water Geyser	2400	2000
Television	150	80
Air Conditioner	2400	1677

Table 3.2.3. - Equipment Wattage.

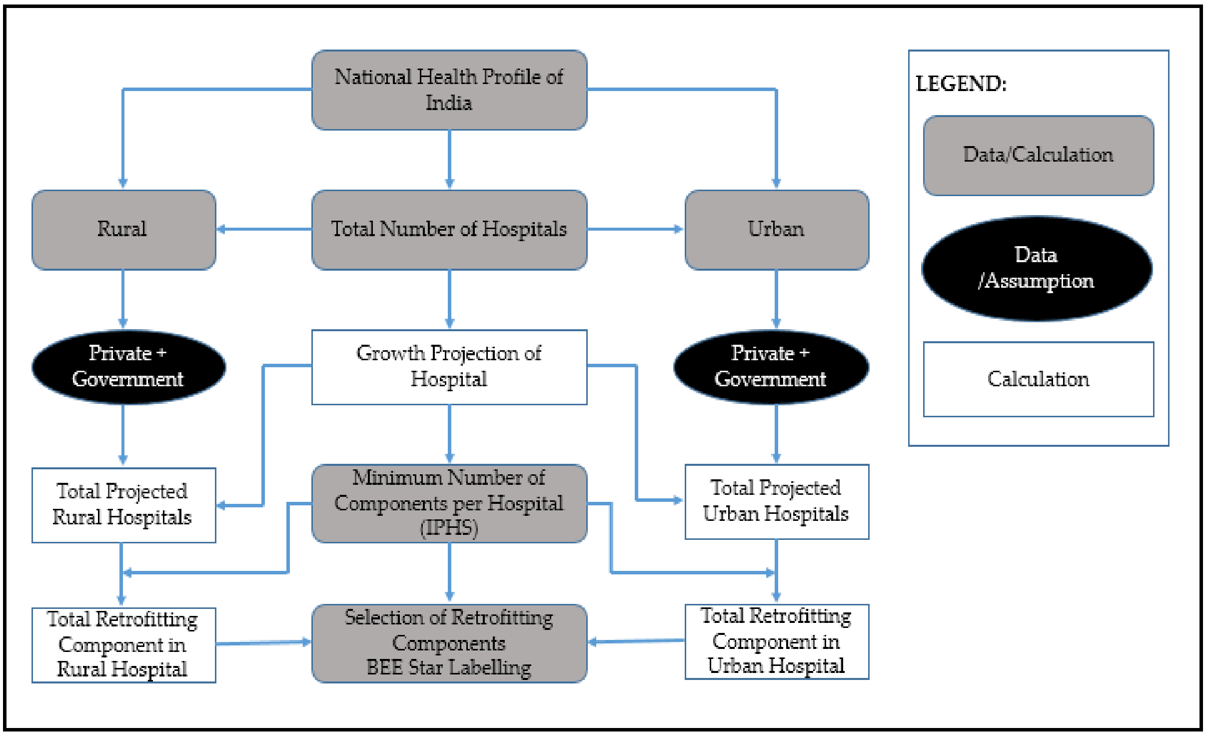


Fig 3.2.1. - Growth projection and Retrofitting framework.

The legend of Fig. 3.2.1. includes:

Data or assumption - These are the direct input of data regarding private and government hospital ratio and in cases where no data are available, assumptions are made;

Calculation - These are calculations made based on the existing data and other inputs;

And***, Data or calculation*** - This can be either a direct data input or a calculation. The main example of this is the total number of hospital considered from the national health profile.

Key Assumptions

The assumptions and projections of Number of Hospitals (NOH) in the public and private sector were based on the historical data that is published by National Health profile (NHP) of India from the period 2010 to 2015.

The projection of hospital was made up to the year 2032 assuming that there will be the same growth rate as in the previous years.

Appliance efficiencies, Operation hours and energy consumption per unit of various appliances were based on the data inputs of Bureau of Energy Efficiency (BEE), India.

The conclusive pathways were derived from the projections and assumptions to calculate future energy demands, savings, and emissions.

3.3. Economic Analysis

The economic analysis for the various retrofitting components is based using the inputs:

- Net energy savings, by retrofitting component (kWh);
- Capital costs of the energy efficiency measures, by retrofitting component;
- Operating costs of the energy efficiency measures, by retrofitting component.

To analyze the profitability of investment in retrofitting, Discounted payback period, Internal rate of return and net present value are calculated in this thesis.

3.3.1. Discounted Payback Period

Discounted payback period is calculated component wise in both rural and urban hospitals to analyze the return on investment. Simple payback period is neglected in this study since it ignores the time value of money. Discounted payback period accounts for the time value of money by discounting the cash inflows of the project [18]. The discounted payback period is calculated using the equation 6.

Equation 6 - Discounted Payback Period:

$$\boxed{\textit{Discounted Payback Period (DPP)} = A + (B / C)}$$

Where:

A - Last period with a negative discounted cumulative cash flow;

B - Absolute value of discounted cumulative cash flow at the end of the period A;

C - Discounted cash flow during the period after A.

In discounted payback period we calculated the present value of each cash inflow taking the start of the first period as a zero point. For this purpose, a suitable discount rate of 7.5% has chosen in this study. The discounted cash inflow for each period is calculated using the equation 7.

Equation 7 - Discounted Cash flow:

$$\textit{Discounted Cash Inflow} = \frac{\textit{Actual Cash Inflow}}{(1 + i)^n}$$

Where, i is the discount rate, and n is the period to which the cash inflow relates.

3.3.2. Net Present Value

Net present value (NPV) is the possible change in an investor's wealth caused by a project while time value of money is being accounted for. It equals the current value of net cash inflows generated by a project less the initial investment on the project [62].

The following inputs were used to calculate the net present value in this study:

- Projected net cash flows in successive periods of the project;
- The hurdle rate.

Where, Net cash flow is the total cash inflow during the period and the Hurdle rate is the rate used to discount the net cash inflows.

The net present value is calculated using the equation 8.

Equation 8 - Calculating Net Present Value:

$$NPV = R \times [1 - (1 + i)^{-n}] / i - \textit{Initial Investment}$$

Where, R is the net cash inflow received in each period; i is the required rate of return per period; n is the period in which the project is expected to operate and generate cash inflows.

3.3.3. Internal Rate of Returns

The internal rate of return (IRR) is the discount rate upon which the net present value of an investment becomes zero. It is one of the several measures used for investment evaluation [63].

Equation 9 - Calculating Internal Rate of Returns.

$$\left[\frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1+r)^3} + \ldots\right] - \text{Initial Investment} = 0$$

Where, r is the internal rate of return; CF1 is the first period of net cash inflow; CF2 is the second period of net cash inflow, CF3 is the third period of net cash inflow, and so on.

3.3.4. Cost of Saved Energy

The cost of saved energy is the amount of money saved during the operation of energy efficient equipment, the cost of saved energy is calculated using the equation 10:

Equation 10 - Calculating cost of Saved Energy.

*Cost of Saved Energy = Energy saving of component * cost of kWh*

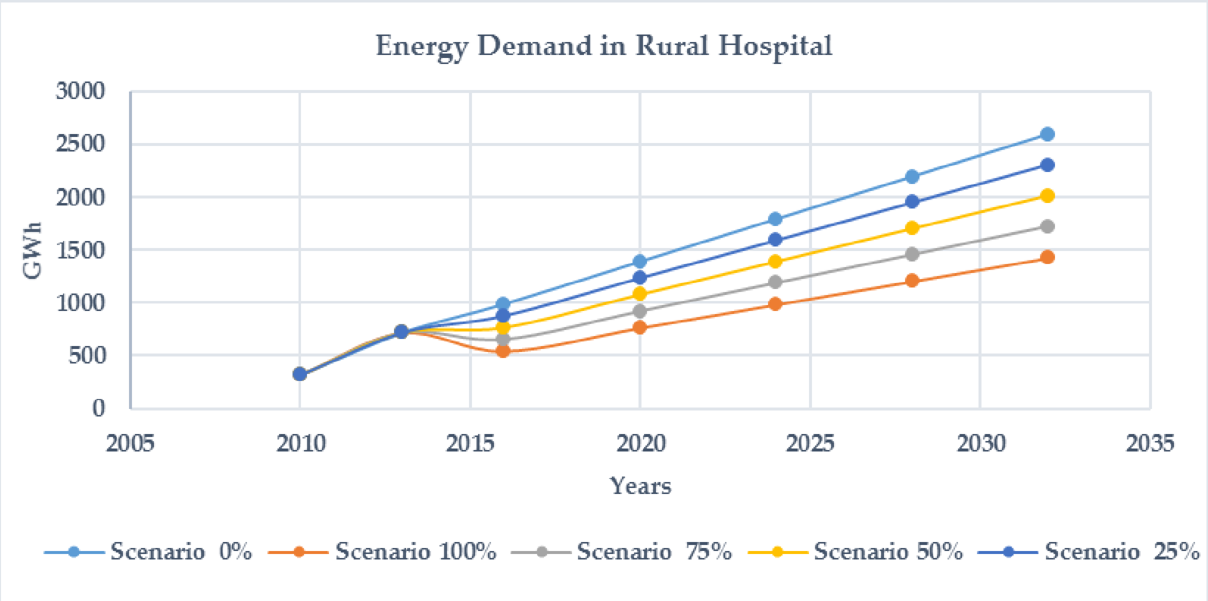
The inputs for the above equations regarding the cost, life span and energy savings of components are present in annexure-6. An 8 cent per kWh price is chosen for this study [25].

Chapter IV

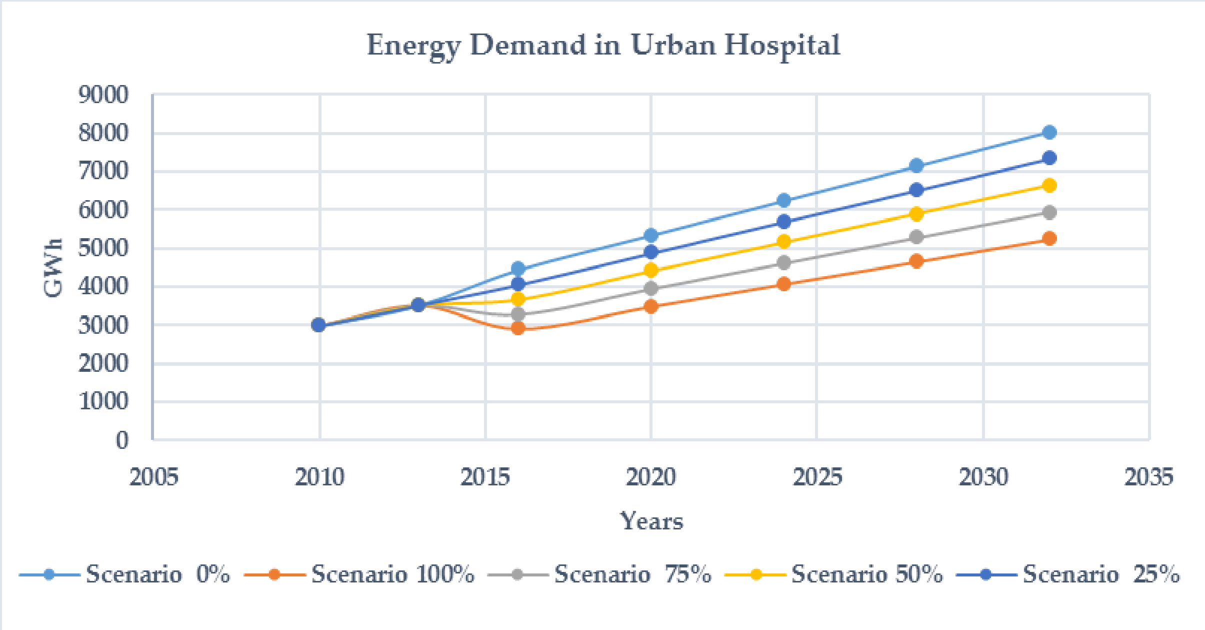
Results and Discussion

4.1 Energy demand

The final energy demand in rural hospitals and urban hospitals are estimated, the energy demand in the rural hospital in 2010 and 2013 was estimated as 317 GWh and 718 GWh and the projected energy demand for rural hospitals estimated to stand at 2597 GWh in 2032. Energy demand in the urban hospital in 2010 and 2013 was 2980 GWh and 3513 GWh and the projected energy demand for urban hospitals estimated to stand at 8021 GWh in 2032. The variations in energy demand in both urban and rural hospitals for scenarios of low 0%, 25%, 50% and high 100% patterns of energy efficient equipment changes are shown. The Graphs 4.1.1. and 4.1.2. below reflect the increasing energy demand forecasts under 5 different scenarios in GWh. A detailed analysis is presented in annex 9 to 15 for rural hospitals and annex 16 to 22 for urban hospitals.



Graphic 4.1.1. - Energy Demand in Rural Hospital.



Graphic 4.1.2. - Energy Demand in Urban Hospital.

When best available technology is used with a 100% replacement ratio, a reduction of 35% energy demand in urban hospitals and 45% in rural is observed. The detailed component wise analysis of energy demand is presented in table 4.1.1 and 4.1.2 for both urban and rural hospitals. The findings show that the Water Geyser in urban hospitals and Refrigerators in rural hospitals are the most energy intensive components.

Urban Hospitals		**2010**	**2013**	**2016**	**2020**	**2024**	**2028**	**2032**
Business as Usual	Tubular fluorescent lamps (TFL)	547	645	815	980	1145	1309	1474
	Refrigerator	592	697	881	1059	1237	1414	1592
	Air condition	425	501	633	761	889	1017	1144
	Water pumps	126	149	188	226	264	302	339
	Computer	77	91	115	139	162	185	208
	Ceiling Fan	365	430	543	653	763	872	982
	Water Geyser	822	970	1225	1472	1719	1967	2214
	Television	25	29	37	44	52	59	67
	GWh	**2980**	**3513**	**4439**	**5334**	**6230**	**7125**	**8021**
Best Available Technology	Tubular fluorescent lamps (TFL)	547	645	489	588	687	785	884
	Refrigerator	592	697	363	437	510	583	657
	Air condition	425	501	442	532	621	710	800
	Water pumps	126	149	94	113	132	151	170
	Computer	77	91	69	83	97	111	125
	Ceiling Fan	365	430	398	479	559	640	720
	Water Geyser	822	970	1021	1227	1433	1639	1845
	Television	25	29	20	24	28	32	36
	GWh	**2980**	**3513**	**2898**	**3482**	**4067**	**4651**	**5236**

Table 4.1.1. - Energy Demand in Urban Hospitals Component Wise Analysis.

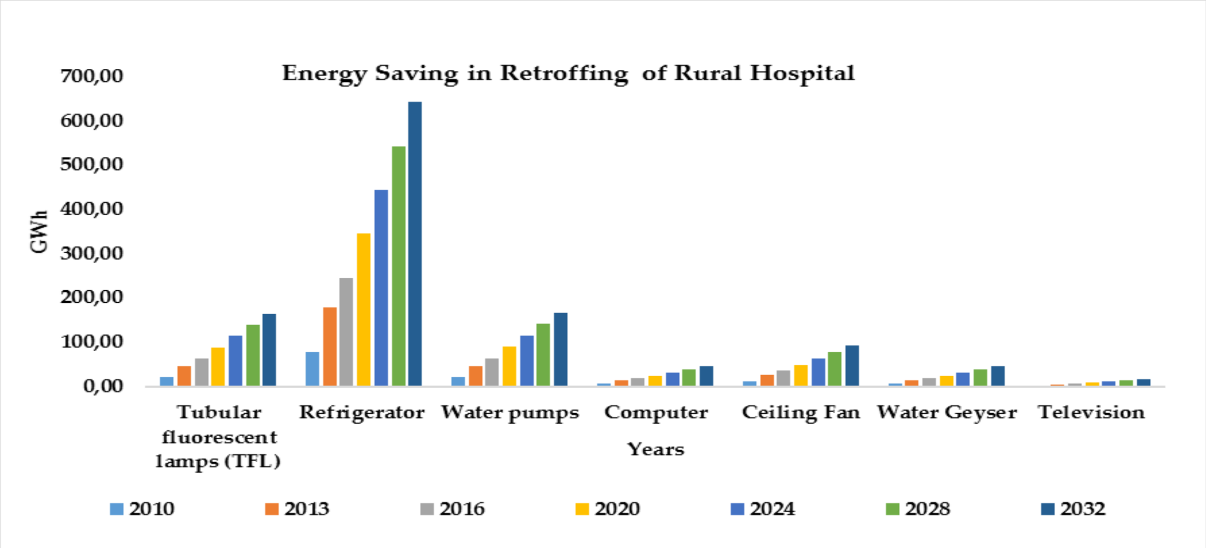
Rural Hospitals		2010	2013	2016	2020	2024	2028	2032
Business as Usual	Tubular fluorescent lamps (TFL)	50	113	156	220	283	346	410
	Refrigerator	133	302	417	586	755	923	1092
	Air condition	0	0	0	0	0	0	0
	Water pumps	41	92	127	178	230	281	332
	Computer	14	31	43	61	79	96	114
	Ceiling Fan	42	94	130	183	236	289	341
	Water Geyser	33	76	104	146	189	231	273
	Television	4	9	13	18	24	29	34
	GWh	**317**	**718**	**991**	**1392**	**1794**	**2195**	**2597**
Best Available Technology	Tubular fluorescent lamps (TFL)	50	113	94	132	170	208	246
	Refrigerator	133	302	172	242	311	381	451
	Air condition	0	0	0	0	0	0	0
	Water pumps	41	92	63	89	115	140	166
	Computer	14	31	26	37	47	58	68
	Ceiling Fan	42	94	96	134	173	212	250
	Water Geyser	33	76	87	122	157	192	228
	Television	4	9	7	10	13	15	18
	GWh	**317**	**718**	**544**	**765**	**986**	**1206**	**1427**

Table 4.1.2. - Energy Demand in Rural Hospitals Component Wise Analysis.

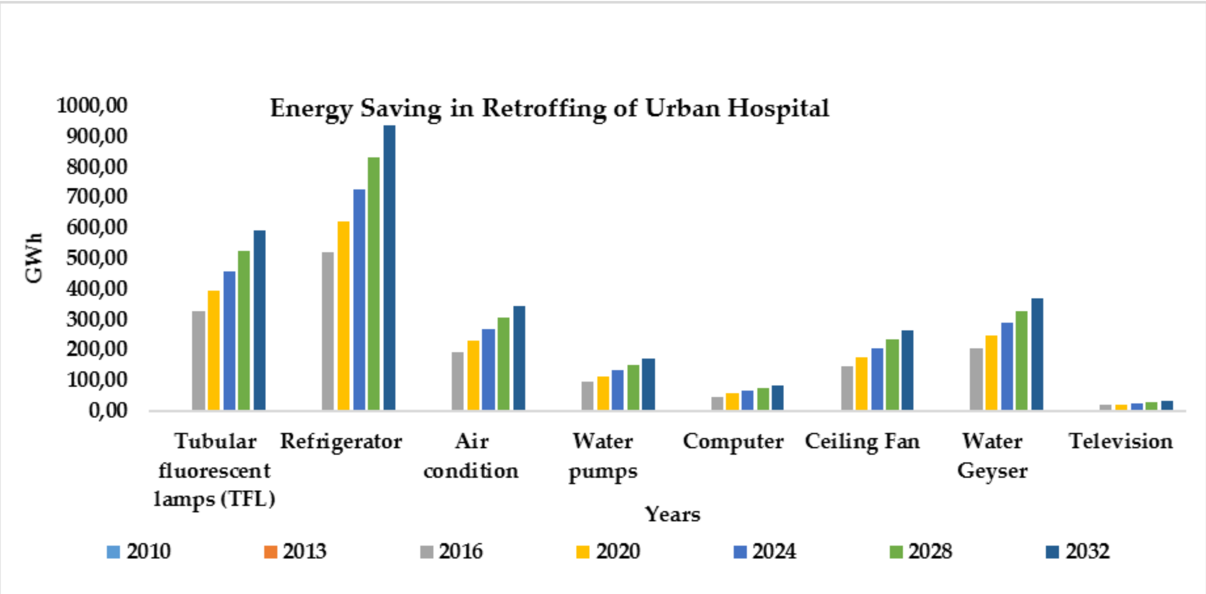
4.2 Energy savings

The graphs below reflect the achievable energy savings from retrofitting of various equipment's in hospitals under 5 different scenarios and the results are presented in GWh. The achievable energy savings in both urban and rural hospitals for scenarios of low (0%), 25% 50% and high (100%) use of energy efficient equipment changes are shown in Graph 4.2.1., for Urban and Graph 4.2.2., for Rural hospitals. A detailed analysis is presented in annex 9 to 15 for rural hospitals and annex 16 to 22 for urban hospitals.

In urban hospitals, the water geyser has shown the maximum energy saving technical potential after tubular fluorescent lamps (TFL) and followed by refrigerator, air condition, water pumps and least energy saving are observed in Ceiling fan. In rural hospitals, the refrigerator shows the higher energy saving technical potential followed by tubular fluorescent lamps (TFL), water pumps and least energy saving potential is observed in television.



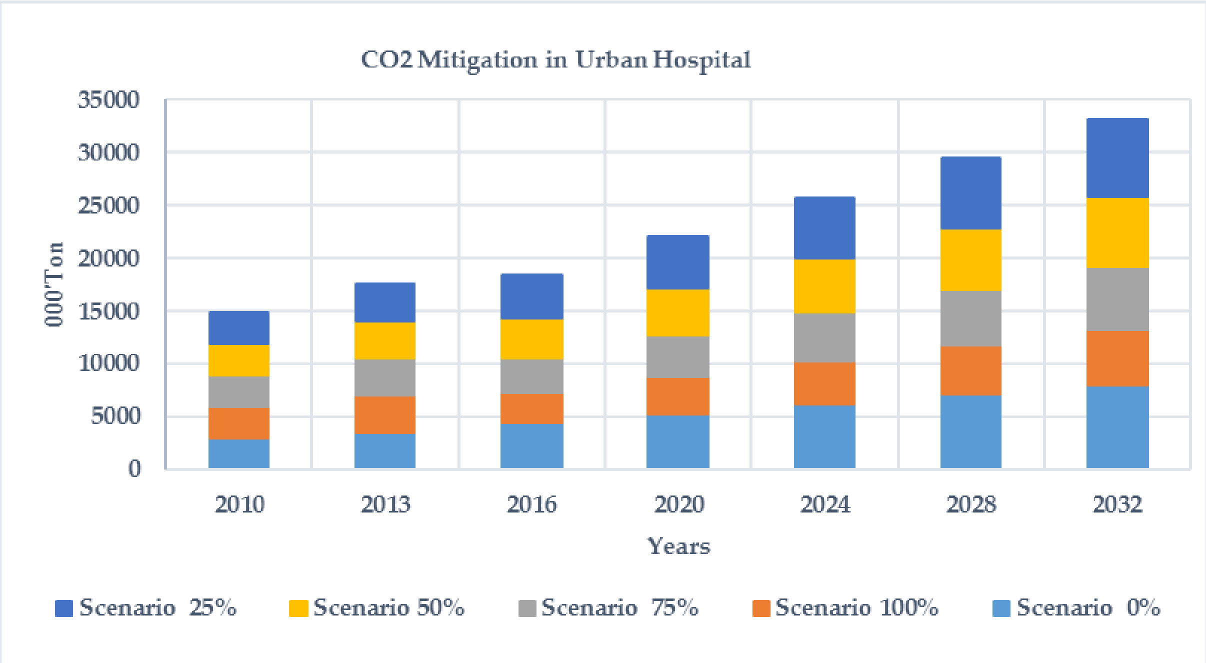
Graphic 4.2.1. - Energy Saving in Retrofitting of Rural Hospital.



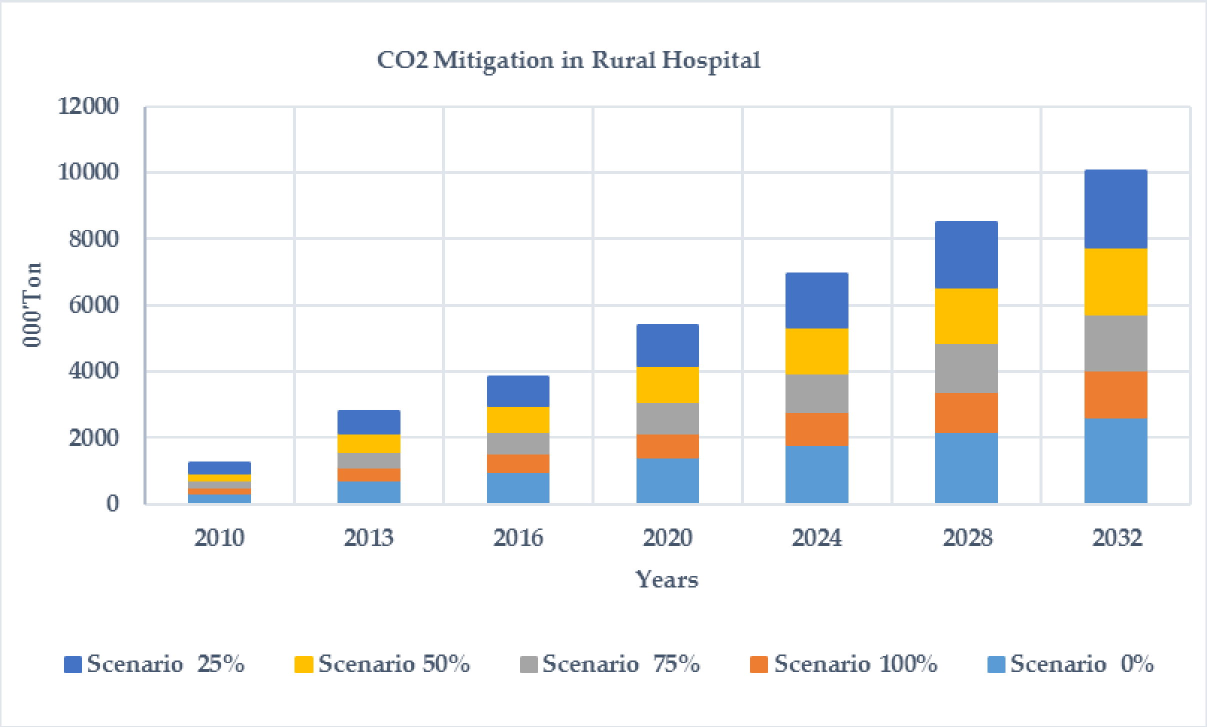
Graphic 4.2.2. - Energy Saving in Retrofitting of Urban Hospital.

4.3. Carbon dioxide Emission Mitigation

The graphs below reflect the CO_2 emission mitigations for 5 different scenarios in the measure of tons. The variations in CO_2 emissions from hospitals for scenarios of low 0%, 25%, 50% and high (100%) are assessed. In case of urban hospitals as shown in Graph 4.3.1., Co2 mitigation potential is observed as 34%, 26%, 17% and 9% respectively for 100%, 75%, 50% and 25% scenarios. In case of rural hospitals as shown in Graph 4.3.2., Co2 mitigation potential is observed as 45%, 34%, 22% and 11% respectively 100%, 75%, 50% and 25% scenarios.



Graphic 4.3.1. - CO2 Mitigation in Urban Hospital.



Graphic 4.3.2. - CO2 Mitigation in Rural Hospital.

4.4. Economic Analysis

In rural hospitals, water pumps have shown significant returns with a shorter payback of 5 months followed by refrigerator, TFL, and water geyser. And a longer payback of 8.6 years is seen in the ceiling fan. The analysis shows that the television and computer are economically inefficient due it's longer payback than the life of equipment. The highest internal rate of returns and net present value is observed in water pumps and refrigerators. Negative rate of returns and net present value is observed in computer and television which shows that the retrofitting of these components are economically inefficient. The table 4.4.1. represents the values of Discounted Pay Back, NPV and IRR for rural hospitals, a detailed analysis is presented in the annexes 7.1, 7.2, and 7.3.

From	To	Investment ($)	Savings ($) / Year	Life Span in years	Energy Saved kWh/year	Pay Back (years)	NPV ($)	IRR	Carbon Emissions Mitigation (Kg)
TFL BAU	TFL BAT	7,45	5,61	7,00	70,08	1,46	22,24	74%	402,26
Refrigerator BAU	Refrigerator BAT	286,71	329,38	10,00	4117,20	0,94	1457,86	115 %	33761,04
Air condition BAU	Air condition BAT	-	-	-	-	-	-	-	-
Water pumps BAU	Water pumps BAT	79,25	170,53	15,00	2131,60	0,50	823,97	215 %	26218,68
Computer BAU	Computer BAT	595,70	23,36	5,00	292,00	-	-501,19	-38%	1197,20
Ceiling Fan BAU	Ceiling Fan BAT	28,89	4,67	10,00	58,40	8,63	-4,14	10%	478,88
Water Geyser BAU	Water Geyser BAT	128,84	46,72	13,00	584,00	3,21	118,62	36%	6225,44
Television BAU	Television BAT	171,28	16,35	10,00	204,40	-	-84,67	-1%	1676,08

Table 4.4.1. - Discounted Pay Back, NPV & IRR for rural hospitals.

In urban hospitals, water geyser has shown significant returns with a shorter payback of 5 months followed by TFL, water pumps, refrigerator, ceiling fan and air conditioners. The analysis shows that the television and computer are economically inefficient due it's longer payback than the life of the equipment. The highest internal rate of returns and net present value is observed in water geyser, TFL and water pumps. Negative rate of returns and net present value is observed in computer which shows that the retrofitting of the component is economically inefficient. The table 4.4.2. represent the values of Discounted Pay Back, NPV and IRR for rural hospitals, a detailed analysis is presented in the annexes 8.1., 8.2., and 8.3.

From	To	Investment ($)	Savings ($) / year	Life Span in years	Energy saved kWh/year	Pay Back (years)	NPV ($)	IRR	Carbon Emissions Mitigation (Kg)
TFL BAU	TFL BAT	7,5	14,0	3,0	175,2	0,6	29,0	180 %	431,0
Refrigerator BAU	Refrigerator BAT	286,7	329,4	10,0	4117,2	0,9	1974,2	115 %	33761,0
Air condition BAU	Air condition BAT	446,4	173,5	10,0	2169,0	3,0	744,7	37%	17785,8
Water pumps BAU	Water pumps BAT	79,3	127,9	15,0	1598,7	0,7	1049,7	161 %	19664,0
Computer BAU	Computer BAT	595,7	29,2	5,0	365,0	-	-477,6	-34%	1496,5
Ceiling Fan BAU	Ceiling Fan BAT	28,9	9,3	10,0	116,8	3,7	35,2	30%	957,8
Water Geyser BAU	Water Geyser BAT	128,8	280,3	13,0	3504,0	0,5	2149,0	218 %	37352,6
Television BAU	Television BAT	171,3	24,5	10,0	306,6	-	-2,9	7%	2514,1

Table 4.4.2. - Discounted Pay Back, NPV & IRR for Urban Hospitals.

Chapter - V

Conclusion and Future Work

5.1. Conclusion

The research presented in this thesis is an important indicator that shows that the hospital buildings of all sizes can be benefitted from adopting efficient appliances by increased energy efficiency and improved environments. The thesis could serve as a baseline data source and supports the current state of knowledge on India's hospital buildings energy consumption which benefits the users, policy makers, and stake holders.

Previous studies have shown that an untapped potential of energy efficiency exists in Indian hospitals. However, in order to achieve the untapped potential, a discrete and adequate assessment of various alternatives have been made in this work. The appliance retrofitting with best available technology has proven to be a simple, inexpensive and effective alternative to achieve energy efficiency in hospitals.

The work has developed a framework for assessing the growth in number of hospitals and their increasing energy demand. The constructed scenarios in the present thesis demonstrate that the hospital buildings in India can play a major role in climate change mitigation. The investigation indicates that a decrease of approximately 35% in urban hospital and 45% in rural hospital energy demand is possible in India's hospitals. This is attainable through the proliferation of today's most energy efficient building equipment. The saving is achievable without stepping back in comfort or compromising in services.

The outcomes of the work suggest that CO2 emissions in could be reduced by 0.7 million tons in rural and 1.8 million tons in urban hospitals in the year 2030 through reductions in energy demand. The end results of the work remind that the appliance retrofitting measures in hospitals are highly economically feasible due to their shorter paybacks and higher rate of returns. However, negative rate of returns and net present value is observed in computer and television which shows that the retrofitting of these components are economically inefficient due to less use hours and shorter life spans.

At the same time, yet well known the facts of energy efficiency potential in Indian hospitals, the energy efficiency gap still exists and the further question remains about different barriers that hamper the realization of substantial, partly cost-effective measures for energy efficiency opportunities. Many of these barriers could be overcome or mitigated through the implementation of policies and measures, educating hospital managements and making the end users aware of their role in energy efficiency. One way to reduce these barriers could be by framing regulations and legislations aiming at facilitating the energy service companies.

Finally, a conducted review on hospital buildings energy data in India at rural and urban level shown that availability of data is quite limited. To facilitate research, in particularly the collection and public provision of data on the potential and retrofitting measures of energy-efficiency need to be extended.

5.2. Future Work

The developed thesis is subjected to several constraints and simplifications, while conducting this research various theoretical and practical issues were identified for further research;

From a theoretical and methodological perspective, a methodology could be developed for separate modeling of policies for energy efficiency improvements in hospitals. And a more intense research could be developed considering all the special areas in hospitals and by assessing all forms of energy. Improvements could also include the integration of future expected changes in user behavior and energy prices.

From a practical perspective, an analytical assessment using various models like REDUCE can be made to understand the life cycle impacts of the measures. Not covered by the thesis is the analysis of costs associated with operation and maintenance of energy efficient measures. Such an analysis could be useful to evaluate the required total investment and reduced maintenance costs of the measures.

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Annexure

Annex 1 - Projected Number of Rural Government and Private Hospitals.

	Year	Rural	
		Hospital (Government)	**Hospital (Private)**
NHP	2010	6795	2718
	2011	7347	2939
	2012	18967	7587
	2013	15398	6159
	2015	16816	6726
Forecast	2016	21241	**8496**
	2017	23393	9357
	2018	25544	10218
	2019	27696	11078
	2020	29847	**11939**
	2021	31999	12800
	2022	34151	13660
	2023	36302	14521
	2024	38454	**15382**
	2025	40606	16242
	2026	42757	17103
	2027	44909	17964
	2028	47061	**18824**
	2029	49212	19685
	2030	51364	20546
	2031	53516	21406
	2032	55667	**22267**

Annex 2 - Projected Number of Urban Government Hospitals.

	Year	Urban Government Hospitals					
		Hospital (G)	**31-50 Beds**	**50-100 Beds**	**101-200 Beds**	**201-300 Beds**	**> 300 Beds**
NHP	2010	3748	2811	450	300	112	75
	2011	4146	3110	498	332	124	83
	2012	4949	3712	594	396	148	99
	2013	4419	3314	530	354	133	88
Forecast	2016	5583	4187	670	447	167	112
	2017	5864	4398	704	469	176	117
	2018	6146	4609	738	492	184	123
	2019	6428	4821	771	514	193	129
	2020	6709	5032	805	537	201	134
	2021	6991	5243	839	559	210	140
	2022	7272	5454	873	582	218	145
	2023	7554	5665	906	604	227	151
	2024	7836	5877	940	627	235	157
	2025	8117	6088	974	649	244	162
	2026	8399	6299	1008	672	252	168
	2027	8680	6510	1042	694	260	174
	2028	8962	6721	1075	717	269	179
	2029	9244	6933	1109	739	277	185
	2030	9525	7144	1143	762	286	191
	2031	9807	7355	1177	785	294	196
	2032	10088	7566	1211	807	303	202

Annex 3 - Projected Number of Urban Private Hospitals

	Year	Urban Private Hospitals					
		Hospital (P)**	**31-50 Beds**	**50-100 Beds**	**101-200 Beds**	**201-300 Beds**	**> 300 Beds**
NHP	2010	33732	30696	2024	877	67	67
	2011	37314	33956	2239	970	75	75
	2012	44541	40532	2672	1158	89	89
	2013	39771	36192	2386	1034	80	80
Forecast	2016	50244	45722	3015	1306	100	100
	2017	52779	48029	3167	1372	106	106
	2018	55313	50335	3319	1438	111	111
	2019	57848	52641	3471	1504	116	116
	2020	60382	54948	3623	1570	121	121
	2021	62916	57254	3775	1636	126	126
	2022	65451	59560	3927	1702	131	131
	2023	67985	61866	4079	1768	136	136
	2024	70520	64173	4231	1834	141	141
	2025	73054	66479	4383	1899	146	146
	2026	75588	68785	4535	1965	151	151
	2027	78123	71092	4687	2031	156	156
	2028	80657	73398	4839	2097	161	161
	2029	83192	75704	4991	2163	166	166
	2030	85726	78011	5144	2229	171	171
	2031	88260	80317	5296	2295	177	177
	2032	90795	82623	5448	2361	182	182

Annex 4 - Minimum Number of Components & Operational Hours for Rural Hospitals.

Retrofitting component	**Number of component Units**	**Operational hours**	**No. of Days**
Tubular fluorescent lamps (TFL)	30	8	365
Refrigerator	2	24	365
Water pumps	1	8	365
Computer	2	8	365
Ceiling Fan	20	8	365
Water Geyser	1	4	365
Television	1	8	365

Annex 5 - Minimum Number of Components & Operational Hours for Urban Hospitals.

Retrofitting component	Beds	Number of component Units	Operational hours	No. of Days
Tubular fluorescent lamps (TFL)	31-50	30	20	365
	51-100	50	20	365
	101-200	70	20	365
	201-300	120	20	365
	301 >	120	20	365
Refrigerator	31-50	2	24	365
	51-100	4	24	365
	101-200	5	24	365
	201-300	5	24	365
	301 >	5	24	365
Air condition	31-50	1	12	250
	51-100	4	12	250
	101-200	10	12	250
	201-300	10	12	250
	301 >	10	12	365
Water pumps	31-50	1	6	365
	51-100	1	6	365
	101-200	2	6	365
	201-300	3	6	365
	301 >	4	6	365
Computer	31-50	2	10	365
	51-100	4	10	365
	101-200	5	10	365
	201-300	6	10	365
	301 >	7	10	365
Ceiling Fan	31-50	20	16	365
	51-100	30	16	365
	101-200	50	16	365
	201-300	70	16	365
	301 >	120	16	365
Water Geyser	31-50	1	24	365
	51-100	1	24	365
	101-200	2	24	365
	201-300	2	24	365
	301 >	3	24	365
Television	31-50	1	12	365
	51-100	1	12	365
	101-200	1	12	365
	201-300	2	12	365
	301 >	2	12	365

Annex 6 - Price and Lifespan of Equipment's.

Price & Life Span of Equipment's					
Retrofitting component	**Price(INR)**	**Price(USD)**	**Life Span in years (Rural hospitals)**	**Life Span in years (Urban hospitals)**	**Source**
TFL	500	7.45	7	3	Bijli Bachao
Refrigerator	19250	286.71	10	10	My smart price
Water pumps	5321	79.25	15	15	Pumpkart
Computer	40000	595.77	5	5	My smart price
Ceiling Fan	1940	28.89	10	10	Bijli Bachao
Water Geyser	8650	128.84	13	13	My smart price
Television	11500	171.28	10	10	Compare India
Air Conditioner	30000	446.83	10	10	Compare India

Annex 7.1. - Discounted Payback Analysis for Rural Hospitals.

Component		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Pay back (YEARS)**
TFL	Investment & Return	7.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6									
	Discounted Returns		5.2	4.9	4.5	4.2	3.9	3.6	3.4									
	Cumulative Amount		5.2	10.1	14.6	18.8	22.7	26.3	29.7									**1.5**
Refrigerator	Investment & Return	286.7	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4						
	Discounted Returns		306.4	285.0	265.1	246.6	229.4	213.4	198.5	184.7	171.8	159.8						
	Cumulative Amount		306.4	591.4	856.6	1103.2	1332.6	1546.0	1744.6	1929.3	2101.1	2260.9						**0.9**
Water pumps	Investment & Return	79.3	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	
	Discounted Returns		158.6	147.6	137.3	127.7	118.8	110.5	102.8	95.6	88.9	82.7	77.0	71.6	66.6	62.0	57.6	
	Cumulative Amount		158.6	306.2	476.7	647.3	817.8	988.3	1158.8	1329.4	1499.9	1670.4	1840.9	2011.5	2182.0	2352.5	2523.1	**0.5**
Computer	Investment & Return	595.7	23.4	23.4	23.4	23.4	23.4											
	Discounted Returns		21.7	20.2	18.8	17.5	16.3											**> life span**
	Cumulative Amount		21.7	41.9	60.7	78.2	94.5											
Ceiling Fan	Investment & Return	28.9	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7						
	Discounted Returns		4.3	4.0	3.8	3.5	3.3	3.0	2.8	2.6	2.4	2.3						
	Cumulative Amount		4.3	8.4	12.1	15.6	18.9	21.9	24.7	27.4	29.8	32.1						**8.6**
Water Geyser	Investment & Return	128.8	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7			
	Discounted Returns		43.5	40.4	37.6	35.0	32.5	30.3	28.2	26.2	24.4	22.7	21.1	19.6	18.2			
	Cumulative Amount		43.5	83.9	121.5	156.5	189.0	219.3	247.5	273.7	298.0	320.7	341.8	361.4	379.6			**3.2**
Television	Investment & Return	171.3	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	
	Discounted Returns		15.2	14.1	13.2	12.2	11.4	10.6	9.9	9.2	8.5	7.9	7.4	6.9	6.4	5.9	5.5	
	Cumulative Amount		15.2	29.4	42.5	54.8	66.2	76.8	86.6	95.8	104.3	112.2	119.6	126.5	132.9	138.8	144.3	**> life span**

Annex 7.2. - Net Present Value Analysis for Rural Hospitals.

Component		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV ($)
	Investment & Return	7.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6									
TFL	Discounted Returns		5.2	4.9	4.5	4.2	3.9	3.6	3.4									22.244866
	Cumulative Amount		5.2	10.1	14.6	18.8	22.7	26.3	29.7									
	Investment & Return	286.7	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4						
Refrigerator	Discounted Returns		306.4	285.0	265.1	246.6	229.4	213.4	198.5	184.7	171.8	159.8						1457.8634
	Cumulative Amount		306.4	591.4	856.6	1103.2	1332.6	1546.0	1744.6	1929.3	2101.1	2260.9						
	Investment & Return	79.3	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	
Water pumps	Discounted Returns		158.6	147.6	137.3	127.7	118.8	110.5	102.8	95.6	88.9	82.7	77.0	71.6	66.6	62.0	57.6	823.96883
	Cumulative Amount		158.6	306.2	476.7	647.3	817.8	988.3	1158.8	1329.4	1499.9	1670.4	1840.9	2011.5	2182.0	2352.5	2523.1	
	Investment & Return	595.7	23.4	23.4	23.4	23.4	23.4											
Computer	Discounted Returns		21.7	20.2	18.8	17.5	16.3											-501.18813
	Cumulative Amount		21.7	41.9	60.7	78.2	94.5											
	Investment & Return	28.9	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7						
Ceiling Fan	Discounted Returns		4.3	4.0	3.8	3.5	3.3	3.0	2.8	2.6	2.4	2.3						-4.1442786
	Cumulative Amount		4.3	8.4	12.1	15.6	18.9	21.9	24.7	27.4	29.8	32.1						
	Investment & Return	128.8	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7			
Water Geyser	Discounted Returns		43.5	40.4	37.6	35.0	32.5	30.3	28.2	26.2	24.4	22.7	21.1	19.6	18.2			118.61721
	Cumulative Amount		43.5	83.9	121.5	156.5	189.0	219.3	247.5	273.7	298.0	320.7	341.8	361.4	379.6			
	Investment & Return	171.3	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	
Television	Discounted Returns		15.2	14.1	13.2	12.2	11.4	10.6	9.9	9.2	8.5	7.9	7.4	6.9	6.4	5.9	5.5	-84.669975
	Cumulative Amount		15.2	29.4	42.5	54.8	66.2	76.8	86.6	95.8	104.3	112.2	119.6	126.5	132.9	138.8	144.3	

Annex 7.3. - Internal Rate of Returns Analysis for Rural Hospitals.

From	To	Investment	savings / year	Life Span	IRR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TFL TS	TFL ES	7.5	5.6	7.0	0.7	-7.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6								
Refrigerator TS	Refrigerator ES	286.7	329.4	10.0	1.1	-286.7	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4					
Air condition TS	Air condition ES	-	-	-																	
Water pumps TS	Water pumps ES	79.3	170.5	15.0	2.2	-79.3	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5
Computer TS	Computer ES	595.7	23.4	5.0	-0.4	-595.7	23.4	23.4	23.4	23.4	23.4										
Ceiling Fan TS	Ceiling Fan ES	28.9	4.7	10.0	0.1	-28.9	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7					
Water Geyser TS	Water Geyser ES	128.8	46.7	13.0	0.4	-128.8	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7		
Television TS	Television ES	171.3	16.4	10.0	0.0	-171.3	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4					

Annex 8.1. - Discounted Payback Analysis for Urban Hospitals.

Component		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Payback
	Investment & Return	7.5	14.0	14.0	14.0													**0.6**
	Discounted Returns		13.0	12.1	11.3													
TFL	Cumulative Amount		13.0	25.2	36.4													
	Investment & Return	286.7	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4						**0.9**
	Discounted Returns		306.4	285.0	265.1	246.6	229.4	213.4	198.5	184.7	171.8	159.8						
Refrigerator	Cumulative Amount		306.4	591.4	856.6	1103.2	1332.6	1546.0	1744.6	1929.3	2101.1	2260.9						
	Investment & Return	446.4	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5						**3.0**
	Discounted Returns		161.4	150.2	139.7	129.9	120.9	112.4	104.6	97.3	90.5	84.2						
Air condition	Cumulative Amount		161.4	311.6	451.2	581.2	702.0	814.5	919.1	1016.4	1106.9	1191.1						
	Investment & Return	79.3	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	**0.7**
	Discounted Returns		119.0	110.7	103.0	95.8	89.1	82.9	77.1	71.7	66.7	62.1	57.7	53.7	50.0	46.5	43.2	
Water pumps	Cumulative Amount		119.0	229.6	332.6	428.4	517.5	600.3	677.4	749.1	815.8	877.9	935.6	989.3	1039.3	1085.7	1129.0	
	Investment & Return	595.7	29.2	29.2	29.2	29.2	29.2											
	Discounted Returns		27.2	25.3	23.5	21.9	20.3											
Computer	Cumulative Amount		27.2	52.4	75.9	97.8	118.1											
	Investment & Return	28.9	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3						**3.7**
	Discounted Returns		8.7	8.1	7.5	7.0	6.5	6.1	5.6	5.2	4.9	4.5						
Ceiling Fan	Cumulative Amount		8.7	16.8	24.3	31.3	37.8	43.9	49.5	54.7	59.6	64.1						
	Investment & Return	128.8	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3			**0.5**
	Discounted Returns		260.8	242.6	225.6	209.9	195.3	181.6	169.0	157.2	146.2	136.0	126.5	117.7	109.5			
Water Geyser	Cumulative Amount		260.8	503.3	729.0	938.9	1134.1	1315.8	1484.7	1641.9	1788.1	1924.1	2050.7	2168.4	2277.8			
	Investment & Return	171.3	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5						
	Discounted Returns		22.8	21.2	19.7	18.4	17.1	15.9	14.8	13.8	12.8	11.9						
Television	Cumulative Amount		22.8	44.0	63.8	82.2	99.2	115.1	129.9	143.7	156.5	168.4						

Annex 8.2. - Net Present Value Analysis for Urban Hospitals.

Component		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV
	Investment & Return	7.5	14.0	14.0	14.0													
	Discounted Returns		13.0	12.1	11.3													29
TFL	Cumulative Amount		13.0	25.2	36.4													
	Investment & Return	286.7	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4	329.4						
	Discounted Returns		306.4	285.0	265.1	246.6	229.4	213.4	198.5	184.7	171.8	159.8						1974
Refrigerator	Cumulative Amount		306.4	591.4	856.6	1103.2	1332.6	1546.0	1744.6	1929.3	2101.1	2260.9						
	Investment & Return	446.4	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5						
	Discounted Returns		161.4	150.2	139.7	129.9	120.9	112.4	104.6	97.3	90.5	84.2						745
Air condition	Cumulative Amount		161.4	311.6	451.2	581.2	702.0	814.5	919.1	1016.4	1106.9	1191.1						
	Investment & Return	79.3	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	127.9	
	Discounted Returns		119.0	110.7	103.0	95.8	89.1	82.9	77.1	71.7	66.7	62.1	57.7	53.7	50.0	46.5	43.2	1050
Water pumps	Cumulative Amount		119.0	229.6	332.6	428.4	517.5	600.3	677.4	749.1	815.8	877.9	935.6	989.3	1039.3	1085.7	1129.0	
	Investment & Return	595.7	29.2	29.2	29.2	29.2	29.2											
	Discounted Returns		27.2	25.3	23.5	21.9	20.3											-478
Computer	Cumulative Amount		27.2	52.4	75.9	97.8	118.1											
	Investment & Return	28.9	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3						
	Discounted Returns		8.7	8.1	7.5	7.0	6.5	6.1	5.6	5.2	4.9	4.5						35
Ceiling Fan	Cumulative Amount		8.7	16.8	24.3	31.3	37.8	43.9	49.5	54.7	59.6	64.1						
	Investment & Return	128.8	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3	280.3			
	Discounted Returns		260.8	242.6	225.6	209.9	195.3	181.6	169.0	157.2	146.2	136.0	126.5	117.7	109.5			2149
Water Geyser	Cumulative Amount		260.8	503.3	729.0	938.9	1134.1	1315.8	1484.7	1641.9	1788.1	1924.1	2050.7	2168.4	2277.8			
	Investment & Return	171.3	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5						
	Discounted Returns		22.8	21.2	19.7	18.4	17.1	15.9	14.8	13.8	12.8	11.9						-3
Television	Cumulative Amount		22.8	44.0	63.8	82.2	99.2	115.1	129.9	143.7	156.5	168.4						

Annex 8.3. - Internal Rate of Returns for Urban Hospitals.

From	To	Investment	savings / year	Life Span	IRR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TFL TS	TFL ES	7.45	14.02	3.00	180%	-7.45	14.02	14.02	14.02												
Refrigerator TS	Refrigerator ES	286.71	329.38	10.00	115%	-286.71	329.38	329.38	329.38	329.38	329.38	329.38	329.38	329.38	329.38	329.38					
Air condition TS	Air condition ES	446.38	173.52	10.00	37%	-446.38	173.52	173.52	173.52	173.52	173.52	173.52	173.52	173.52	173.52	173.52					
Water pumps TS	Water pumps ES	79.25	127.90	15.00	161%	-79.25	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90	127.90
Computer TS	Computer ES	595.70	29.20	5.00	-34%	-595.70	29.20	29.20	29.20	29.20	29.20										
Ceiling Fan TS	Ceiling Fan ES	28.89	9.34	10.00	30%	-28.89	9.34	9.34	9.34	9.34	9.34	9.34	9.34	9.34	9.34	9.34					
Water Geyser TS	Water Geyser ES	128.84	280.32	13.00	218%	-128.84	280.32	280.32	280.32	280.32	280.32	280.32	280.32	280.32	280.32	280.32	280.32	280.32	280.32		
Television TS	Television ES	171.28	24.53	10.00	7%	-171.28	24.53	24.53	24.53	24.53	24.53	24.53	24.53	24.53	24.53	24.53					

Annex 9 - Energy Analysis of Rural Hospitals, 2010.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous (computer,ceiling,hot water geyser)	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Rural		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Y Traditional	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
				Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	6795	2718	60	60	30	8	365	50,00	50,00	0,00
E02	Refrigration	Refrigirator	Yes	6795	2718	800	800	2	24	365	133,33	133,33	0,00
E03	HVAC	Air condition	Yes	6795	2718	2400	2400	0	8	365	0,00	0,00	0,00
E04	Water pumping	Water pumps	Yes	6795	2718	1460	1460	1	8	365	40,56	40,56	0,00
E05	Miscellanous	Computer	Yes	6795	2718	250	250	2	8	365	13,89	13,89	0,00
		Ceiling Fan	Yes	6795	2718	75	75	20	8	365	41,67	41,67	0,00
		Water Geyser	Yes	6795	2718	2400	2400	1	4	365	33,33	33,33	0,00
		Television	Yes	6795	2718	150	150	1	8	365	4,17	4,17	0,00

Annex 10 - Energy Analysis of Rural Hospitals, 2013.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous (comp	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Rural		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Year	Potential Energy Saving (GWh)
				Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	15398	6159	60	60	30	8	365	113,30	113,30	0,00
E02	Refrigration	Refrigirator	Yes	15398	6159	800	800	2	24	365	302,15	302,15	0,00
E03	HVAC	Air condition	Yes	15398	6159	2400	2400		8	365	0,00	0,00	0,00
E04	Water pumping	Water pumps	Yes	15398	6159	1460	1460	1	8	365	91,90	91,90	0,00
E05	Miscellanous	Computer	Yes	15398	6159	250	250	2	8	365	31,47	31,47	0,00
		Ceiling Fan	Yes	15398	6159	75	75	20	8	365	94,42	94,42	0,00
		Water Geyser	Yes	15398	6159	2400	2400	1	4	365	75,54	75,54	0,00
		Television	Yes	15398	6159	150	150	1	8	365	9,44	9,44	0,00

Annex 11 - Energy Analysis of Rural Hospitals, 2016.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigeration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous (computer,ceiling,hot	3

Code	Component	Technology	Energy label scheme (Govt.of India)	Rural		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Year	Potential Energy Saving (GWh)
				Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	21241	8496	60	36	30	8	365	156,30	93,78	62,52
E02	Refrigration	Refrigerator	Yes	21241	8496	800	330	2	24	365	416,80	171,93	244,87
E03	HVAC	Air condition	Yes	21241	8496	2400	1677	0	8	365	0,00	0,00	0,00
E04	Water pumping	Water pumps	Yes	21241	8496	1460	730	1	8	365	126,78	63,39	63,39
E05	Miscellanous	Computer	Yes	21241	8496	250	150	2	8	365	43,42	26,05	17,37
		Ceiling Fan	Yes	21241	8496	75	55	20	8	365	130,25	95,52	34,73
		Water Geyser	Yes	21241	8496	2400	2000	1	4	365	104,20	86,83	17,37
		Television	Yes	21241	8496	150	80	1	8	365	13,02	6,95	6,08

Annex 12 - Energy Analysis of Rural Hospitals, 2020.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous (computer,ceiling,hot water geyser)	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Rural		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Year	Potential Energy Saving (GWh)
				Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	29847	11939	60	36	30	8	365	219,63	131,78	87,85
E02	Refrigration	Refrigerator	Yes	29847	11939	800	330	2	24	365	585,68	241,59	344,09
E03	HVAC	Air condition	Yes	29847	11939	2400	1677	0	8	365	0,00	0,00	0,00
E04	Water pumping	Water pumps	Yes	29847	11939	1460	730	1	8	365	178,14	89,07	89,07
E05	Miscellanous	Computer	Yes	29847	11939	250	150	2	8	365	61,01	36,60	24,40
		Ceiling Fan	Yes	29847	11939	75	55	20	8	365	183,02	134,22	48,81
		Water Geyser	Yes	29847	11939	2400	2000	1	4	365	146,42	122,02	24,40
		Television	Yes	29847	11939	150	80	1	8	365	18,30	9,76	8,54

Annex 13 - Energy Analysis of Rural Hospitals, 2024.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous (computer,ceiling,hot water geyser)	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Rural Govt	Rural Private	Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	38454	15382	60	36	30	8	365	282,96	169,78	113,18
E02	Refrigration	Refrigerator	Yes	38454	15382	800	330	2	24	365	754,56	311,26	443,30
E03	HVAC	Air condition	Yes	38454	15382	2400	1677	0	8	365	0,00	0,00	0,00
E04	Water pumping	Water pumps	Yes	38454	15382	1460	730	1	8	365	229,51	114,76	114,76
E05	Miscellanous	Computer	Yes	38454	15382	250	150	2	8	365	78,60	47,16	31,44
		Ceiling Fan	Yes	38454	15382	75	55	20	8	365	235,80	172,92	62,88
		Water Geyser	Yes	38454	15382	2400	2000	1	4	365	188,64	157,20	31,44
		Television	Yes	38454	15382	150	80	1	8	365	23,58	12,58	11,00

Annex 14 - Energy Analysis of Rural Hospitals, 2028.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous (computer,ceiling,hot	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Rural Govt	Rural Private	Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	47061	18824	60	36	30	8	365	346,29	207,77	138,52
E02	Refrigration	Refrigerator	Yes	47061	18824	800	330	2	24	365	923,44	380,92	542,52
E03	HVAC	Air condition	Yes	47061	18824	2400	1677	0	8	365	0,00	0,00	0,00
E04	Water pumping	Water pumps	Yes	47061	18824	1460	730	1	8	365	280,88	140,44	140,44
E05	Miscellanous	Computer	Yes	47061	18824	250	150	2	8	365	96,19	57,72	38,48
		Ceiling Fan	Yes	47061	18824	75	55	20	8	365	288,58	211,62	76,95
		Water Geyser	Yes	47061	18824	2400	2000	1	4	365	230,86	192,38	38,48
		Television	Yes	47061	18824	150	80	1	8	365	28,86	15,39	13,47

Annex 15 - Energy Analysis of Rural Hospitals, 2032.

Hospital sector		
Code	**Technology labels**	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Rural		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
				Govt	Private								
E01	Lighting	Tubular fluorescent lamps	Yes	55667	22267	60	36	30	8	365	410	246	164
E02	Refrigration	Refrigerator	Yes	55667	22267	800	330	2	24	365	1092	451	642
E03	HVAC	Air condition	Yes	55667	22267	2400	1677	0	8	365	0	0	0
E04	Water pumping	Water pumps	Yes	55667	22267	1460	730	1	8	365	332	166	166
E05	Miscellanous	Computer	Yes	55667	22267	250	150	2	8	365	114	68	46
		Ceiling Fan	Yes	55667	22267	75	55	20	8	365	341	250	91
		Water Geyser	Yes	55667	22267	2400	2000	1	4	365	273	228	46
		Television	Yes	55667	22267	150	80	1	8	365	34	18	16

Annex 16 - Energy Analysis of Urban Hospitals, 2010.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Beds	Location of Hospital		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ YTrdational	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
					Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	31-50	2811	30696	60	60	30	20	365	440,28	440,28	0,00
				51-100	450	2024	60	60	50	20	365	54,17	54,17	0,00
				101-200	300	877	60	60	70	20	365	36,08	36,08	0,00
				201-300	112	67	60	60	120	20	365	9,46	9,46	0,00
				Above 300	75	67	60	60	120	20	365	7,49	7,49	0,00
												547,48	547,48	0,00
E02	Refrigration	Refrigerator	Yes	31-50	2811	30696	800	800	2	24	365	469,64	469,64	0,00
				51-100	450	2024	800	800	4	24	365	69,34	69,34	0,00
				101-200	300	877	800	800	5	24	365	41,24	41,24	0,00
				201-300	112	67	800	800	5	24	365	6,30	6,30	0,00
				Above 300	75	67	800	800	5	24	365	4,99	4,99	0,00
												591,51	591,51	0,00
E03	HVAC	Air condition	Yes	31-50	2811	30696	2400	2400	1	12	250	241,25	241,25	0,00
				51-100	450	2024	2400	2400	4	12	250	71,24	71,24	0,00
				101-200	300	877	2400	2400	10	12	250	84,73	84,73	0,00
				201-300	112	67	2400	2400	10	12	250	12,95	12,95	0,00
				Above 300	75	67	2400	2400	10	12	365	14,97	14,97	0,00
												425,15	425,15	
E04	Water pumping	Water pumps	Yes	31-50	2811	30696	1460	1460	1	6	365	107,14	107,14	0,00
				51-100	450	2024	1460	1460	1	6	365	7,91	7,91	0,00
				101-200	300	877	1460	1460	2	6	365	7,53	7,53	0,00
				201-300	112	67	1460	1460	3	6	365	1,73	1,73	0,00
				Above 300	75	67	1460	1460	4	6	365	1,82	1,82	0,00
												126,12	126,12	0,00
E05	Miscellanous	Computer	Yes	31-50	2811	30696	250	250	2	10	365	61,15	61,15	0,00
				51-100	450	2024	250	250	4	10	365	9,03	9,03	0,00
				101-200	300	877	250	250	5	10	365	5,37	5,37	0,00
				201-300	112	67	250	250	6	10	365	0,98	0,98	0,00
				Above 300	75	67	250	250	7	10	365	0,91	0,91	0,00
												77,44	77,44	0,00
		Ceiling Fan	Yes	31-50	2811	30696	75	75	20	16	365	293,52	293,52	0,00
				51-100	450	2024	75	75	30	16	365	32,50	32,50	0,00
				101-200	300	877	75	75	50	16	365	25,77	25,77	0,00
				201-300	112	67	75	75	70	16	365	5,52	5,52	0,00
				Above 300	75	67	75	75	120	16	365	7,49	7,49	0,00
												364,80	364,80	
		Water Geyser	Yes	31-50	2811	30696	2400	2400	1	24	365	704,45	704,45	0,00
				51-100	450	2024	2400	2400	1	24	365	52,01	52,01	0,00
				101-200	300	877	2400	2400	2	24	365	49,49	49,49	0,00
				201-300	112	67	2400	2400	2	24	365	7,56	7,56	0,00
				Above 300	75	67	2400	2400	3	24	365	8,98	8,98	0,00
												822,49	822,49	0
		Television	Yes	31-50	2811	30696	150	150	1	12	365	22,01	22,01	0,00
				51-100	450	2024	150	150	1	12	365	1,63	1,63	0,00
				101-200	300	877	150	150	1	12	365	0,77	0,77	0,00
				201-300	112	67	150	150	2	12	365	0,24	0,24	0,00
				Above 300	75	67	150	150	2	12	365	0,19	0,19	0,00
					3748	33732						24,84	24,84	0

Annex 17 - Energy analysis of urban hospitals, 2013.

Hospital sector		
Code	Technology labels	
B01	Lighting	1
B02	Refrigration	1
B04	HVAC	1
B05	Water pumping	1
B06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Beds	Location of Hospital		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
					Govt	Private								
B01	Lighting	Tubular fluorescent lamps (TFL)	Yes	31-50	3314	36192	60	60	30	20	365	519,11	519,11	0,00
				51-100	530	2386	60	60	50	20	365	63,87	63,87	0,00
				101-200	354	1034	60	60	70	20	365	42,54	42,54	0,00
				201-300	133	80	60	60	120	20	365	11,15	11,15	0,00
				Above 300	88	80	60	60	120	20	365	8,83	8,83	0,00
												645,50	645,50	0,00
B02	Refrigration	Refrigerator	Yes	31-50	3314	36192	800	800	2	24	365	553,71	553,71	0,00
				51-100	530	2386	800	800	4	24	365	81,76	81,76	0,00
				101-200	354	1034	800	800	5	24	365	48,62	48,62	0,00
				201-300	133	80	800	800	5	24	365	7,43	7,43	0,00
				Above 300	88	80	800	800	5	24	365	5,88	5,88	0,00
												697,41	697,41	0,00
B03	HVAC	Air condition	Yes	31-50	3314	36192	2400	2400	1	12	250	284,44	284,44	0,00
				51-100	530	2386	2400	2400	4	12	250	84,00	84,00	0,00
				101-200	354	1034	2400	2400	10	12	250	99,90	99,90	0,00
				201-300	133	80	2400	2400	10	12	250	15,27	15,27	0,00
				Above 300	88	80	2400	2400	10	12	365	17,65	17,65	0,00
												501,27	501,27	0,00
B04	Water pumping	Water pumps	Yes	31-50	3314	36192	1460	1460	1	6	365	126,32	126,32	0,00
				51-100	530	2386	1460	1460	1	6	365	9,33	9,33	0,00
				101-200	354	1034	1460	1460	2	6	365	8,87	8,87	0,00
				201-300	133	80	1460	1460	3	6	365	2,03	2,03	0,00
				Above 300	88	80	1460	1460	4	6	365	2,15	2,15	0,00
												148,70	148,70	0,00
B05	Miscellanous	Computer	Yes	31-50	3314	36192	250	250	2	10	365	72,10	72,10	0,00
				51-100	530	2386	250	250	4	10	365	10,65	10,65	0,00
				101-200	354	1034	250	250	5	10	365	6,33	6,33	0,00
				201-300	133	80	250	250	6	10	365	1,16	1,16	0,00
				Above 300	88	80	250	250	7	10	365	1,07	1,07	0,00
												91,31	91,31	0,00
		Ceiling Fan	Yes	31-50	3314	36192	75	75	20	16	365	346,07	346,07	0,00
				51-100	530	2386	75	75	30	16	365	38,32	38,32	0,00
				101-200	354	1034	75	75	50	16	365	30,39	30,39	0,00
				201-300	133	80	75	75	70	16	365	6,50	6,50	0,00
				Above 300	88	80	75	75	120	16	365	8,83	8,83	0,00
												430,11	430,11	0,00
		Water Geyser	Yes	31-50	3314	36192	2400	2400	1	24	365	830,57	830,57	0,00
				51-100	530	2386	2400	2400	1	24	365	61,32	61,32	0,00
				101-200	354	1034	2400	2400	2	24	365	58,34	58,34	0,00
				201-300	133	80	2400	2400	2	24	365	8,92	8,92	0,00
				Above 300	88	80	2400	2400	3	24	365	10,59	10,59	0,00
												969,74	969,74	0,00
		Television	Yes	31-50	3314	36192	150	150	1	12	365	25,96	25,96	0,00
				51-100	530	2386	150	150	1	12	365	1,92	1,92	0,00
				101-200	354	1034	150	150	1	12	365	0,91	0,91	0,00
				201-300	133	80	150	150	2	12	365	0,28	0,28	0,00
				Above 300	88	80	150	150	2	12	365	0,22	0,22	0,00
					4419	39771						29,28	29,28	0,00

Annex 18 - Energy Analysis of Urban Hospitals, 2016.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Beds	Number of Hospital		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Year	Potential Energy Saving (GWh)
					Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	31-50	4187	45722	60	36	30	20	365	655,81	393,49	262
				51-100	670	3015	60	36	50	20	365	80,69	48,42	32
				101-200	447	1306	60	36	70	20	365	53,75	32,25	21
				201-300	167	100	60	36	120	20	365	14,08	8,45	6
				Above 300	112	100	60	36	120	20	365	11,15	6,69	4
												815,48	489,29	326
E02	Refrigration	Refrigerator	Yes	31-50	4187	45722	800	330	2	24	365	699,53	288,56	411
				51-100	670	3015	800	330	4	24	365	103,29	42,61	61
				101-200	447	1306	800	330	5	24	365	61,42	25,34	36
				201-300	167	100	800	330	5	24	365	9,39	3,87	6
				Above 300	112	100	800	330	5	24	365	7,43	3,07	4
												881,06	363,44	518
E03	HVAC	Air condition	Yes	31-50	4187	45722	2400	1677	1	12	250	359,35	251,09	108
				51-100	670	3015	2400	1677	4	12	250	106,12	74,15	32
				101-200	447	1306	2400	1677	10	12	250	126,21	88,19	38
				201-300	167	100	2400	1677	10	12	250	19,29	13,48	6
				Above 300	112	100	2400	1677	10	12	365	22,30	15,58	7
												633,27	442,50	191
E04	Water pumping	Water pumps	Yes	31-50	4187	45722	1460	730	1	6	365	159,58	79,79	80
				51-100	670	3015	1460	730	1	6	365	11,78	5,89	6
				101-200	447	1306	1460	730	2	6	365	11,21	5,60	6
				201-300	167	100	1460	730	3	6	365	2,57	1,29	1
				Above 300	112	100	1460	730	4	6	365	2,71	1,36	1
												187,85	93,93	94
E05	Miscellanous	Computer	Yes	31-50	4187	45722	250	150	2	10	365	91,08	54,65	36
				51-100	670	3015	250	150	4	10	365	13,45	8,07	5
				101-200	447	1306	250	150	5	10	365	8,00	4,80	3
				201-300	167	100	250	150	6	10	365	1,47	0,88	1
				Above 300	112	100	250	150	7	10	365	1,36	0,81	1
												115,35	69,21	46
		Ceiling Fan	Yes	31-50	4187	45722	75	55	20	16	365	437,21	320,62	117
				51-100	670	3015	75	55	30	16	365	48,42	35,50	13
				101-200	447	1306	75	55	50	16	365	38,39	28,15	10
				201-300	167	100	75	55	70	16	365	8,22	6,03	2
				Above 300	112	100	75	55	120	16	365	11,15	8,18	3
												543,38	398,48	145
		Water Geyser	Yes	31-50	4187	45722	2400	2000	1	24	365	1049,29	874,41	175
				51-100	670	3015	2400	2000	1	24	365	77,46	64,55	13
				101-200	447	1306	2400	2000	2	24	365	73,71	61,42	12
				201-300	167	100	2400	2000	2	24	365	11,27	9,39	2
				Above 300	112	100	2400	2000	3	24	365	13,38	11,15	2
												1225,12	1020,93	204
		Television	Yes	31-50	4187	45722	150	80	1	12	365	32,79	17,49	15
				51-100	670	3015	150	80	1	12	365	2,42	1,29	1
				101-200	447	1306	150	80	1	12	365	1,15	0,61	1
				201-300	167	100	150	80	2	12	365	0,35	0,19	0
				Above 300	112	100	150	80	2	12	365	0,28	0,15	0
					5583	50244						36,99	19,73	17

Annex 19 - Energy Analysis of Urban Hospitals, 2020.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Beds	Location of Hospital		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Year	Potential Energy Saving (GWh)
					Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	31-50	5032	54948	60	36	30	20	365	788	473	315
				51-100	805	3623	60	36	50	20	365	97	58	39
				101-200	537	1570	60	36	70	20	365	65	39	26
				201-300	201	121	60	36	120	20	365	17	10	7
				301-500+	134	121	60	36	120	20	365	13	8	5
												980	588	392
E02	Refrigration	Refrigerator	Yes	31-50	5032	54948	800	330	2	24	365	841	347	494
				51-100	805	3623	800	330	4	24	365	124	51	73
				101-200	537	1570	800	330	5	24	365	74	30	43
				201-300	201	121	800	330	5	24	365	11	5	7
				301-500+	134	121	800	330	5	24	365	9	4	5
												1059	437	622
E03	HVAC	Air condition	Yes	31-50	5032	54948	2400	1677	1	12	250	432	302	130
				51-100	805	3623	2400	1677	4	12	250	128	89	38
				101-200	537	1570	2400	1677	10	12	250	152	106	46
				201-300	201	121	2400	1677	10	12	250	23	16	7
				301-500+	134	121	2400	1677	10	12	365	27	19	8
												761	532	229
E04	Water pumping	Water pumps	Yes	31-50	5032	54948	1460	730	1	6	365	192	96	96
				51-100	805	3623	1460	730	1	6	365	14	7	7
				101-200	537	1570	1460	730	2	6	365	13	7	7
				201-300	201	121	1460	730	3	6	365	3	2	2
				301-500+	134	121	1460	730	4	6	365	3	2	2
												226	113	113
E05	Miscellanous	Computer	Yes	31-50	5032	54948	250	150	2	10	365	109	66	44
				51-100	805	3623	250	150	4	10	365	16	10	6
				101-200	537	1570	250	150	5	10	365	10	6	4
				201-300	201	121	250	150	6	10	365	2	1	1
				301-500+	134	121	250	150	7	10	365	2	1	1
												139	83	55
		Ceiling Fan	Yes	31-50	5032	54948	75	55	20	16	365	525	385	140
				51-100	805	3623	75	55	30	16	365	58	43	16
				101-200	537	1570	75	55	50	16	365	46	34	12
				201-300	201	121	75	55	70	16	365	10	7	3
				301-500+	134	121	75	55	120	16	365	13	10	4
												653	479	174
		Water Geyser	Yes	31-50	5032	54948	2400	2000	1	24	365	1261	1051	210
				51-100	805	3623	2400	2000	1	24	365	93	78	16
				101-200	537	1570	2400	2000	2	24	365	89	74	15
				201-300	201	121	2400	2000	2	24	365	14	11	2
				301-500+	134	121	2400	2000	3	24	365	16	13	3
												1472	1227	245
		Television	Yes	31-50	5032	54948	150	80	1	12	365	39	21	18
				51-100	805	3623	150	80	1	12	365	3	2	1
				101-200	537	1570	150	80	1	12	365	1	1	1
				201-300	201	121	150	80	2	12	365	0	0	0
				301-500+	134	121	150	80	2	12	365	0	0	0
					6709	60382						44	24	21

Annex 20 - Energy Analysis of Urban Hospitals, 2024.

Hospital sector		
Code	**Technology labels**	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Beds	Location of Hospital		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
					Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	31-50	5877	64173	60	36	30	20	365	920	552	368,18
				51-100	940	4231	60	36	50	20	365	113	68	45,30
				101-200	627	1834	60	36	70	20	365	75	45	30,17
				201-300	235	141	60	36	120	20	365	20	12	7,91
				Above 300	157	141	60	36	120	20	365	16	9	6,26
												1145	687	457,82
E02	Refrigration	Refrigerator	Yes	31-50	5877	64173	800	330	2	24	365	982	405	576,81
				51-100	940	4231	800	330	4	24	365	145	60	85,17
				101-200	627	1834	800	330	5	24	365	86	36	50,65
				201-300	235	141	800	330	5	24	365	13	5	7,74
				Above 300	157	141	800	330	5	24	365	10	4	6,13
												1237	510	726,50
E03	HVAC	Air condition	Yes	31-50	5877	64173	2400	1677	1	12	250	504	352	151,94
				51-100	940	4231	2400	1677	4	12	250	149	104	44,87
				101-200	627	1834	2400	1677	10	12	250	177	124	53,36
				201-300	235	141	2400	1677	10	12	250	27	19	8,16
				Above 300	157	141	2400	1677	10	12	365	31	22	9,43
												889	621	267,76
E04	Water pumping	Water pumps	Yes	31-50	5877	64173	1460	730	1	6	365	224	112	111,99
				51-100	940	4231	1460	730	1	6	365	17	8	8,27
				101-200	627	1834	1460	730	2	6	365	16	8	7,87
				201-300	235	141	1460	730	3	6	365	4	2	1,80
				Above 300	157	141	1460	730	4	6	365	4	2	1,90
												264	132	131,83
E05	Miscellanous	Computer	Yes	31-50	5877	64173	250	150	2	10	365	128	77	51,14
				51-100	940	4231	250	150	4	10	365	19	11	7,55
				101-200	627	1834	250	150	5	10	365	11	7	4,49
				201-300	235	141	250	150	6	10	365	2	1	0,82
				Above 300	157	141	250	150	7	10	365	2	1	0,76
												162	97	64,76
		Ceiling Fan	Yes	31-50	5877	64173	75	55	20	16	365	614	450	163,64
				51-100	940	4231	75	55	30	16	365	68	50	18,12
				101-200	627	1834	75	55	50	16	365	54	40	14,37
				201-300	235	141	75	55	70	16	365	12	8	3,08
				Above 300	157	141	75	55	120	16	365	16	11	4,17
												763	559	203,37
		Water Geyser	Yes	31-50	5877	64173	2400	2000	1	24	365	1473	1227	245,45
				51-100	940	4231	2400	2000	1	24	365	109	91	18,12
				101-200	627	1834	2400	2000	2	24	365	103	86	17,24
				201-300	235	141	2400	2000	2	24	365	16	13	2,64
				Above 300	157	141	2400	2000	3	24	365	19	16	3,13
												1719	1433	286,58
		Television	Yes	31-50	5877	64173	150	80	1	12	365	46	25	21,48
				51-100	940	4231	150	80	1	12	365	3	2	1,59
				101-200	627	1834	150	80	1	12	365	2	1	0,75
				201-300	235	141	150	80	2	12	365	0	0	0,23
				Above 300	157	141	150	80	2	12	365	0	0	0,18
					7836	70520						52	28	24,23

Annex 21 - Energy Analysis of Urban Hospitals, 2028.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Beds	Location of Hospital		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Year	Potential Energy Saving (GWh)
					Govt	Private								0
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	31-50	6721	73398	60	36	30	20	365	1053	632	421
				51-100	1075	4839	60	36	50	20	365	130	78	52
				101-200	717	2097	60	36	70	20	365	86	52	35
				201-300	269	161	60	36	120	20	365	23	14	9
				301-500+	179	161	60	36	120	20	365	18	11	7
												1309	785	524
E02	Refrigration	Refrigerator	Yes	31-50	6721	73398	800	330	2	24	365	1123	463	660
				51-100	1075	4839	800	330	4	24	365	166	68	97
				101-200	717	2097	800	330	5	24	365	99	41	58
				201-300	269	161	800	330	5	24	365	15	6	9
				301-500+	179	161	800	330	5	24	365	12	5	7
												1414	583	831
E03	HVAC	Air condition	Yes	31-50	6721	73398	2400	1677	1	12	250	577	403	174
				51-100	1075	4839	2400	1677	4	12	250	170	119	51
				101-200	717	2097	2400	1677	10	12	250	203	142	61
				201-300	269	161	2400	1677	10	12	250	31	22	9
				301-500+	179	161	2400	1677	10	12	365	36	25	11
												1017	710	306
E04	Water pumping	Water pumps	Yes	31-50	6721	73398	1460	730	1	6	365	256	128	128
				51-100	1075	4839	1460	730	1	6	365	19	9	9
				101-200	717	2097	1460	730	2	6	365	18	9	9
				201-300	269	161	1460	730	3	6	365	4	2	2
				301-500+	179	161	1460	730	4	6	365	4	2	2
												302	151	151
E05	Miscellanous	Computer	Yes	31-50	6721	73398	250	150	2	10	365	146	88	58
				51-100	1075	4839	250	150	4	10	365	22	13	9
				101-200	717	2097	250	150	5	10	365	13	8	5
				201-300	269	161	250	150	6	10	365	2	1	1
				301-500+	179	161	250	150	7	10	365	2	1	1
												185	111	74
		Ceiling Fan	Yes	31-50	6721	73398	75	55	20	16	365	702	515	187
				51-100	1075	4839	75	55	30	16	365	78	57	21
				101-200	717	2097	75	55	50	16	365	62	45	16
				201-300	269	161	75	55	70	16	365	13	10	4
				301-500+	179	161	75	55	120	16	365	18	13	5
												872	640	233
		Water Geyser	Yes	31-50	6721	73398	2400	2000	1	24	365	1684	1404	281
				51-100	1075	4839	2400	2000	1	24	365	124	104	21
				101-200	717	2097	2400	2000	2	24	365	118	99	20
				201-300	269	161	2400	2000	2	24	365	18	15	3
				301-500+	179	161	2400	2000	3	24	365	21	18	4
												1967	1639	328
		Television	Yes	31-50	6721	73398	150	80	1	12	365	53	28	25
				51-100	1075	4839	150	80	1	12	365	4	2	2
				101-200	717	2097	150	80	1	12	365	2	1	1
				201-300	269	161	150	80	2	12	365	1	0	0
				301-500+	179	161	150	80	2	12	365	0	0	0
					8962	80657						59	32	28

Annex 22 - Energy Analysis of Urban Hospitals, 2032.

Hospital sector		
Code	Technology labels	
E01	Lighting	1
E02	Refrigration	1
E04	HVAC	1
E05	Water pumping	1
E06	Miscellanous	4

Code	Component	Technology	Energy label scheme (Govt.of India)	Beds	Location of Hospital		Traditional (Watts)	Replacement with Energy efficient (EE) watts	Number of component Unit	Operation hours	No. of Days	Total Consumption GWh/ Year Traditional	Total Consumption in EE GWh/Y	Potential Energy Saving (GWh)
					Govt	Private								
E01	Lighting	Tubular fluorescent lamps (TFL)	Yes	31-50	7566	82623	60	36	30	20	365	1185	711	474
				51-100	1211	5448	60	36	50	20	365	146	87	58
				101-200	807	2361	60	36	70	20	365	97	58	39
				201-300	303	182	60	36	120	20	365	25	15	10
				301-500+	202	182	60	36	120	20	365	20	12	8
												1474	884	589
E02	Refrigration	Refrigerator	Yes	31-50	7566	82623	800	330	2	24	365	1264	521	743
				51-100	1211	5448	800	330	4	24	365	187	77	110
				101-200	807	2361	800	330	5	24	365	111	46	65
				201-300	303	182	800	330	5	24	365	17	7	10
				301-500+	202	182	800	330	5	24	365	13	6	8
												1592	657	935
E03	HVAC	Air condition	Yes	31-50	7566	82623	2400	1677	1	12	250	649	454	196
				51-100	1211	5448	2400	1677	4	12	250	192	134	58
				101-200	807	2361	2400	1677	10	12	250	228	159	69
				201-300	303	182	2400	1677	10	12	250	35	24	11
				301-500+	202	182	2400	1677	10	12	365	40	28	12
												1144	800	345
E04	Water pumping	Water pumps	Yes	31-50	7566	82623	1460	730	1	6	365	288	144	144
				51-100	1211	5448	1460	730	1	6	365	21	11	11
				101-200	807	2361	1460	730	2	6	365	20	10	10
				201-300	303	182	1460	730	3	6	365	5	2	2
				301-500+	202	182	1460	730	4	6	365	5	2	2
												339	170	170
E05	Miscellanous	Computer	Yes	31-50	7566	82623	250	150	2	10	365	165	99	66
				51-100	1211	5448	250	150	4	10	365	24	15	10
				101-200	807	2361	250	150	5	10	365	14	9	6
				201-300	303	182	250	150	6	10	365	3	2	1
				301-500+	202	182	250	150	7	10	365	2	1	1
												208	125	83
		Ceiling Fan	Yes	31-50	7566	82623	75	55	20	16	365	790	579	211
				51-100	1211	5448	75	55	30	16	365	87	64	23
				101-200	807	2361	75	55	50	16	365	69	51	18
				201-300	303	182	75	55	70	16	365	15	11	4
				301-500+	202	182	75	55	120	16	365	20	15	5
												982	720	262
		Water Geyser	Yes	31-50	7566	82623	2400	2000	1	24	365	1896	1580	316
				51-100	1211	5448	2400	2000	1	24	365	140	117	23
				101-200	807	2361	2400	2000	2	24	365	133	111	22
				201-300	303	182	2400	2000	2	24	365	20	17	3
				301-500+	202	182	2400	2000	3	24	365	24	20	4
												2214	1845	369
		Television	Yes	31-50	7566	82623	150	80	1	12	365	59	32	28
				51-100	1211	5448	150	80	1	12	365	4	2	2
				101-200	807	2361	150	80	1	12	365	2	1	1
				201-300	303	182	150	80	2	12	365	1	0,34	0
				301-500+	202	182	150	80	2	12	365	1	0,27	0
					10088	90795						67	36	31