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# Design as a Tool to Reduce Energy Loss Due to Heat Gain in Hospitals in India: An Approach to Sustainability

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***Abstract***

India is the world's second most populated country in the world with a population of 1.32 billion. It is projected to surpass China (largest population) reaching 1.7 billion by 2050. There is a shortage of 2 million hospital beds in India at present. Roughly 100,000 hospital beds have been added annually over the last decade and if India continues to maintain this rate, it will fall short of target by 1.6 million beds by 2034.

This paper focuses on using design as a tool to reduce energy loss in hospitals in India. Hospital buildings are major energy consumers because of their high demand of heating and cooling for controlled medical parameters and round the clock functioning. In light of present demand and growth of healthcare facilities in India, it is important to understand the energy load on the present infrastructure that will be enhanced manifold in future. None-the-less it maybe understood that huge energy loss is faced by major hospital buildings through uninsulated lengthy conduits and service pipelines responsible for heating and cooling facilities in a hospital. These are installed on the rooftops of major buildings and are responsible for extra load on the heating and cooling systems due to additional heat gain during 75-80% of the yearas Indian climate is primarily hot.

This paper intends to include Energy Efficiency as a major role player in the planning and design stage of a hospital project. Adding further to the existing guidelines the following approach to design and planning maybe explored

1. Segregation and Zoning of building components/ departments as per their energy need and controlled medical environments.
2. Patient centric hospitals focus on therapeutic healing environments. India has defined diverse climatic zones across the country. Adopting design interventions to incorporate active and passive heating and cooling techniques may help in reducing energy consumption.
3. As major population of India resides in rural areas (68.84%), a part of design component may segregate energy demands based on comfort indicators for different regions like physical adaptabilities to heat and cold, socio-economic base, cultural adaptability and regional lifestyles etc.

The suggested approach in the paper may help in significantly reducing energy consumption in these 24X7 running Buildings.

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## I. INTRODUCTION

India is the world's second most populated country in the world with a population of 1.32 billion. It is projected to surpass China (largest population) reaching 1.7 billion by 2050. There is a shortage of 2 million hospital beds in India at present. Roughly 100,000 hospital beds have been added annually over the last decade and if India continues to maintain this rate, it will fall short of target by 1.6 million beds by 2034.

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India faces a huge need gap in terms of availability of number of hospital beds per 1000 population. With a world average of 3.96 hospital beds per 1000 population India stands just a little over 0.9 hospital beds per 1000 population [3]. To satisfy this demand, the private sector is rapidly building new hospitals with the best of facilities and procedures available which can compete with the best hospitals in the world. This raises huge challenges in terms of the energy requirement for all these hospitals and their equipment. (EFFICIENTCARBON, 2017), (CSEINDIA, 2017), (USAID, 2009). Successful hospital planning must be measured over a long term, not just as an inviting and attractive new building but as a structure that supports these intensive and demanding functions on a 24 hour/7 day basis over what is often more than a 50 year useful life. With round- the-clock use and high occupancy, and the need for high capacity and redundant building systems, a hospital is also a large energy consumer and a prime opportunity for the benefits of green and sustainable design. (SPROW, 2016) (EPTA, 2007) (CABE, 2006), (BURGER, 2009), (CASTELLA, 2006), (USAID, 2009), (WHO, 2008). None-the-less it maybe understood that huge energy loss is faced by major hospital buildings through uninsulated lengthy conduits and service pipelines responsible for heating and cooling facilities in a hospital. These are installed on the rooftops of major buildings and are responsible for extra load on the heating and cooling systems due to additional heat gain during 75-80% of the yearas Indian climate is primarily hot.

**Table 1. Baseline Energy use in Commercial Buildings**

| **Number of Buildings** | **Building Type** | **Floor Area (m2)** | **Annual Energy Consumption (kWh)** | **Benchmarking Indices** | |
|---|---|---|---|---|---|
| | OFFICE BUILDINGS | | | kWh/m2/ year | kWh/m2/ hour |
| 145 | One shift Buildings | 16,716 | 20,92,364 | 149 | 0.068 |
| 55 | Three shifts Buildings | 31,226 | 88,82,824 | 349 | 0.042 |
| 88 | Public Sector Buildings | 15,799 | 18,38,331 | 115 | 0.045 |
| 224 | Private Sector Buildings | 28,335 | 44,98,942 | 258 | 0.064 |
| 10 | Green Buildings | 8,382 | 15,89,508 | 141 | - |
| | HOSPITALS | | | kWh/m2/ year | kWh/bed/ year |
| 128 | Multi-specialty Hospitals | 8721 | 24,53,060 | 378 | 13,890 |
| 22 | Government Hospitals | 19,859 | 13,65,066 | 88 | 2,009 |
| | HOTELS | | | kWh/m2/ year | kWh/room/year |
| 89 | Luxury Hotels (4 and 5 Star) | 19,136 | 48,65,711 | 279 | 24,110 |
| | SHOPPING MALLS | | | kWh/m2/ year | kWh/m2/ hour |
| 101 | Shopping Malls | 10,516 | 23,40,939 | 252 | 0.05642 |

Source: Building Energy Benchmarking study undertaken by the USAID ECO-III Project.

Hospitals are the most complex buildings when assessed in terms of functionality, construction and need. Unlike any other building it is one of the major consumers of energy. They have multiple users with varied healthcare demands. There is vast diversity in the energy consumption of the different departments in the hospital depending upon the medically controlled environment, user perspective, infection control and functionality. Some areas like

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the Operating rooms (ORS), Intensive care units (ICU), Accident and Emergency (A&E), Clinical Labs etc. require specific temperature, humidity and air changes to be maintained throughout the period of use. These impose customized load on energy consumption in the building. This paper intends to understand if design innovations in planning a hospital may help in reducing energy consumptions to a certain extent to make the buildings more energy efficient.

## II. LITERATURE

Most of the published works by various authors emphasize on increasing energy efficiency of hospital buildings by use of low energy consuming equipment, high performance lamps for lighting, maintenance of boilers for heating, co-generation system for producing heat and electricity, central cooling and air conditioning systems with regular maintenance, adopting good building management systems, solar water heating and steam generating technologies, Passive heating and cooling techniques etc. (EPTA, 2007), (EFFICIENTCARBON, 2011), (CABE,2011), (BURGER, 2009), (BEE, 2012), (UNEP, 2008), (CASTELLA, 2006), (USAID, 2009), (WHO, 2008). Majorly simple and low cost measures are discussed vastly by many researchers concern mostly controlling heat gain or loss from a building, equipment planning, placement of windows and reflective glass etc., controlled door and window openings, sealing passages of heat flow in ducts, maintenance of machinery and medical equipment on regular basis, thermal insulation etc. (EPTA, 2007), (CABE, 2011), (CSEINDIA, 2014), (BEE, 2012), (UNEP, 2008), (CASTELLA, 2006), (USAID, 2009), (WHO, 2008).

Many case studies researched in secondary study have taken many design parameters like patient facilities, dignity and privacy, healing environments, need and expectations, accessible services, adaptable accommodation, multi-functional spaces, evidence based design, need assessment and material preference, lighting and space conditioning types and methods adopted, spaces and their ambience and size have been optimally studied. (HOSPICE FOUNDATION, 2014), (EFFICIENTCARBON, 2017), (CABE, 2011), (BURGER, 2011), (BEE, 2012), (USAID, 2009). Integrated and coordinated Design can make a difference to health and wellbeing in a hospital referring to the physical and social environment in a hospital, neighbourhood and the community itself. Maximising green spaces, therapeutic environment and sustainable transport solutions is another parameter to design. (CABE, 2011), (USAID, 2009), (WHO, 2008).

Many energy efficiency codes like ECBC, BEE, Teri-Griha, LEED etc. have formulated guidelines and parameters for all compliance approaches. These include the building systems envelope, HVAC, Lighting, electrical power, solar hot water and pumping etc. (EFFICIENTCARBON, 2017), (CSEINDIA, 2017), (USAID, 2009).

The primary consumers of electricity in a hospital are:

**Table 2. Baseline Energy use in Commercial Buildings (To be edited)**

| | |
|---|---|
| HVAC system + fans | 35 - 50% of the total energy |
| Lighting | 20 - 30% of the total energy |
| Motors | 5 - 10% of the total energy |
| Medical equipment | 10% of the total energy |
| Computers, Others | 5% of the total energy |

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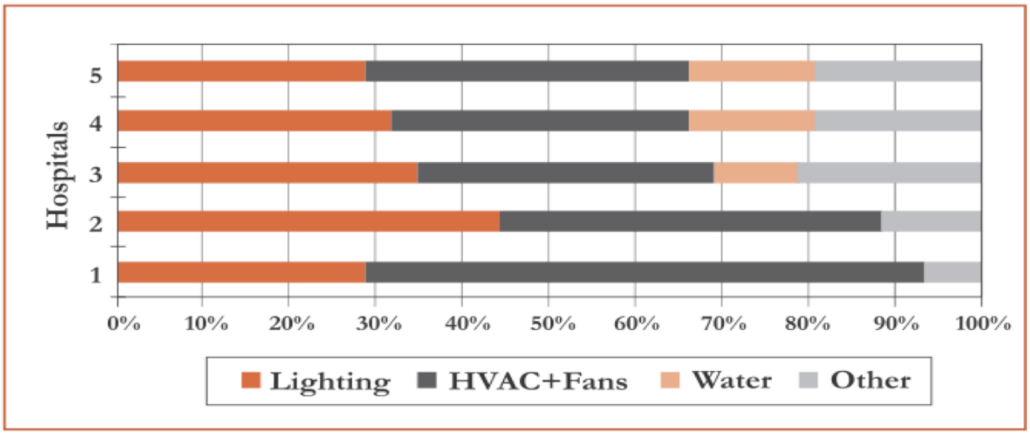


3: Break up of Electricity Consumption in Five Hospitals

SOURCE: USAID AND BEE, ECO III PROJECT (2011)

**Figure 1. Maximum Energy Consumption in Lighting and Air conditioning**

The rooms with large volumes, long corridors, big size of the building, loss of heat through long pipelines, loss of air conditioning through long ducting systems, steam networks with very long pipes, power loss due to harmonic currents, etc. add up to a large amount of energy consumption in the hospital building. (EPTA, 2007), (BURGER, 2009), (USAID, 2009), (WHO, 2008)

On analysis of the research, it may be explored that other than all the above mentioned measures for reducing energy consumption in hospital buildings, if we may be able to reduce the length of ducting and exposure and segregate similar functionality areas into various zones without hampering the medical flow-paths, we may be able to reduce the energy consumption to some extent and the values maybe substantially good.

It may also be considered that Indian hospitals are flooded with visitors on daily basis with most walk-in patients in the public sector hospitals. Even in the private sector the population visiting through appointments is almost negligible as compared to walk-in visits. With the low value of doctor to patient ratio on a global level, Indian hospitals serve masses.

This paper intends to include Energy Efficiency as a major role player in the planning and design stage of a hospital project. Adding further to the existing guidelines the following approach to design and planning maybe explored

1. Segregation and Zoning of building components/departments as per their energy need and controlled medical environments.

2. Patient centric hospitals focus on therapeutic healing environments. India has defined diverse climatic zones across the country. Adopting design interventions to incorporate active and passive heating and cooling techniques may help in reducing energy consumption.

3. As major population of India resides in rural areas (68.84%), a part of design component may segregate energy demands based on comfort indicators for different regions like physical adaptabilities to heat and cold, socio-economic base, cultural adaptability and regional lifestyles etc.

Thus, all three approaches have enough opportunity for individual research. This paper focuses on the first approach as mentioned above followed by two case studies keeping the parameters of approach 2 and 3 similar for an equitable comparison.

## III. SUGGESTED APPROACH

Energy efficiency consciousness is a not a very old concept in sustainability design. The concept or methodology of energy efficient building design has been either developed as a parallel thought process or an afterthought in major buildings in India. The technologies and methodologies related to the same is concentrating on reducing energy consumption by controlled use and maintenance of medical equipment and advanced building material and technical systems for lighting, heating and HVAC. The prime thrust of the paper is to realize energy efficiency as a design tool right from the concept to commissioning of the project. This would help to further reduce the load of electricity consumption in the building and avoid losses due to lengthy ducting and ignorant layout planning.

Every healthcare architect must keep in view the four major perspective players in the design and development of a healthcare facility. They are Patient's and other end-users, innovations in design, therapeutic healing and energy efficiency. The layout planning plays an important role guiding the way any hospital would function. Other than the medical flow-paths of various departments and their supporting infrastructure for a patient centric design, it is important to know that the placement of vertical and horizontal circulation planning also eases the end users in proper way-finding, security, privacy and reduction in the use of lifts etc.

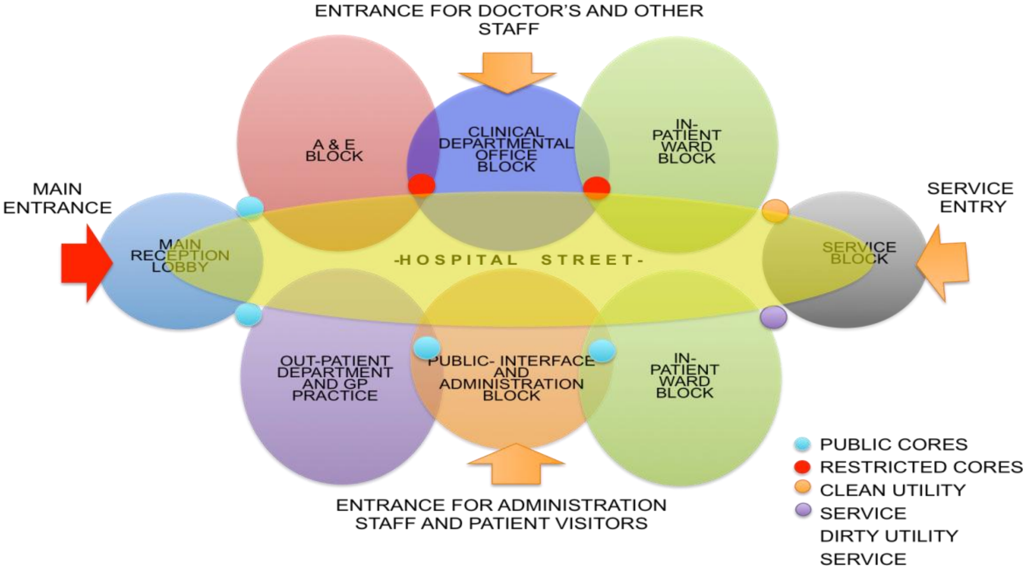


**Figure 2. Maximum Energy Consumption in Lighting and Air conditioning**

For example, in a hospital major inflowing population per day comprises of maximum floating population (those visitors coming for consultation and diagnostics in the Out-patient Department (OPD), treatment, follow-ups and observations only) as compared to the resident population (patient visitors in the In-patient Department (IPD), Intensive care units (ICU), Operating Rooms (OR's) and Accident and Emergency (A&E). if the layout plan is such that the floating population visits are limited to first floor only, then major population visit is pedestrianized and visitors on wheel chairs or otherwise-abled may use the ramp. This would reduce the use of Lifts to a large extent. The resident population, doctors, staff and administrators would use them who maybe placed at higher levels in the hospital building.

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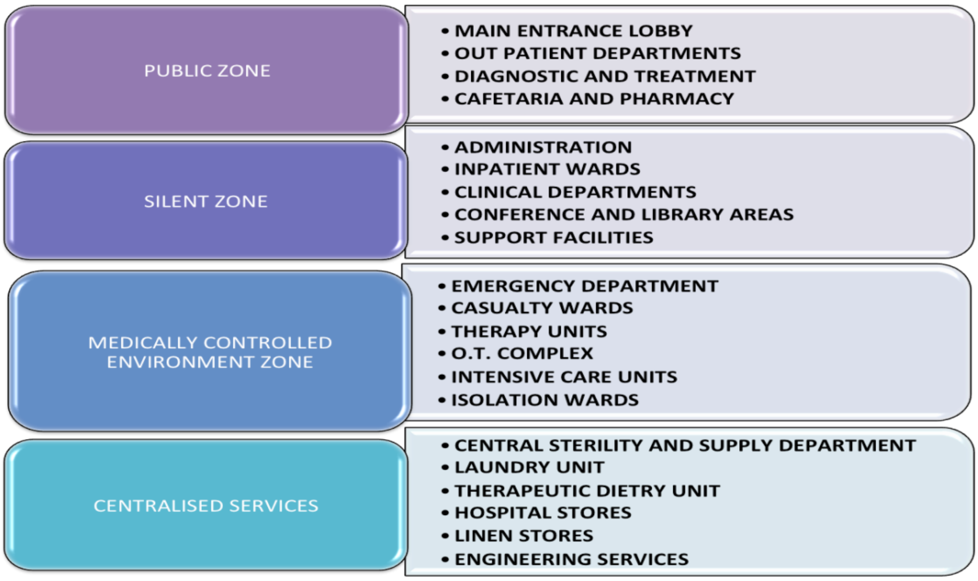


**Figure 3. Segregation of Space as per Energy Consumption (Concept of Centralisation and Decentralisation)**

Similarly segregating entrances as per user mobility would enhance work efficiency, monitoring and security, privacy and ownership of healthcare workforce, decentralized work placement of reception and information staff from the billing and admissions.

The various departments of a hospital building maybe segregated as per energy consumption and functionality. This would help the healthcare planners to design the vertical stacking and horizontal circulations simultaneously and with the use of energy efficiency as a design tool. The segregation would facilitate in

- Reducing the length of ducting systems of Air Conditioning, Heating etc. if medically controlled departments are stacked one over the other and the supply from chillers and air handling units may also be stacked vertically. This would also facilitate in maintenance works from the service cores without any disturbance to patients etc.

- Reducing the length of electrical cabling and networking throughout the building as per the need of the type of department like stacking of all OPD areas vertically or placed horizontally over a floor plate. This may help to provide a distinguished and dedicated electrical system, air cooling/conditioning system etc.

- Reduction in the length of medical gas pipelines leading to bed head panels. If the IPD’s are stacked one over the other then the medical gas pipelines, electrical cabling, air-handling units per ward, air cooling/conditioning systems can also be stacked. This block or area may have a dedicated lift and staircase core for the patients, doctors and staff and patient relatives and visitors separately.

- Reducing the length of water supply, sanitation and drainage pipelines. Streamlining of dirty and clean services in the hospital.

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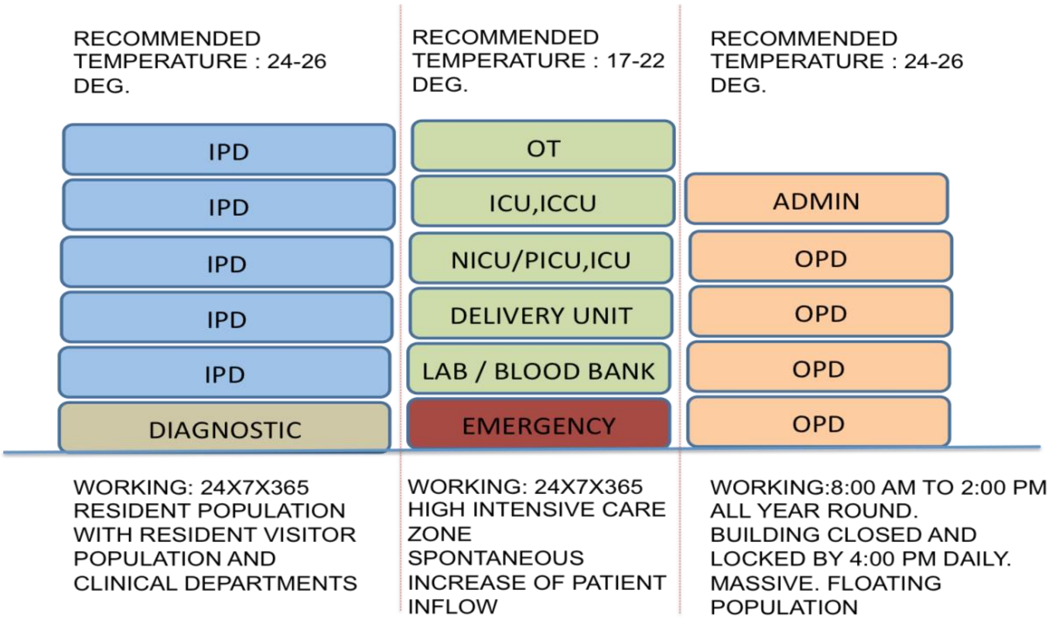


**Figure 4. Segregation of Space as per Functionality (User Friendly)**

- Reducing the length of pneumatic tube systems ducting and enhancing its functionality by stacking Departments of use vertically. This would enable faster emergency diagnostics from the Labs and vice versa resulting in faster patient treatment and minimizing triage time.

- The segregation and stacking system although is a block model system yet every floor is complete in its own capacity. The reduction in lengths of the above mentioned ducts, cables and pipelines would enable a huge drop in the installation costs, maintenance costs and ease of service delivery.

- It may also be noted that the OPD and Administration usually functions only till the evening hours in every hospital. If this block is segregated as a separate unit, then after the closing hours, the entire electrical supply to the block maybe shut down. On the contrary where these activities are scattered over different floor plates and different locations, the vertical lift and staircase cores and the lobbies have to be kept lit 24x7. This if observed separately as energy loss may account for a substantial cost.

To further the research with a backing of experience in the field of design of 18 years, this paper also analysis the above theory through two case studies. It may be noted that the approaches mentioned as 2 and 3 above have been maintained on similar parameters so that the case studies maybe analyzed on equitable grounds. Both the case studies are of general teaching hospitals with 500-bed strength, located in same climatic region of Bihar state in India with similar areas, floor heights and building construction. The Government of Bihar has made both the projects. The only difference being that case study 1 is planned with energy efficiency as a parallel or after thought concept while case study 2 is designed with energy efficiency as a design tool on a similar concept of segregation as discussed in the theory above.

To further substantiate the theory a comparative analysis is done on the basis of installation and running costs of air conditioning, Heating and electrical consumption of the two case studies. The Architectural consultants have been generous to share the required data for the study. A copy of the financial ledger was not shared due to privacy guidelines but numeric values were disclosed for academic study only.

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Case Study 1: 500 Bed Teaching Hospital at ESIC Medical College, Bihta Bihar

This project commenced in 2014. The project has a Medical college building, 500 bed teaching hospital, Residential accommodations and all support facilities and buildings in line with the guidelines set by Medical Council of India for a 100 intake medical college.

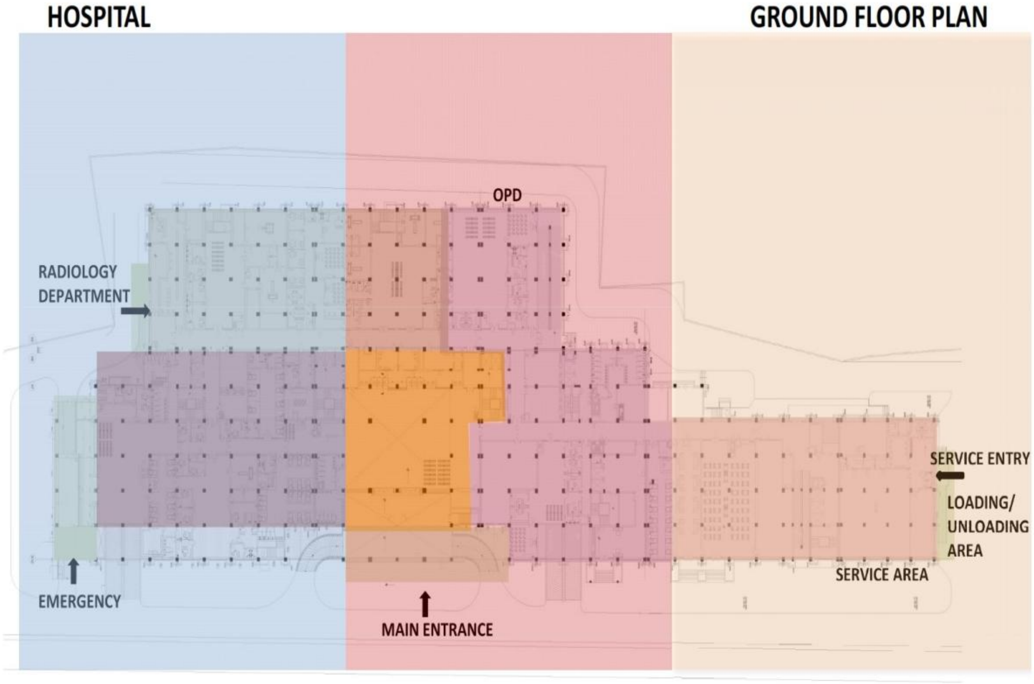


**Figure 5. Segregation of Space as per Functionality (User Friendly)**

As can be seen in the layout plan, the building is one consolidated block with an elongated structural form. There are long connected corridors that are doubly loaded. The A&E department and some OPD's occupy the ground floor plan. After OPD hours in the evening, other than A&E department, all corridors and lobbies are functional as the main entrance to the above floors is through the ground floor only. There is no segregated and dedicated lobby to manage the vertical circulation in the building. Similar condition prevails in the above two floors. The operation theatre complex and the ICU floors are the highest floors as can be seen in the stack section of the building. The ducting, cabling and pipelines run across the floor plate of every floor and vertically above to the terrace floor. The long ducting and pipelines may pose additional heat gain/loss as per cool air/hot water is required in the building respectively.  Some solar panels have been installed but are not in use at present, thus load of heating on cost cannot be assessed.

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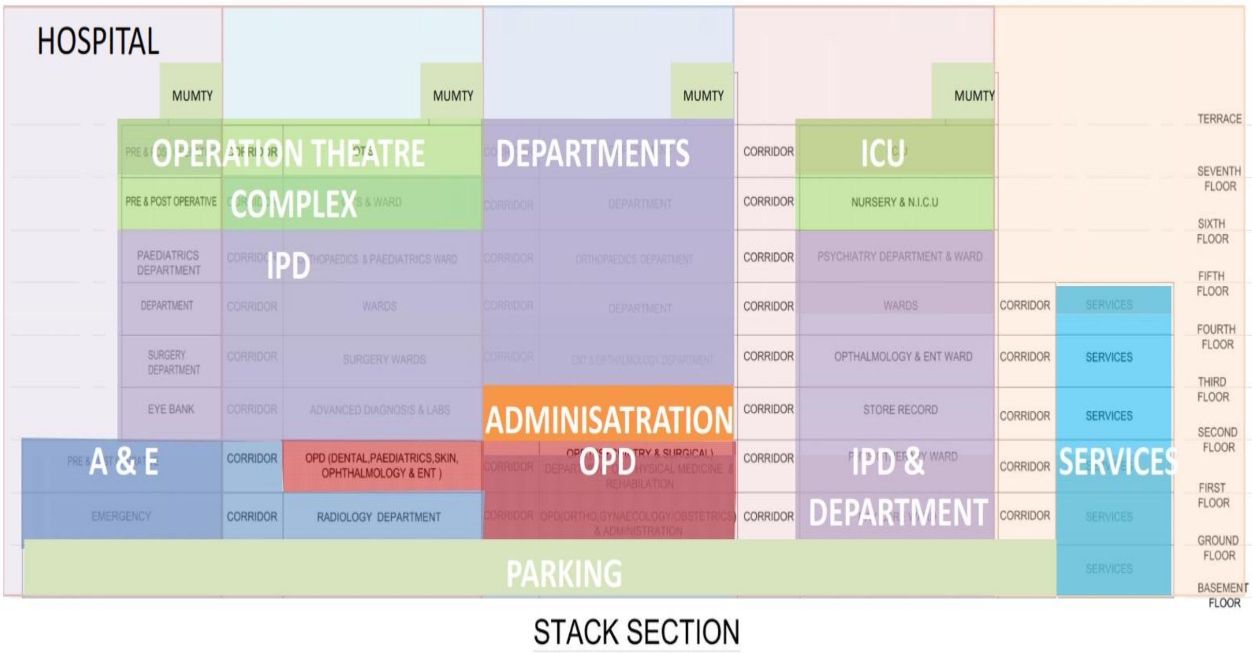


**Figure 6. Segregation of Space as per Functionality (User Friendly)**

The administration and some services occupy an entire floor. After Administration is closed in the evening, only some portion of the floor is shut down while the rest of the areas are accessible through common corridors and lift cores on the floor. Some of the departments are exposed to meager daylight because of the design and site constraints owing to which electrical usage; lighting etc. is also functional during the day. This may pose additional load on the energy consumption. The Departments in themselves seem to be designed as per the guidelines and norms and considering the patient and end user criteria yet some interventions related to energy efficiency of the building are limited to choice of medical equipment, electrical equipment, use of solar panel etc.

The design of this hospital building although incorporates climatic factors and therapeutic healing concepts yet some parts of the entire building are shut down after OPD and administration hours only. The design allows all lobbies and corridors to be functional throughout the day and night also. The stretch of the building and the network of ducts, conduits, cables and pipelines is like a jargon of metal and plastic inbuilt in the building like muscles and nerves under the human skin. It is difficult to comprehend the mechanism and management of maintenance and operations of the building which might as well be more time consuming and least cost effective.

Case Study 2: 500 Bed Teaching Hospital at Vardhman Institute of Medical Sciences, Pawapuri, Nalanda, Bihar

This project commenced in 2015. The project has a Medical college building, 500 bed teaching hospital, Residential accommodations and all support facilities and buildings in line with the guidelines set by Medical Council of India for a 100 intake medical college.

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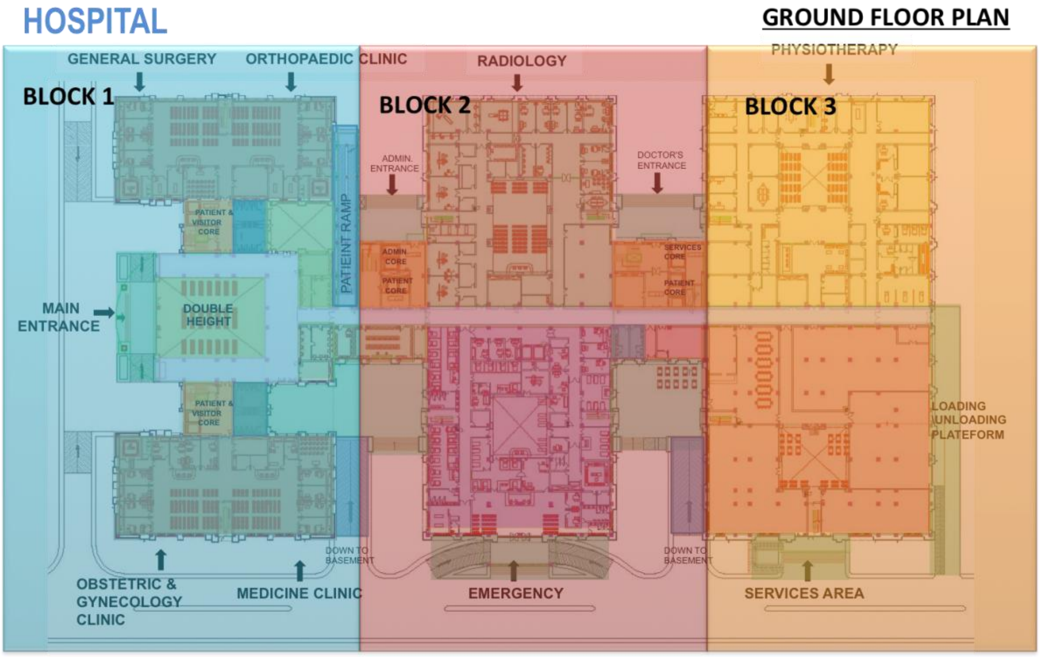


**Figure 7. Segregation of Space as per Functionality (User Friendly)**

As can be seen in the layout plan, there are clear and distinctive three blocks with segregation of departments. The block 1 comprises of OPD and administrative areas only. This block functions between 8:00 am to 4:00 pm per day. The complete block is electrically shut down after closure. Block 2 shares OPD rooms and related departments. There is floor wise segregation of spaces. All electrical supplies run independently per floor.

The topmost floor of blocks 2 and 3 have the intensive care units and the operation theater complex. These departments have medically controlled environments (specific temperature, humidity, air changes per minute etc.). Every operating room has a different Air Handling Unit (AHU) for infection control. The chiller plant and cooling units are placed on the terrace, thus the ducting from every area of the department to its AHU is just one floor length vertically. This would have reduced the installation costs substantially. The electrical rooms and services rooms are also stacked vertically in the circulation cores in between the blocks. Thus ducting, cabling and piping is vertically oriented.

Owing to similar departments on the same floor and in stack, the compressors of the split air conditioning systems in IPD, Lobbies and corridors have been stacked together near the service balcony and camouflaged by a grill door with planters. The length of ducting thus reduced and heat gain is controlled.

The medical gas pipelines and other services like dietary, laundry, Central sterility and service department (CSSD) etc. are placed partly in the ground floor and basement of the blocks 2 and 3 for easy access for maintenance and reducing length of installation to IPD, OT's, ICU's etc. Heating is done through solar panels proposed to be installed on the terrace of block 2 and 3. As it is yet not complete running cost could not be found out. The length of ducting would be reduced as the toilets in both the blocks 2 and 3 are also stacked one over the other. It seems that an effort has been done to use energy efficiency as a design tool from the inception of the project.

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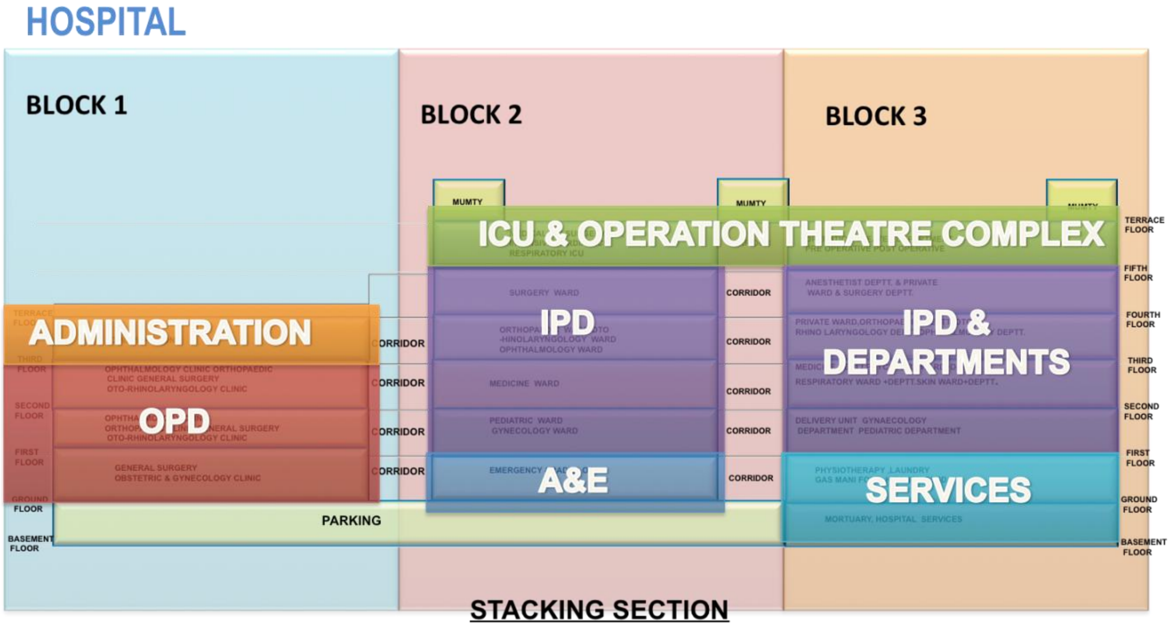


**Figure 8. Segregation of Space as per Functionality (User Friendly)**

Parametric Analysis: Comparative Study of Installation and Running Costs of Case Study 1 and 2.

According to the data available with the Architectural consultancy company, the following table has been developed with tabulation of data received. It may be noted that all the climatic, regional and cultural parameters in both the case studies have been the same as stated previously. Both projects have an applied load of 4.0 MVA at present.

**Table 3. Baseline Energy use in Commercial Buildings (To be edited)**

| Parameters For Comparison | Case study 1 (CS1) | Case study 2 (CS2) | Difference | Energy Efficiency in CS2 |
|---|---|---|---|---|
| Total Electrical Load Estimated | 9MVA | 6MVA | 3MVA | 33.33% |
| Cost Of Installation Of HVAC (In Millions) | 459.1 | 331.3 | 127.8 | 27.84% |
| Approx. Running Cost Of HVAC Per Annum (In Millions) | 10.2 | 6.86 | 3.34 | 32.75% |
| Cost Of Electrical Installations (In Millions) | 880.0 | 667.5 | 212.5 | 24.15% |
| Approx. Running Cost Of Electrical Per Annum (In Millions) | 28.46 | 16.94 | 11.52 | 40.48% |

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As can be seen in the table above, the electrical load estimated is higher in Case Study 1 by 33.33% than Case Study 2. The cost of installation of HVAC and electrical is less in case of Case Study 2 (CS2) by 27.84% and 24.15%. Thus it may be seen in the context of layout plan of air conditioned spaces, the distance between them, the distance between the cooling towers and the output room. The length of ducting, cabling and pipelines was more in CS1 than in CS2 and hence the difference in the installation costs. Thus additional cost may also be accounted for heat gain and loss through them.

The reflection of the same can be seen in the annual running costs of HVAC and electrical, which are 32.75% and 40.48% respectively. At present it may be seen that annual running cost of all installations is substantially more than the installation costs. With time lapse these running costs and the maintenance costs would also increase. This is a substantial cost levied on hospitals and it becomes difficult for sustainability.

## CONCLUSION

The research has revealed that if energy efficiency is realized as a design tool and applied to building concepts even before the building commences on the natural ground, a substantial difference can be seen and buildings can be made more energy efficient. Secondly, the new approach to sustainability in Hospitals may also help in reducing the installation and running costs. The design segregation methodology maybe used to streamline the proper functioning of a hospital building along with all the centralized services. It may also be understood that Hospitals are very complex buildings and careful deliberation of every aspect related to functionality and energy efficiency maybe dealt with proper care. The design may also look into various parameters as mentioned in approach 2 and 3 to further reduce the energy consumption in Hospitals in India making them more energy efficient and reducing operational and maintenance costs through planned Hospital Energy Efficient Design (HEED).

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