U.S.– India Joint Center for Building Energy Research and Development (CBERD)

Caring for the Energy Health of Healthcare Facilities

Reshma Singh, Paul Mathew, Jessica Granderson
Lawrence Berkeley National Laboratory, USA

Rohini Srivastava
Carnegie Mellon University, USA

Yash Shukla
Center for Environmental Planning and Technology, India

Industry Collaborator: **Mazzetti, USA**

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Authors

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CARING FOR THE ENERGY HEALTH OF HEALTHCARE FACILITIES

1. Introduction

1.1 Context

The U.S.-India Joint Center for Building Energy Research & Development (CBERD), created through the Partnership to Accelerate Clean Energy (PACE) agreement between the United States and India, is a research and development (R&D) center with over thirty institutional and industry partners from both nations. This five-year presidential initiative is jointly funded by the U.S. Department of Energy and the Government of India. CBERD aims to build upon a foundation of collaborative knowledge, tools and technologies, and human capabilities that will increase development of high-performance buildings. To reach this goal, the R&D focuses on energy use reduction throughout the entire life cycle of buildings—i.e., design, construction, and operations. During the operations phase of buildings, even with best-practice energy-efficient design, actual energy use can be much higher than the design intent. It is a reality that every day, much of the electricity consumed by buildings is not actually being utilized for any purpose. (Roth et al. 2005).

Building energy information systems (EIS) are commercially available products that building owners and facility managers can use to assess their building operational energy efficiency by measuring, visualizing, and analyzing building energy cost and consumption. Energy information systems can enable significant energy savings by identifying consumption patterns, tracking energy waste, and benchmarking performance against similar buildings. The CBERD team has identified potential energy savings of approximately 2 quads of primary energy in the U.S., and building energy audits in India have indicated potential energy savings of up to 30 percent. Additionally, the CBERD team has identified healthcare facilities (e.g., hospitals, clinics), hotels, and offices as the three highest-growth sectors that have significant energy consumption, that would benefit most from implementation of EIS. This report focuses on effective engineering of EIS packages specifically for the healthcare sector, to enable deeper market penetration and scale-up to facilitate energy savings in both countries.

1.2 Audience for this report

There are two primary audiences for this publication: healthcare facility owners and managers, and EIS companies and vendors.

1.3 General healthcare facilities trends

While the U.S. is well known for advanced medical research and treatment, India is emerging as a center for healthcare expertise and also attracting medical tourism. In order to understand the healthcare sector better in both countries, our team conducted a literature review to categorize U.S. and Indian healthcare facilities (See Appendix 1: Categorization of Healthcare Facilities in U.S. and India).

Market studies show that the Indian healthcare sector is booming, with significant growth in both inpatient facilities (14 percent compound annual growth rate) and outpatient facilities (8 percent compound annual growth rate) (IBEF, 2015). Even though 50 percent of the existing medical workforce does not practice in the formal health system, India is slated to create new facilities to house an additional 1.75 million beds by 2025, and to more than double from a current 0.9 beds to 2.1 beds per thousand population ((Gudwani et al. 2012). High growth is projected in the private sector, major metropolitan areas, tier-2 cities, and medi-cities that attract medical tourism. Medical tourists are expected to increase from 150,000 in 2005 to 3.2 million in 2015 (IBEF, 2015). According to the building energy benchmarking study conducted through the ECO-III program in 2010, energy use intensity (EUI) ranges widely, from **7.7 thousand Btu per square foot per year (kBtu/ft^2-yr)** (88 kilowatt-hours per square meter [kWh/m^2]) for government and municipal hospitals to almost five times that, at **33.3 kBtu/ft^2-yr** (378 kWh/m^2) for private-sector, multi-specialty hospitals. HVAC and lighting end-uses contribute up to 80% of the energy demand in India (Figure 1) (Kapoor and Kumar 2011).

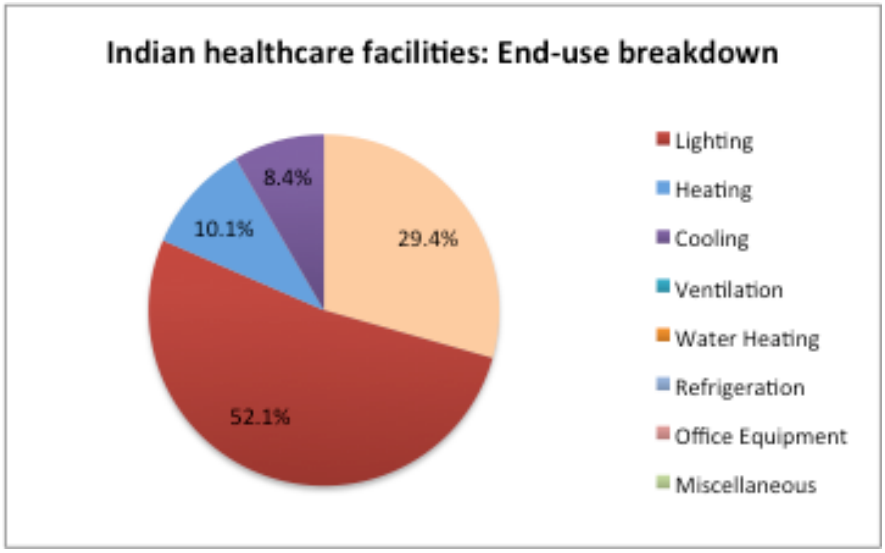


Figure 1: Chart showing the end-use breakdown in Indian healthcare facilities. Over 80 percent of energy use is from HVAC and lighting. (Source: Kapoor and Kumar 2010)

Three factors contribute to increasingly higher EUI in Indian healthcare facilities:

- the exponential increase in the footprint of healthcare facilities,
- aspirations towards higher levels of service (e.g., higher standards of climate control to avoid dehydration, perspiration, and fungal growth in India's warm climate), and
- a rapid increase of specialized high energy-use equipment such as X-rays, CT scanners, and ECG machines. (Thamba et al. 2012)

For instance, intensive care units (ICUs) in Indian healthcare facilities contribute to 50 percent of secondary infections in those facilities. If operated according to hospital ventilation standards, to reduce the incidence of infection, ICU and operating areas could constitute as much as 65 percent of the facility's energy bill (Dey 2013). Thus, EUIs of the newer Indian facilities are seeing a strong rising trend as they

comply with international standards of service and patient delivery. At the same time, there is an imperative to reduce costs, resource consumption, and infections, and to bring in new technology. With energy contributing to a 5–6 percent of annual operating costs in hospitals, facility managers need a more structured and informed approach to reduce energy use, rather than just turning off the HVAC system at night.

On the other hand, in the United States, healthcare facility market trends indicate significant growth in the outpatient and urgent care functions, (Askin and Moore 2014) and the retrofit of existing facilities. Large hospitals comprise 1 percent of commercial buildings and 2 percent of commercial floorspace (1.96 billion ft^2), but 4.3 percent of total delivered energy in the United States. Inpatient functions have significantly higher EUI than outpatient facilities. The median EUI in U.S. outpatient facilities is **62.2 kBtu/ft^2-yr** or 706 kWh/m^2-yr; while the median EUI in U.S. inpatient facilities is three times that, at **195.4 kBtu/ft^2-yr** or 2,219 kWh/m^2-yr (EIA 2003)(EERE 2012). In fact, a rule of thumb in the engineering industry is that 20 percent of an inpatient footprint in a hospital contributes 80 percent of its energy use. (Mazzetti 2015) Over half of the energy use is due to HVAC loads, driven by filtration, continual air changes to remove pollutants and contaminants, climate control, and negative pressurization. Overall, lighting, heating, and hot water represent between 60–80 percent of total energy use (depending on climate zone) (Figure 2) (EIA 2003), making those systems and end uses the best targets for energy savings.

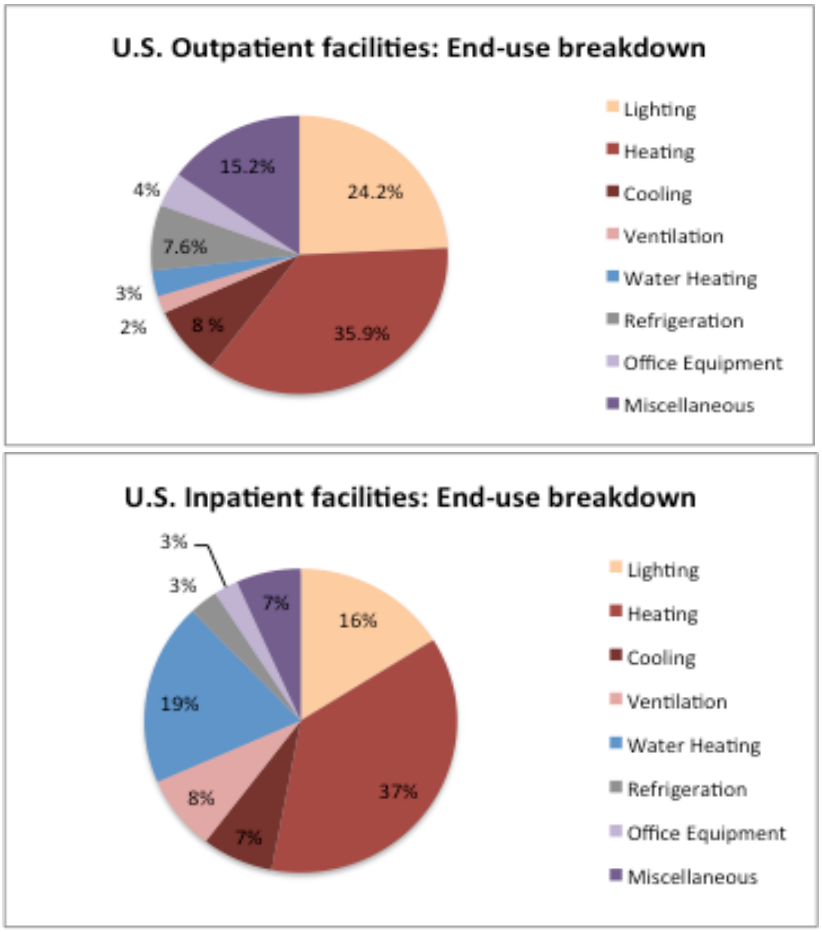


Figure 2: Charts showing the end-use breakdown in U.S. outpatient and inpatient facilities (Source: CBECS 2003)

1.4 Overall objectives and our approach for packaged EIS

Given the high energy use intensity in healthcare facilities, and also the large amount of energy waste, building energy information systems (EIS) are a relevant technology to enable energy savings. As mentioned above, building owners and facility managers can use EIS to assess their building operations by measuring, analyzing , and visualizing building energy cost and consumption (Figure 3). These systems can enable significant energy savings by identifying consumption patterns, tracking energy waste, and benchmarking building energy performance against similar buildings. Even though the market offers approximately a hundred EIS solutions with increasing technical capability, the adoption of such systems is limited to high-end markets since they are custom-designed, sophisticated, and expensive. The vast array of software features, data integration, and analysis options make it difficult to navigate, creating a barrier to more pervasive use of these promising technologies.

To combat barriers to adoption and facilitate widespread building application, the CBERD team has developed technical requirements for scalable, cost effective EIS packages. These EIS packages are healthcare sector-specific and designed to be ready to install right "out of the box." A simplified "EIS-in-a box" product is geared towards hospital and clinic owners and facility managers that are interested in understanding and reducing their property's energy utilization but have minimal resources to research, procure, and configure a complex custom EIS solution.

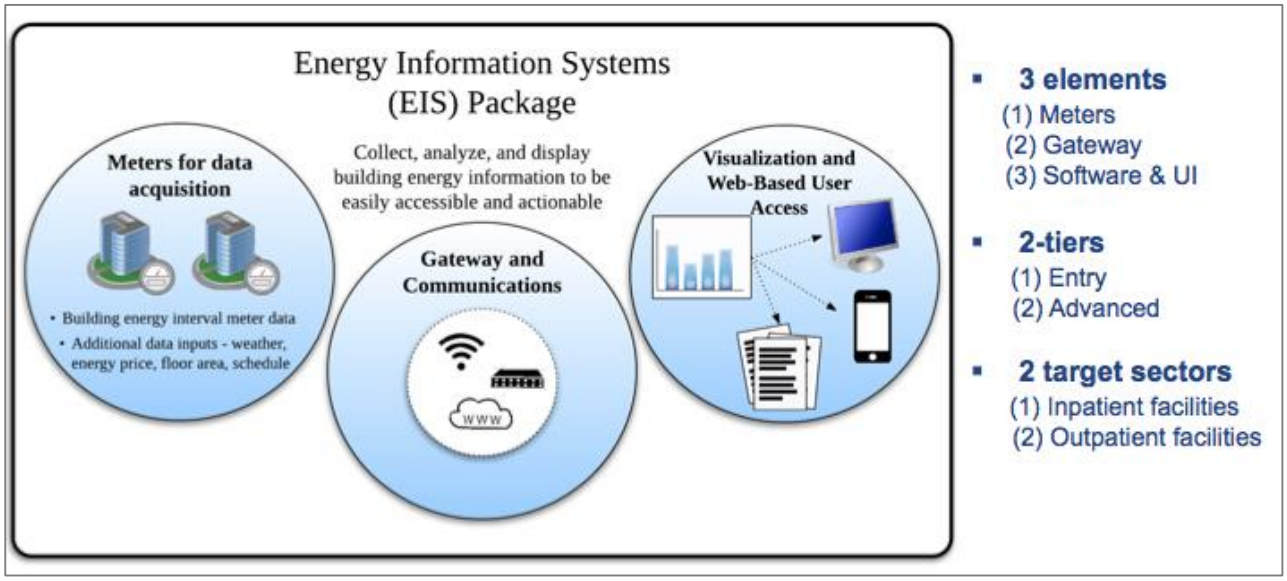


Figure 3: Energy Information Systems (EIS) comprise data acquisition meters, communication gateways, and performance monitoring software with a user interface. These systems collect, analyze, and display building energy data, and enable site operational efficiency.

2. Methodology

To develop an EIS-in-a-box for healthcare, we followed three steps:

1. An assessment and **framing of the transaction costs** for the installation and use of EIS solutions.
2. A **characterization of heterogeneity** in the healthcare sector in both countries, and its influence on EIS package design and engineering.
3. A **usability analysis**, to inform the user interface for the EIS packages.

2.1. Transaction cost framework

Today's market offers approximately 100 EIS solutions; however, customization often leads to high transaction costs for procurement, installation, and operation. We broke down the components of the transaction process and the reasons for the high costs of current EIS solutions.

The transaction process consists of a five-step process that starts with a facility owner developing a curiosity for energy monitoring and ends with the facility manager using the EIS (Figure 4).

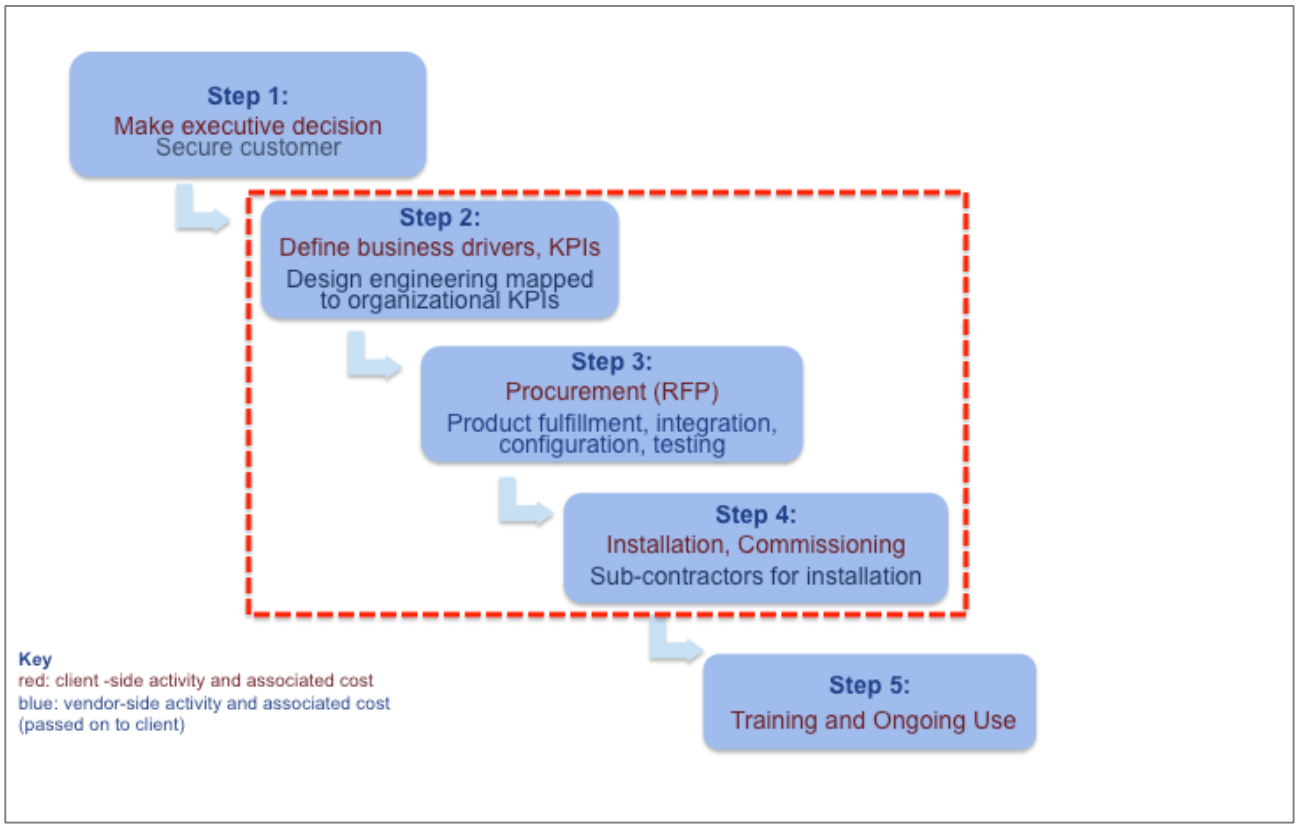


Figure 4: Transactional cost framework for the specification, installation, and use of EIS packages. Steps 2–4 lead to highest transaction time and cost.

The costs of these steps are borne by the vendor and eventually transferred to the client. We interviewed EIS vendors to identify the proportion of cost incurred by vendors during each step of the process. We determined that a significant portion of the cost is from implementing steps 2–4 (i.e., defining business

drivers and key performance indicators [KPIs], procurement, and installation and commissioning). Hence, our efforts have been to streamline these steps in order to reduce the time and first cost incurred to the facility owner for installing and operating an EIS.

The CBERD vision is that within a compressed period of transaction time (on the order of a few days) the product requirement can be fulfilled and the installation completed. This can be achieved by the commoditization of a complex EIS solution into packaged products, making it easier for facility staff to quickly and painlessly specify, procure, install, and use the product. The components of such a package would include predetermined hardware and software, a user-interface, and built-in tips for training and use (e.g., how to interpret charts that a facility manager should answer, take action on, and report on). Hence, to reduce costs, simplicity should be built into the package. This approach can substantially decrease first cost by defining a core set of hardware and software that could reduce configuration and development time for EIS vendors. The package also should be easy to use, to help reduce a user's ongoing operating and services costs.

2.2 Characterization of heterogeneity

As the second step of the methodology, we investigated the heterogeneity or variety of healthcare facilities, with the objective that the EIS packages would be engineered to enhance scalability across a range of healthcare facilities by recognizing and accommodating this variety.

Two aspects make a building sector such as healthcare highly heterogeneous: (1) the wide range of physical facilities, and (2) the diversity in characteristics of healthcare organizations. The following sections describe these two aspects in more detail:

2.2.1 Heterogeneity of the physical infrastructure

2.2.1.1 Mapping physical infrastructure

First, we conducted an investigation into the types of physical spaces and end-uses in Indian and U.S. healthcare facilities, finding various similarities and differences between facilities in both countries. There is particularly significant diversity in Indian facilities, which range from one-room, naturally ventilated clinics to high-rise, multi-specialty state-of-the-art hospitals. The study focused on higher-end facilities with mechanical cooling and ventilation, and where an EIS could create an energy savings impact. For more details on space and end-use classification, please refer to Appendix 1, Categorization of Healthcare Facilities in U.S. and India.

2.2.1.2 Identifying metrics for inpatient and outpatient facilities

Next, we identified important physical aspects to monitor and control, based on business drivers and metrics for the inpatient and outpatient sub-sectors. For instance, in addition to the standard metrics such as EUI and cost/time period, other important metrics included the EUI per adjusted patient day for outpatient facilities and EUI per (occupied) hospital bed for an in-patient facility.

2.2.1.3 Generating a pick list of potential loads

Next, we developed list of all potential loads in a healthcare facility by end use (Figure 5). Then, we mapped non-critical end-uses, as being different from critical, emergency, and standby end uses (Figure 6). This delineation helps to characterize loads that can be controlled, managed, or scheduled (non-critical), and those that are too critical to be actionable in a healthcare facility. The latter category of loads is needed to maintain continuity of service at all times through access to standby power. Healthcare facilities will often have several days of backup emergency power in reserve. Finally, we mapped the end uses to the space types in a healthcare facility to generate a matrix of loads, which is presented in tables 1 and 2 in Section 3: Results.

Typical List of Fuels and End Uses in a Healthcare Facility

1. Whole Building Electricity
- 1.1 All electricity-grid
- 1.2 Standby power from fuel oil / gas generators

2. Whole Building Gas/ Fuel Oil

3. Whole Building Steam

4. Electricity Sub-meters
- 4.1 Central cooling (chiller plant, cooling towers)
- 4.2 Zone cooling
- 4.3 Air Handlers
- 4.4 Pumps (hot water, heat recovery, water booster, chilled water, condenser water)
- 4.5 Indoor Lighting
- 4.6 Outdoor Lighting
- 4.7 Miscellaneous electric loads (MELs)/ Plug loads (receptacles, computers etc.)
- 4.8 Communication systems (IT, data network, emergency/alarms, intercom, picture archiving, CCTV, electronic health records)
- 4.9 Medical equipment (dialysis, radiation/inhalation/therapy)
- 4.10 Imaging equipment (CT, MRI…)
- 4.11 Kitchen equipment
- 4.12 Laundry equipment
- 4.13 Process Loads for transportation (elevators, trolleys incl. pneumatic tubes systems)
- 4.14 Plant medical equipment (clinical air compressors, clinical vacuum pumps, blowers, reverse osmosis water purification)

5. Gas/ Fuel Oil Sub-meters
- 5.1 Central Heating (furnace)
- 5.2 Central heating (boiler- gas or fuel oil)
- 5.3 Reheat (separation, if done at terminal units)
- 5.4 Service/ domestic hot water
- 5.5 Kitchen gas equipment
- 5.6 Laundry gas equipment

6. Steam Sub-meters
- 6.1 Process steam loads

Figure 5: Typical list of fuels and end uses in healthcare facilities

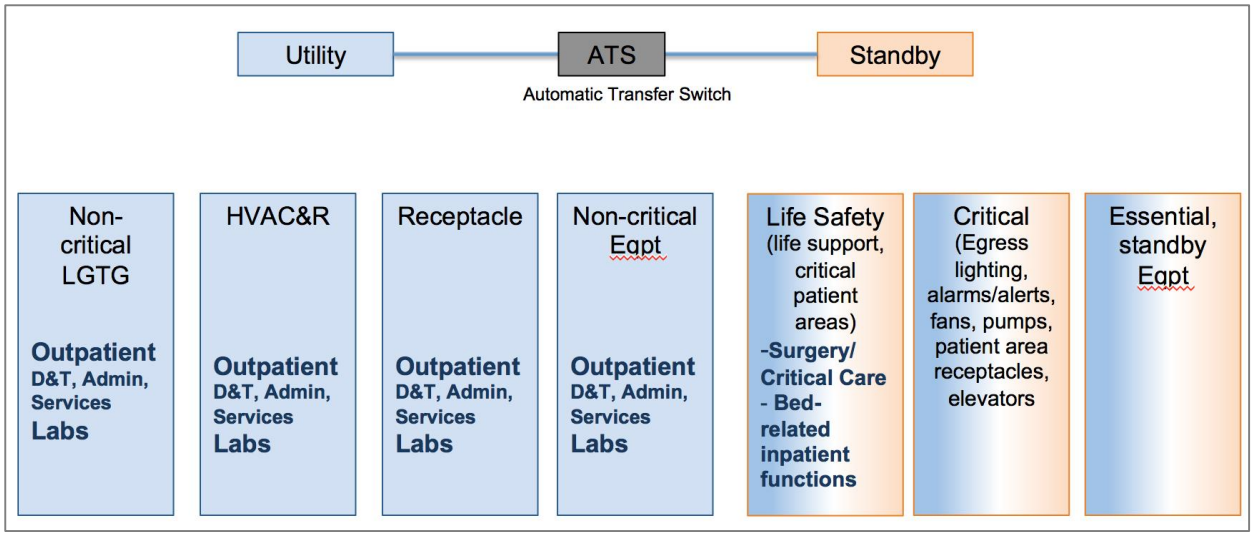


Figure 6: Non-critical loads (in green) and critical loads (shaded green and red) in a healthcare facility with inpatient and outpatient functions (Source: IEEE Health Care Renovations Std 602-2007)

The loads matrix has several loads that would potentially require hundreds of points to comprehensively submeter, which is neither practical nor cost effective. Hence, we prioritized the loads that would be important to monitor, in order to provide the data to feed into the pertinent metrics. For instance, empirically we identified that it is strategically important to measure air flows and supply air temperature, both of which can cause large swings in the EUI of a healthcare facility—probably more than any other factor in such a ventilation-heavy setting. To systematize the selection of primary loads to submeter, we prioritized the loads for submetering (Figure 7), using three deciding factors:

1. **Contribution:** identifying the most significant loads by size in a healthcare facility, based on three proxies: (1) air changes per hour (ACH) as an indicator of ventilation load, (2) lighting power density (LPD) as an indication of high lighting loads, and (3) equipment power, as an indicator of equipment load (Figure 8 and Appendix 3).
2. **Actionability:** investigating which of those loads are actually available to control. Some of the loads are too regulated by standards and regulatory bodies to be actionable.
3. **Meterability:** determining whether the wiring provides an opportunity to disaggregate pertinent loads. Note that U.S. healthcare facilities are required to follow the National Fire Protection Association (NFPA) 70, NFPA 99, and Institute of Electrical and Electronics Engineers (IEEE) White Book (IEEE 2007)(FGI 2014) guidelines for electrical circuit design. In this case, it is easier to predetermine the standardized points for energy monitoring. However, there is more variance in the wiring design in Indian healthcare facilities, therefore the meterability of points may need a facility-by-facility investigation.

At the end of this loads investigation, we generated a prioritized picklist of loads and established a core set of primary monitored points for a packaged EIS. This core set forms a least common denominator of energy monitoring points for a healthcare facility. It provides a shortlist of loads that are both significant and open to the opportunity to be managed, scheduled, and controlled.

This picklist can then be used to inform users of the types of meters and gateways and the associated analysis and visualization. By creating this predefined package of EIS components, one can reduce the usual transaction costs borne from developing custom EIS configurations on a facility-by-facility basis.

	Is the load contributing to major consumption? CONTRIBUTION (Y/N) Y	Is the load available to control/ schedule? ACTIONABLE (Y/N) Y	Can the load be sub-meter discretely? METERABLE (Y/N) Y
Load 1, e.g., Zone Ventilation	✖	–	✖
Load 2, e.g Operating Theater Lighting	✖	✖	–
Load 3, e.g. Imaging Lab	✖		✖
Load 4, e.g. Diagnostic & Treatment Rooms	✖		

Figure 7: Decision framework for picklist of loads (example)

1. What loads are the prominent energy guzzlers for healthcare facilities?
ACH (1 of 3 proxies used: ACH, LPD, and heat gain from equipment)

	Bed related inpatient functions					Outpatient related functions			Diagnostics and treatment	Service functions	Administrative functions	Research and teaching
United States ACH	Nursing area	Surgery + critical care *ICU	Specialized care/ trauma	Patient rooms (inpatient towers)	Autopsy and mortuary services	Labs	Radiology + imaging	Workroom	Diagnostics + treatment	Services	Ancillary	
4-6				■				■	■	Storage area (2) ■	Patient Corridor (2) Pharmacy (4) ■	
6-8	■	■				■			X-ray (6) ■			
8-10	Toilet room (10) ■					Glass wash, sterilize (10) ■	■					
10-12	Isolation (12) ■	X-ray (15) ■			■			■		■		
12-20		■	■									

AIA, Academy of Architecture for Health and the U.S Department of Health and Human Services "Guidelines for Design & construction of Hospital and Health Care Facilities". retrieved from http://www.filterair.info/pdf/aia%20dhhs%20ventilation%20requirements%20for%20areas%20affecting%20patient%20care%20in%20hospitals.pdf

Figure 8: Air Changes per Hour, one of the three proxies used to identify high-energy loads in a healthcare facility. For the other two proxies, Lighting Power Density and Equipment Power, see Appendix 2. (Source: Academy of Architecture for Health and the U.S. Department of Health and Human Services.)

2.2.2 Heterogeneity of organizational characteristics

Based on the varying levels of skills and motivation of an organization, we developed two distinct tiers of packages: Entry and Advanced. These tiers are based on a light-touch and medium-touch approach respectively, that would be commensurate with a particular type of organization. The tiers are driven by the value and justification of EIS features and functionality to determine what each package can and cannot do. The differentiation between the two tiers is in their objective, type of user/audience, and functionality, as well as the usability of the packages. Going from Entry to Advanced tiers also increases the relative complexity, cost, and arguably the energy savings potential.

This separation of tiers enables building managers with extremely limited time and resources to get only the most important information, while allowing those building managers with relatively more time and resources to more closely monitor the energy usage of their building. The approach is that features and functionality of each tier are built around prioritized support provided to the organization types and business drivers important to their organizational goals (Figure 9).

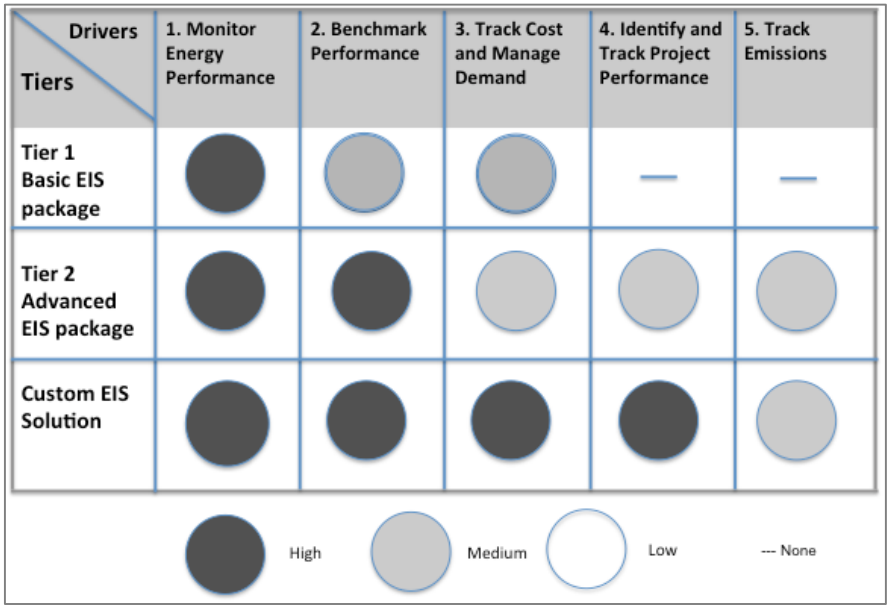


Figure 9: Features and functionality of Entry and Advanced tiers. These are built around prioritized support provided to energy-based drivers and metrics for the sub-sector.

2.3 Usability analysis

In the last step of the methodology, we identified the critical questions for the facility manager to track and report on a short-term (daily/weekly) (Figure 10) or long-term (annual) (Figure 11) basis. Based on these questions, we derived daily and annual dashboards of easy-to-use charts, while also identifying interpretations and thresholds for notifications and alarms. We also identified the two primary audiences for the user interface; namely, facility managers starting at a daily level, and management/executives that would probably see reports monthly or annually. The charts that we have developed as dashboards are shown in Section 3: Results.

Building Pulse at a Glance: *Five metrics to watch daily/weekly*

Primary Audience: Facility Managers, Engineering Staff

1. What is my daily/weekly **absolute energy consumption**? (by fuel: electricity/gas/steam)
   - kWh or kBtu (or therm) per day, per week

2. What is the daily/weekly **normalized energy use intensity** (by fuel: electricity/gas/steam)
   - kWh or kBtu (or therm) per unit square area
   - kWh/occupant (e.g., occupied bed for in-patient facilities, adjusted patient day for outpatient facilities)

3. What is the **load demand per end use** of my building, and are the end uses operating efficiently?
   - kW or kBtu/hour per time period

4. What is the daily/weekly **fuel consumption and cost**
   - kBtu/fuel per time period
   - $ per time period

5. What is my daily/weekly **end-use breakdown (optional)**
   - kBtu or kWh per end use

Figure 10: A list of short-term questions that inform the daily/weekly dashboard

Long-term Picture: *Seven metrics to watch monthly/annually*

Primary Audience: Executives, Facility Managers

1. What is my monthly/annual **absolute energy consumption for the whole building and per selected end use**? (separated by fuel: electricity/gas/steam)
   - kWh or Btu/per month, per year

2. What is the monthly/annual **normalized energy use intensity** (separated by fuel: electricity/gas/steam)
   - kWh or kBtu/unit square area
   - kWh/occupant (e.g., occupied bed for in-patient facilities, adjusted patient day for outpatient facilities)

3. What is the average **load demand per end use** of my building, and are the end uses operating efficiently?
   - kW / time period

4. What is the daily/weekly **fuel consumption and cost**
   - kBtu / time period

5. What is my daily/weekly **end-use breakdown**
   - kBtu or kWh / end use

6. What does an annual snapshot of my facility look like? Is it performing well throughout the course of a month/ year

7. How is my building performing viz. past performance, i.e. Longitudinal benchmarking viz. cost and consumption?

Figure 11: A list of long-term questions that inform the monthly/annual dashboard

3. Results: Technical Requirements for Healthcare EIS-in-a-Box Packages

This section describes the results of our analysis based on the methodology described above**.** We derived the technical requirements for two tiers of packages: Entry and Advanced. Each tier is mapped to the business drivers for the healthcare sector, as shown in Figure 12. Each tier has an associated set of pre-defined metrics, required data inputs, analysis, visualization charts, and notifications (See Appendix 4).

Here is an example of the rationale for the package. A critical **business driver** for the healthcare sector is the continuous monitoring of energy performance. At the Entry tier, in order to respond to that business driver, some of the important **metrics** to track are energy consumption per time period (kWh/kBtu) and power demand (kW, kBtu/hour). **Data inputs** are required to generate the metrics. These are continuously acquired from 15-minute or hourly interval data regarding energy (by fuel) usage from the whole building meters and specific submetered loads, as well as data on continuous loads and peak loads. The EIS back-end software then performs tasks such as tracking readings using the same interval from multiple meters. This provides simple tracking of energy consumption and loads, trend analysis of historical data going back to recommended intervals, and whole building/critical-load daily or weekly load profiling with daytime and nighttime demand loads. For the same business driver, three charts are significant as front-end user **charts:** an Energy Use Area Chart, a Power Demand Trendline, and a Fuel Cost and Consumption Chart. These charts are presented the Section 3.3 Software and user interface for the tiers.

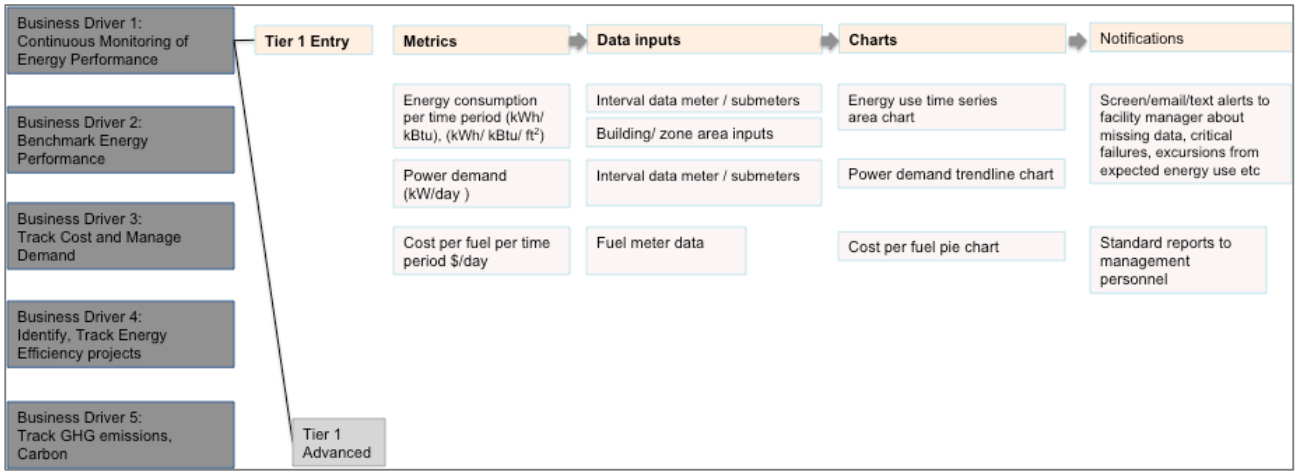


Figure 12: EIS Package mapped to the business drivers

Hence, for each package we determined a set of metrics, mapped to sector-specific business drivers or key performance indictors, as well as a configuration of meters, gateways, and software with a user interface.

As mentioned earlier, an EIS has three components: meters, gateways, and software with a user interface. In terms of the hardware inside the EIS-in-a-box, metering and gateway specifications are provided for each tier, selected from off-the-shelf products that comply with the specifications (Table 1). Gathering whole

building electric, gas, and steam data is an important first-cut task for understanding overall consumption and cost, and to help trigger action towards delving further into a certain fuel or end use. This is followed by submeters identified through the picklist of loads, as described in Section 2.2.1.3 above.

Parameters	Metering Points	Physical Location (Meter Nos)	Communication	Measurement interval	Measured parameters	Accuracy	Data storage capabilities	Additional inputs
Level 1: Entry	Whole Building (WB), 4-6 Major Loads	1 Main distribution board DB (5 Meters)	Wired between meter and gateway, Wi-Fi between gateway (1) and remote database	Hourly	kWh, V, I	Class 1 according to IS13779	5 K Points	None
Level : Advanced	WB, 8-16 Major Loads	1 Main DB + 1 Representative Spaces / Floor DB (15 Meters)	Wired between meter and gateway, Wi-Fi between gateway (1) and remote database	Hourly	kWh, kW, V, I, PF	Class 1 according to IS13779	10 K Points	Level 2 Add Outdoor Air temperature, Add operating schedules Add bldg/ zone areas

Table 1: Metering and gateway requirements for EIS packages

Sections 3.1 and 3.2 present the two tiers for Healthcare EIS-in-a-box.

3.1. The Entry EIS package

The following is a description of the Entry tier Healthcare EIS-in-a-box package (Figure 13).

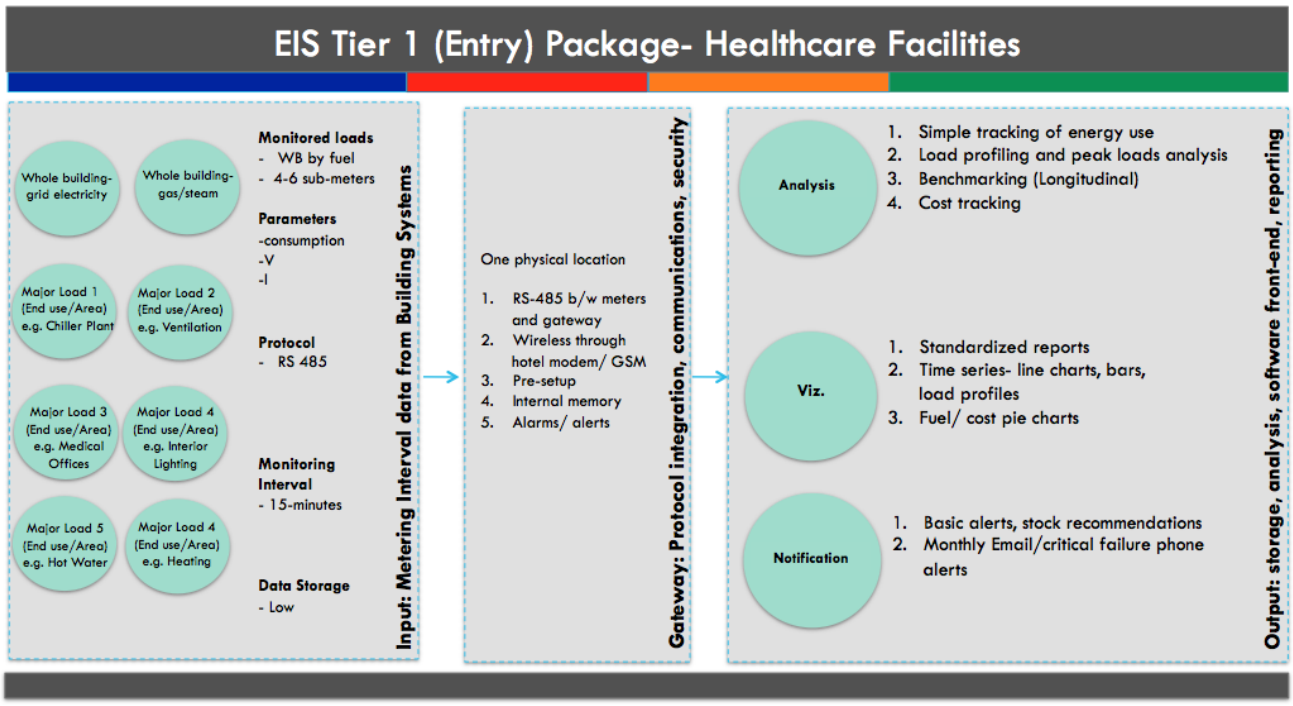


Figure 13: Entry tier EIS package for healthcare facilities

3.1.1 Organization type

The Entry tier is targeted towards healthcare facility owners and managers who have an interest in understanding their building's energy utilization, but have limited skill, resources, and time to do so.

3.1.2 Objective

The Entry tier EIS is a “foot in the door” package to get the user familiarized with installation and use of EIS, and to obtain benefits of a simple EIS based on information about when and how much total energy is being consumed (and wasted), primarily at the whole building level and for the selected submetered loads. This is the simplest and cheapest solution that goes beyond simple utility bill analysis to identify low-hanging fruit for energy savings. The energy savings potential is estimated to be as much as 3–5 percent at a whole building level; each situation will vary.

3.1.3 Metering and data requirements

At the Entry tier, interval meters at whole building load and a small, pre-determined set of 4–6 critical loads, are selected based on the significance of the loads and ease of metering. These loads can be at the end-use level (e.g., a boiler or furnace for heating) or for a particular area (e.g., lab, diagnostics, and treatment rooms). Our analysis showed that HVAC, interior lighting, and hot water comprise the majority of healthcare facility demand; hence, these loads (provided that they are actionable, as determined with the framework shown in Figure 7) are given precedence in the Entry tier package (Table 3). Data inputs from the meters and submeters are directly acquired by the software. No additional user-supplied information need be configured.

3.1.4.Visualization and usability

Visualization and usability consists of seven pre-configured visualization screens—three in the daily dashboard and four in the monthly/annual dashboard (Figures 15–16)—which provide the following:

- Identification of trends and potential electricity waste manually from the basic charts to inform energy efficiency actions. Charts include simple tracking of energy consumption (KWh) and load profiling of critical loads (KW).
- Tracking of whole building energy savings after implementation of an energy efficiency project. The chart shows longitudinal benchmarking to provide visibility into long-term trends about the building's energy performance
- Reconciliation of energy billing cost (Rs/$) and identifying any variances in cost versus actual consumption.
- Notifications, such as basic alerts and stock recommendations to the facility manager, and standard monthly reports to executives.

3.1.5.Required service levels

These simpler levels of analyses can usually be carried out in-house, with limited, infrequent vendor support required for recalibration of meters, software upgrades, etc. The availability of analytics, such as tracking of energy consumption (in kWh or kWh/floor area), energy fuel cost, and hourly load profiling of critical loads (kW) enables users to analyze energy consumption patterns. The identification of high energy consumption and waste enables users to identify big energy guzzlers to target to implement energy efficiency options. It also provides long-term visibility into the building’s energy performance that can be used for benchmarking.

		WB	Ancillary			Adm	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
		Whole Bldg	Labs	Radiology + imaging	Autopsy room		D&T Exam Room	Special procedures	(US only)	Sterill. Eqpt etc	Med. surgical supply	Food prep; laundry	Support space (US only)	Patient rooms nursery, LDRP	Nursing area (isolation ward)	Specialized patient	Surgery and procedures
Heating/Cooling	Central heating: furnace/ boiler	X															
	Central chiller plant, pump, tower	X															
Ventilation	AHUs Outpatient (SAT, flow)	X (multiple)															
	AHUs inpatient (SAT, flow)																
HW	Domestic Water Heating																
Lighting	Non-critical	X															
	critical																
Plugs	MELS																
	Medical																
	Imaging																
	Support eqpt																
	Process loads (refrigeration, elevators)																
	Plant medical eqpt																

Table 2: Picklist of loads for the Entry tier EIS package based on end uses and physical spaces in a healthcare facility (Abbreviations used: SAT Supply air temperature, MELS Miscellaneous electrical loads, AHU Air Handler Units, D&T Diagnostics and Treatment)

3.2 The Advanced EIS package

The following is a description of the Advanced tier Healthcare EIS-in-a-box package (Figure 14).

3.2.1 Organization type

The Advanced tier package is targeted towards healthcare facility owners and managers who have a higher awareness and interest in the benefits of energy efficiency and carbon accounting and the ability to invest dollars and staff resources commensurately.

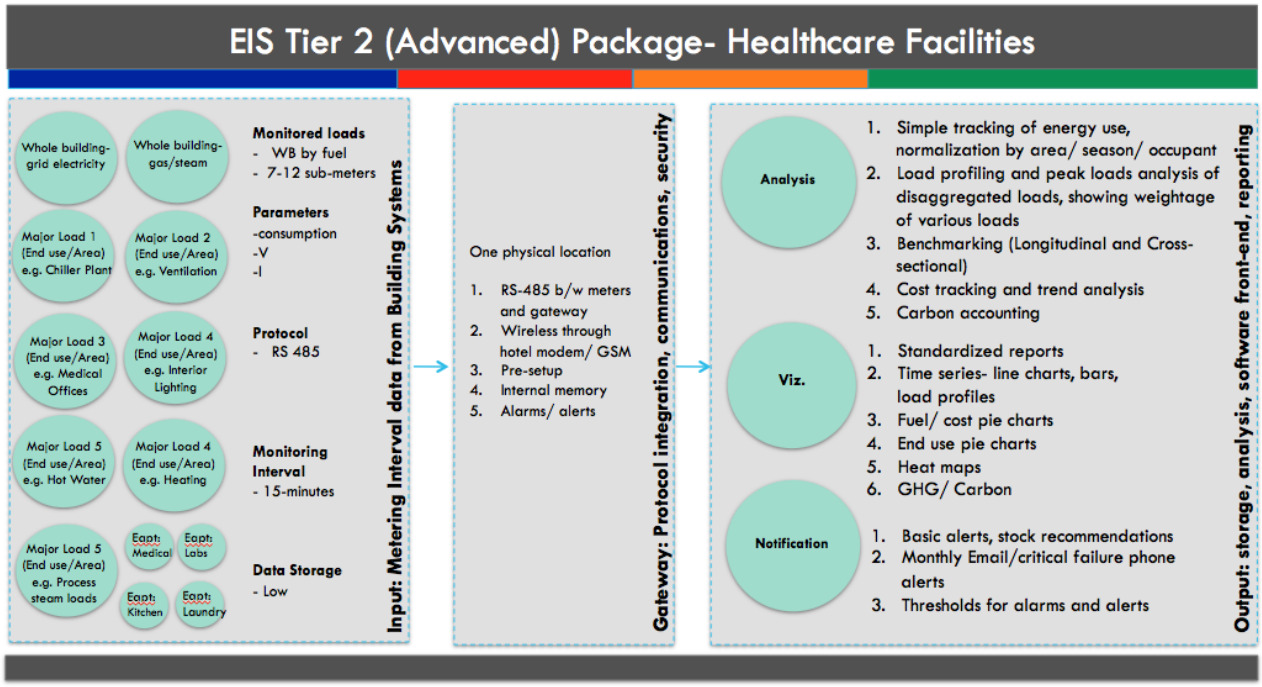


Figure 14: Advanced tier EIS package for healthcare facilities

3.2.2 Objective

A more complex package than the Entry tier, the Advanced tier consolidates more granular data from a larger number of interval meters and provides deeper visibility and analytics in terms of *when* and *how much* and *where* energy is being consumed and wasted. This provides actionable information for arguably higher energy savings, since you can better pinpoint the reasons for use and waste. An Advanced tier package provides deeper benefits of EIS, to provide savings arguably up to 10 percent. The cost is correspondingly higher because of additional metering, upfront software cost, and ongoing software services (analysis, data storage) cost, although the increase in number of points can potentially bring down the cost of the per-point metering cost.

3.2.3 Metering and data requirements

In addition to whole building meters, the Advanced tier EIS requires interval data from 8–16 critical end uses or major areas (See Table 4). Additional user-supplied information needs to be configured into the EIS, such as operating schedules, building/zone square foot areas, and designed occupancy (number of beds, adjusted patient days) that allow normalization and superior analytics.

3.2.4 Visualization and usability

The Advanced tier EIS consists of 10 pre-configured visualization screens: four in the daily/weekly dashboard and six in the monthly/annual dashboard (Figures 15 and 16). In addition to the charts from the Entry EIS package, there are charts depicting cost accounting, carbon accounting, heat maps, and end-use pie charts. See Figure 15 (a)–(d) and Figure 16 (a)–(f), which provide the following:

- Higher granularity and visibility into energy consumption (KWh) and load profiling (kW) of 8–16 major loads drawn from the picklist of prioritized loads. Their selection is based on the primary loads, such heating furnace/boiler and the chiller plant, or major areas that may be actionable, such as administrative areas or medical office buildings. Integration with additional user-provided data makes the Advanced EIS package a powerful tool to provide simple baselines that can be normalized (e.g., for floor area and operational hours) to quickly identify when and where the energy saving opportunities are (i.e., scheduling, anomalies, changes in load profile).
- Cross-sectional benchmarking with respect to a peer group such as a portfolio or other similar healthcare facilities. Benchmarking provides comparative information that reveals the need for improvement in energy performance, helps set energy targets, prioritizes energy efficiency projects, and tracks progress towards those targets.
- Sustainability/greenhouse gas (GHG) tracking, by providing carbon accounting analysis and reports.
- Cost accounting in terms of reporting energy costs against the budget, indicating surplus or deficit.
- Notifications, such as e-mail/phone alerts; some custom recommendations.

Since the Advanced tier relies on data acquisition from a larger set of 8–16 pre-determined meters and has more advanced analytics, it has enhanced capabilities. It can provide simple baseline normalization to ascertain where energy savings opportunities exist through scheduling opportunities, anomaly detections, and changes in load profile. Additional advanced graphics include carbon accounting, cross-sectional benchmarking with peer groups, and energy cost accounting.

3.2.5. Required service levels

The contractual mechanism can be a convenient hybrid of in-house and specific or scheduled vendor-provided services. Vendor services and the ongoing cost can include support, training, upgrade; and cost of any data storage in the cloud-based or vendor-site local server.

		WB	Ancillary			Adm	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
		Whole Bldg	Labs	Radiology + imaging	Autopsy room		D&T Exam Room	Special procedures	(US only)	Sterill. Eqpt etc	Med. surgical supply	Food prep; laundry	Support space (US only)	Patient rooms nursery, LDRP	Nursing area (isolation ward)	Specialized patient	Surgery and procedures
Heating/Cooling	Central heating: furnace/ boiler	X	X			X	X					X					
	Central chiller plant		X			X	X					X					
Ventilation	AHUs Outpatient (SAT, flow)	X (multiple)															
	AHUs inpatient (SAT, flow)	X (multiple)															
HW	Domestic Water Heating	X															
Lighting	Non-critical	X															
	critical																
Plugs	MELS (if controllable)	X															
	Medical																
	Imaging																
	Support eqpt																
	Process loads (refrigeration, elevators)																
	Plant medical eqpt																

Table 3: Picklist of loads for the Advanced EIS package based on end uses and physical spaces in a healthcare facility (Abbreviations used: SAT Supply air temperature, MELS Miscellaneous electrical loads, AHU Air Handler Units, D&T Diagnostics and Treatment)

3.3. Software and user interface for the tiers

Based on the questions to be answered in the short-term (Figure 10), we developed a daily/weekly dashboard. For the Entry level, three charts will be included, and for the Advanced level, all four will be included (Figure 15). Based on the questions to be answered in the long-term (Figure 11), we developed a monthly/annual dashboard. For the Entry level, four charts will be included, and for the Advanced level, all six will be included (Figure 16). These dashboards enable facility staff to monitor and answer pertinent questions quickly and succinctly, and send reports up the management chain to the executive level. Each package provides guidance on how to interpret and relay information from each energy consumption analysis. Flexibility is built in for incremental configuration of charts and associated notifications based on whether they are in the Entry or Advanced packages. See Figures 15 (a)–(d) and Figures 16 (a)–(f).

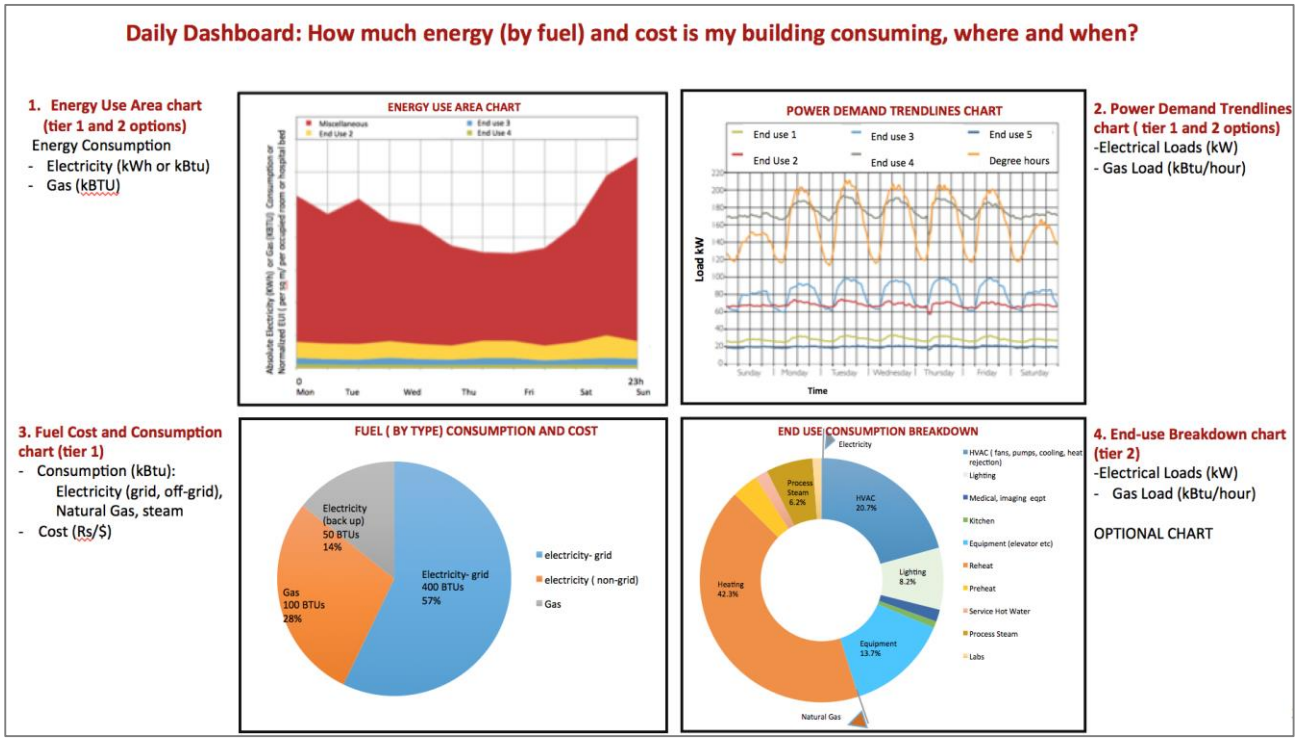


Figure 15: Daily Dashboard for EIS Healthcare packages

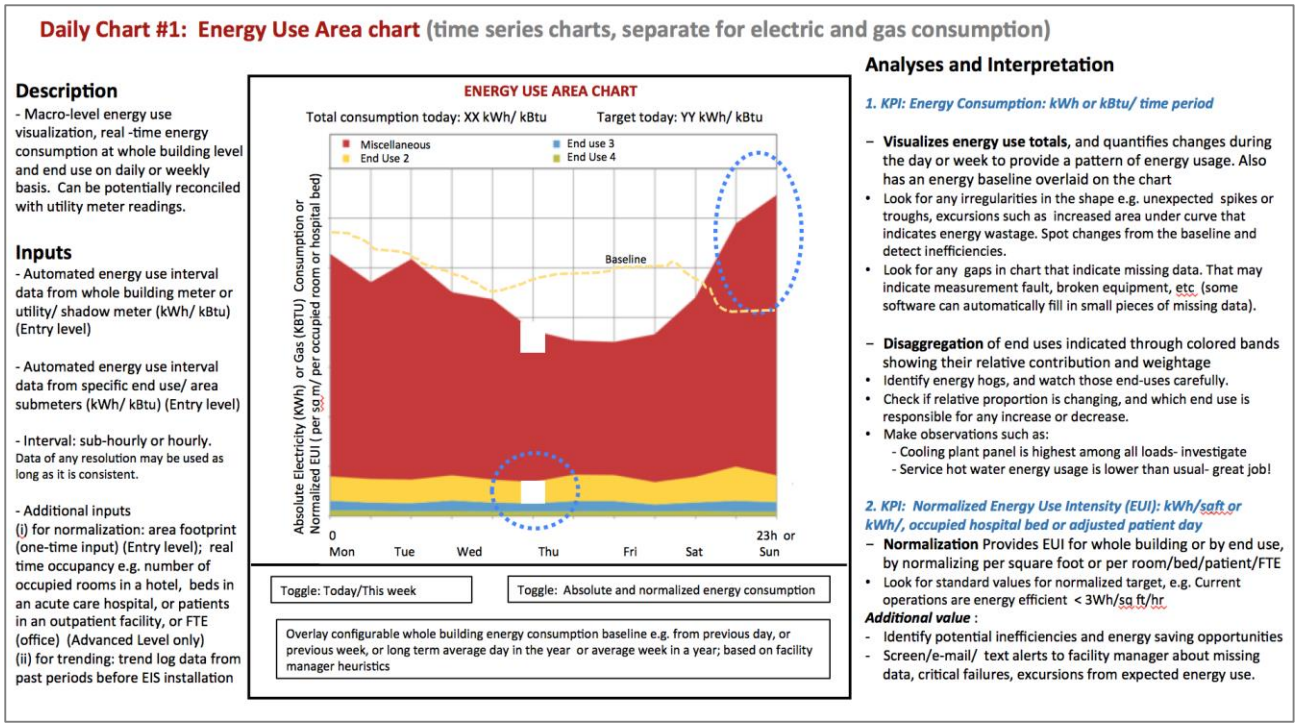


Figure 15(a): Details of Dashboard charts; Daily Chart #1 Energy Use Area Chart. For both Entry and Advanced tiers.

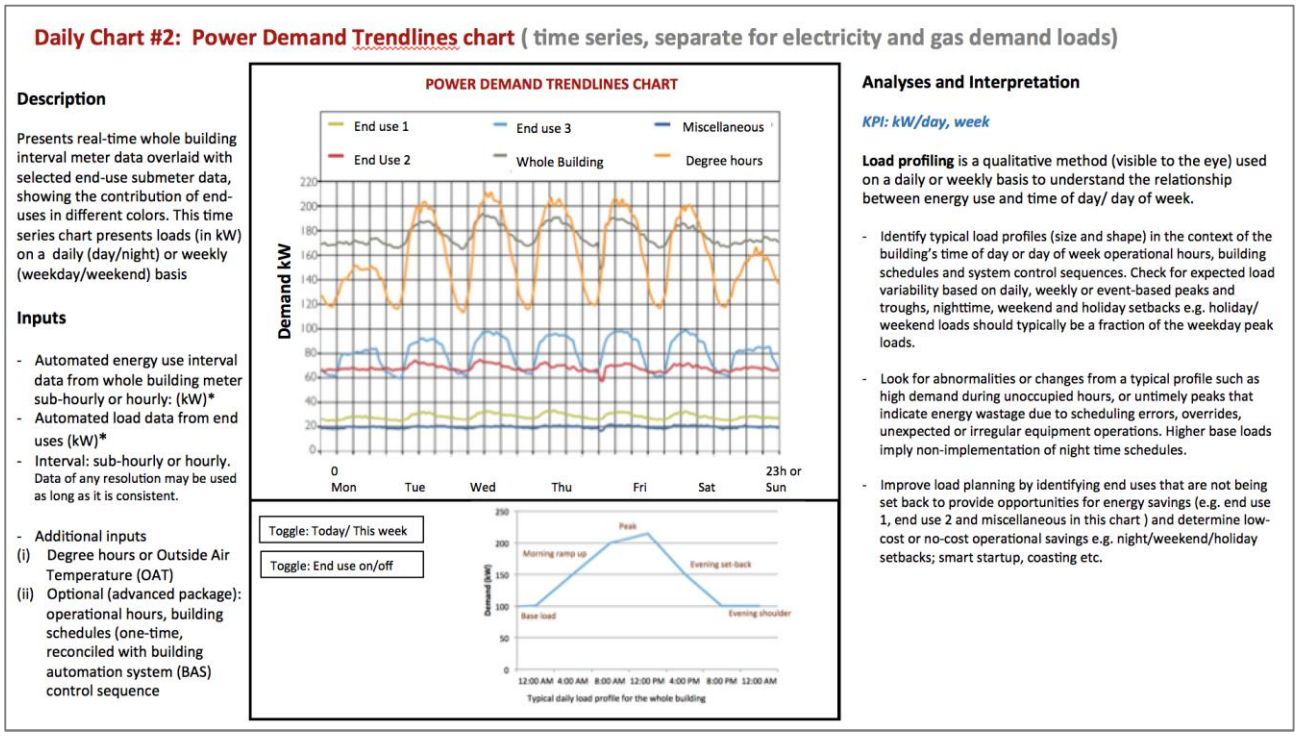


Figure 15(b): Details of Dashboard charts; Daily Chart #2. Power Demand Trendline chart. For both Entry and Advanced tiers.

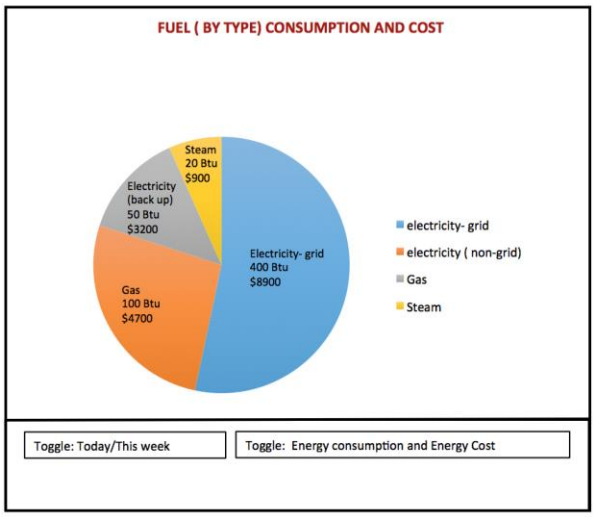
Chart #3: Fuel (by type) Consumption and Cost

Description:

Fuel breakdown: How much fuel of what type is being consumed over the course of a day or a week?

Inputs:

Automated fuel meter data, or utility meter reading over a selected period (kWh/ kBtu)



Interpretation:

KPI: kBtu per fuel type / day or week

Look for energy consumption per fuel type and as a portion of the total consumption

Check consumption against the the monthly utility readings

2. KPI: Cost per fuel type/ day or week

Total Cost per day or week broken down per fuel type

Additional value :

Proportion of back up power utilization for critical functions, UPS etc

- Identify setbacks that reduce use of backup power

Figure 15(c): Details of Dashboard charts; Daily Chart #3. Fuel-type consumption and cost chart. For both Entry and Advanced tiers.

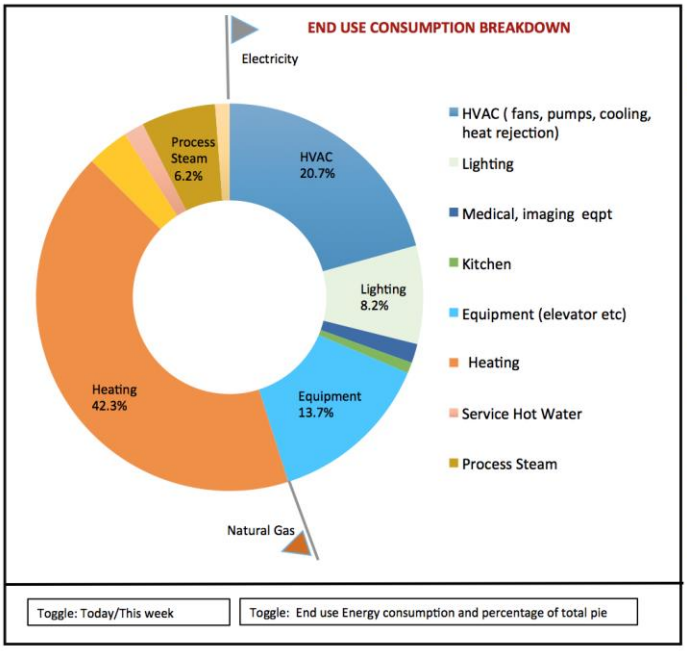
Chart #4: End Use Breakdown chart (optional)

Description:

Snapshot of what fuel is being used to power what end use; and what is the relative weightage of end uses

Inputs:

- Automated fuel meter data, or utility meter reading over a selected period (kWh/ kBtu)



Interpretation:

KPI: kBtu/ end use; % energy consumption/ end use

- **Disaggregation** of end uses indicated through colored bands indicates their relative contribution and comparative weightage
- Identify energy hogs, and watch those end-uses carefully
- Check if relative proportion is changing, and which end use is responsible for any increase or decrease
- Make observations such as:
  - Heating (including reheat) is highest among all loads- investigate cause, and determine action
  - Process steam energy usage is lower than usual- great job!

- System consumption compared by percentage, to help prioritize conservation actions

Additional value that may be derived:

Proportion of gas to electricity usage can help identify what equipment or end uses to set back

Figure 15(d): Details of Dashboard charts; Daily Chart #4. End-use breakdown chart. For Advanced tier.

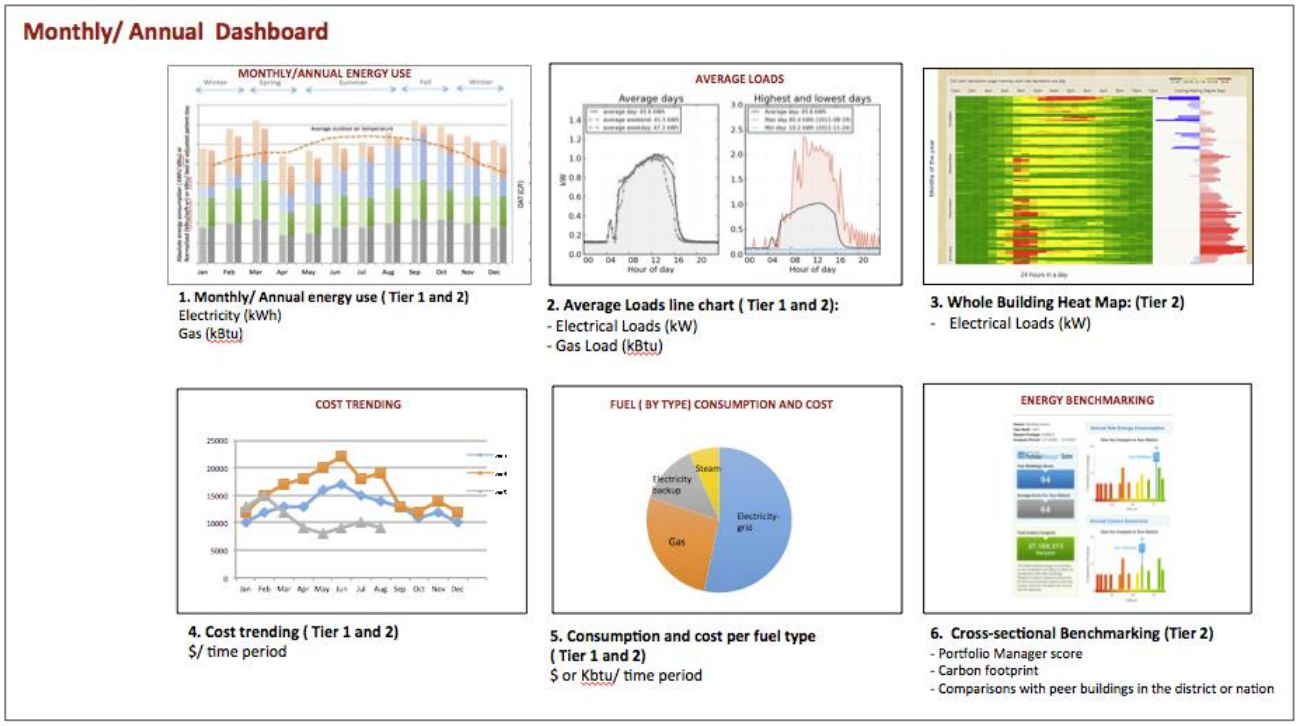


Figure 16: Annual Dashboard for EIS Healthcare packages

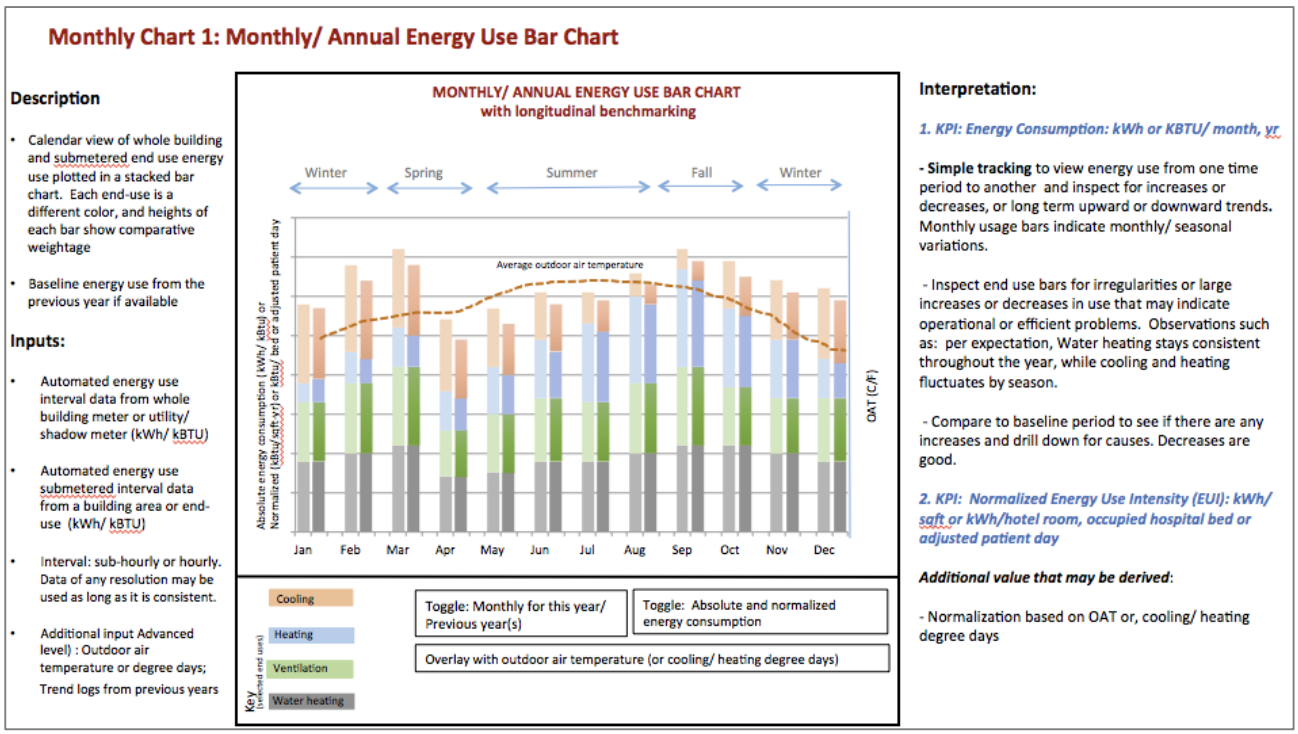


Figure 16(a): Details of Dashboard charts; Monthly Chart #1. End-use breakdown chart. For both Entry and Advanced tier.

Monthly Chart 2: Average Loads Chart

Description: Power intensity

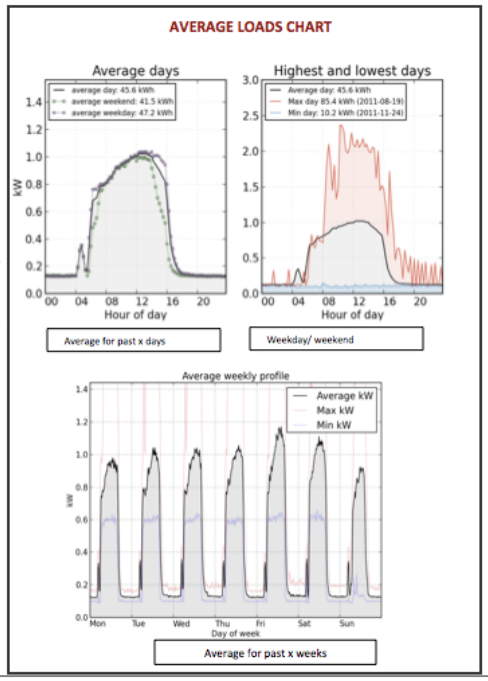
-This chart displays the typical average daily weekly load profile (in kW) corresponding to the buildings occupancy and use for each hour if day or day of the typical week. Loads are shown on the vertical axis, and hours of the day or day of the week are shown on the horizontal axis.

- **Average kW** is the average of all power readings calculated separately for each hour of the week, **Max kW** is the maximum power reading calculated separately for each hour of the week, and **Min kW** is the minimum power reading calculated separately for each hour of the week.

Inputs:

- Automated energy use interval data from whole building meter sub-hourly or hourly: (kW)
- Automated load data from end uses (kW)

Note: Data of any resolution may be used as long as it is consistent.



Interpretation:

KPI: kW/ day or week, examined per month or per season

- Peak load analysis: Presents daily or weekly average, min and max loads and daily range. Daily or weekly max- to-min ratio provides an estimate of how much total load is turned off and on every day or weekly. Usage is observed during non-working hours, and investigated using hourly data
  - Low ratio: indicates that loads are being left on continuously e.g. phantom loads; analysis may provide opportunities for turning off end uses or equipment
  - Medium ratio: indicates good controls e.g. holiday/weekday setbacks are 50% lower than weekday operations; analysis may present opportunities to extend or deepen shut-off periods, and reduce peaks
  - High ratio (e.g.>300%) indicates very high peaks (bad) ; or extremely deep shut-offs (good). Drill down further on the cause for high ratio Provides the range in load across the year, for any time of the year . e.g. at noon, the load varies between 0.2 and 2.3 kW
- Peak load analysis- informs the utility cost expectation. Take actions to reduce the peak demand and reduce utility bills
- Calculates load variability. Low load variability implies the loads can be predicted well using historic data

Additional value that may be derived:

- **Improving Load planning**: e.g. Higher base loads imply non-implementation of night time schedules. Reveals energy savings potential even though day-night differential in hotels and hospitals may not be as high as in offices
- **Peak load analysis** reveals magnitude of peak, including "Most likely maximum load". Can help inform system sizing in retrofit projects

Figure 16(b): Details of Dashboard charts; Monthly Chart #2. Average Loads chart. For both Entry and Advanced tier.

Monthly Chart 3: Whole Building Power Heat map

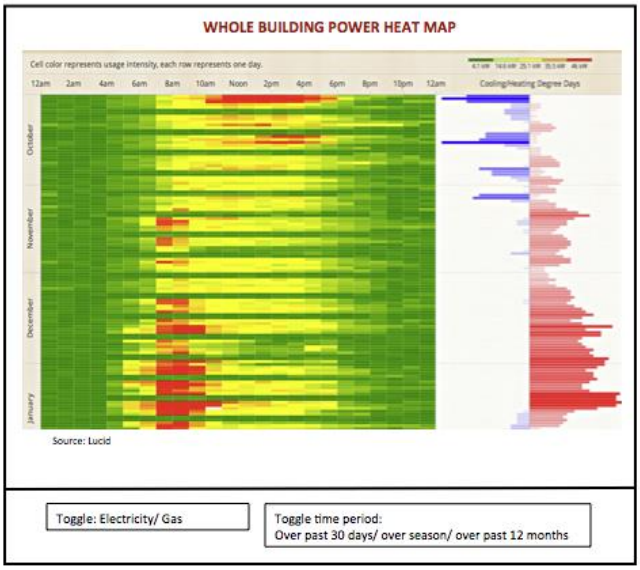
Presentation:

Power Heat Map
View a macro-level snapshot of energy use at a high level, that reveals usage patterns, weather sensitivity, and opportunities for scheduling and controls refinements. Each row is one day, and each column is an hour of the day, the Heat Map can plot an entire year of hourly data — 8,760 data points — in one screen.

Inputs:

- Power demand of every end use/ load meter

Note: Data of any resolution may be used as long as it is consistent.



Interpretation:

KPI: Power intensity: kW

Chart color codes through a pixel grid the power demand of every meter reading, Pixel color indicates high or low power demand- greens are low, yellow/ orange are medium, red is high. Weather is plotted.

- Horizontal bands indicate change in consumption
  - Energy use be highest at midday say for an office when the building is fully occupied and the impact of weather conditions is most pronounced, while off-hours should see reductions in consumption
  - Weekly horizontal bars reveal weekend setbacks with building systems maintaining nighttime set points through the unoccupied weekend. Vacations surface as larger horizontal bars.
  - Lack of vertical band implies poor nighttime shutoff
  - Lack of horizontal banding implies poor weekend shutoff
  - Small horizontal bands implies shutoff during consecutive days e.g. weekends
  - Wider horizontal bands indicates seasonality of energy use
- Vertical bands show consistency of scheduling and tight controls
- Make observations such as:
  - December and January the heating loads are high because of high heating degree days
  - If control schedules are disrupted or changed, changes in the colors or 'hot spots" will encourage further investigation. Sudden high consumption during hours that are normally low may suggest changes in building settings if there aren't any occupancy or weather related factors to explain the increase in consumption. Executives can ask Facility managers to provide reports for hot spots and how they were dealt with.

Figure 16 (c): Details of Dashboard charts; Monthly Chart #3. Whole Building Power Heat map. For Advanced tier.

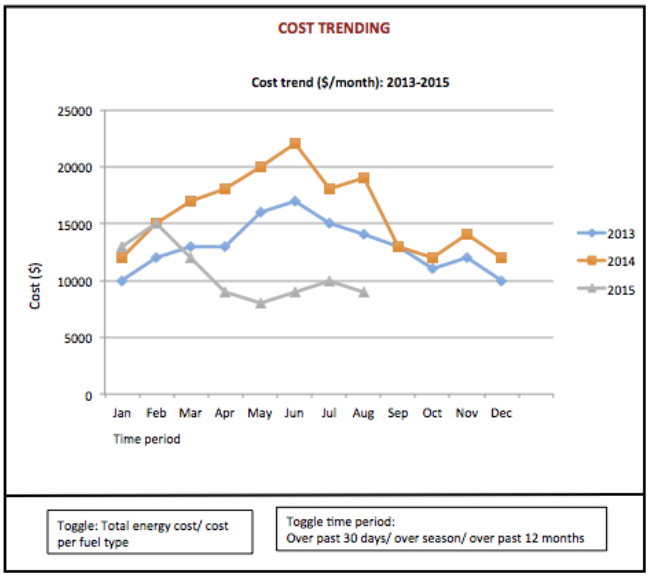
Monthly Chart 4: Cost trending

Presentation:

Line graph revealing the monthly energy cost. Also shows previous years cost profile

Inputs:

Cost, reconciled with utility bills



Interpretation:

KPI: $/month

Figure16 (d): Details of Dashboard charts; Monthly Chart #4. Cost trending chart. For both Entry and Advanced tiers.

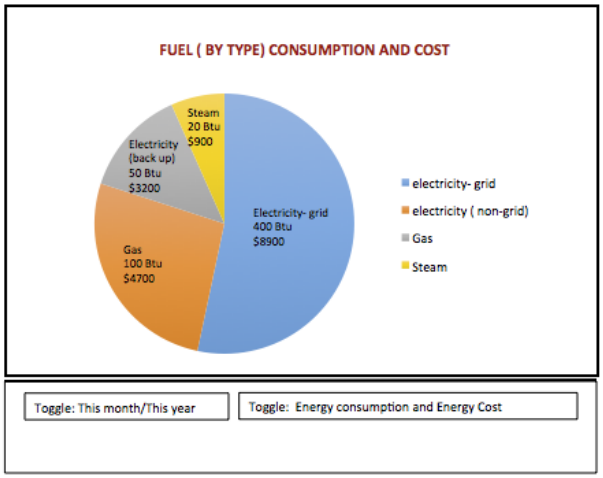
Monthly chart 5: Fuel-type consumption and cost

Description:

Fuel breakdown: How much fuel of what type is being consumed over the course of a day or a week

Inputs:

- Automated fuel meter data, or utility meter reading over a selected period (kWh/ kBTU)



Interpretation:

KPI: kBTU per fuel type / day or week

Look for energy consumption per fuel type and as a portion of the total consumption

Check consumption against the the monthly utility readings

2. KPI: Cost per fuel type/ day or week

Total Cost month or year broken down per fuel type

Additional value :

Proportion of back up power utilization for critical functions, UPS etc

Figure 16(e): Details of Dashboard charts; Monthly Chart #5. Fuel-type consumption and cost chart. For both Entry and Advanced tiers.

Figure 16(f): Details of Dashboard charts; Monthly Chart #6. Benchmarking chart. For Advanced tier.

4. Conclusions

In summary, EIS is a highly relevant technology for driving energy savings in the healthcare sector where 3–5 percent of the annual operating costs are energy related. CBERD Healthcare EIS-in-a-box solutions try to achieve the following three goals:

1. To ease the sales cycle for vendors (especially for new or tough-to-penetrate markets) and procurement and operations by users; characterize transactional costs in current practice and develop a **cost-effective** EIS package.
2. To develop EIS solutions on per-sector basis rather than customized on a per-building basis (current practice); engineer packages to accommodate heterogeneity across buildings in target building sectors, to make them **scalable.** Establish broader market applicability of EIS to various building types and regions.
3. To create EIS solutions that can be applied to levels of organizational key performance indicators (KPIs). Engineer for **simplicity**—integrate the three main components (i.e., meters, gateways, and software) into tiered EIS packages. Technical simplification of products and their usability is a real need and path towards deployment scalability.

While EIS packages do not provide all of the features available through more complex, custom-built EIS solutions, they represent a cost-effective option for stakeholders interested in increasing their property's energy efficiency. The sector-specific packages allow building owners and managers to easily install and monitor their energy usage, as well as identify areas for improvement and cost savings, and encourage market adoption of the technology.

References

Askin, Elisabeth, and Nathan Moore. 2014. *The Health Care Handbook: A Clear and Concise Guide to the United States Health Care System*. First Edit. Washington U in St. Louis.

Dey, Mrinmoy. 2013. "Infrastructure - Healthcare Injecting Growth." *SEL* 1: 60–65.

Office of Energy Efficiency and Renewable Energy, US Department of Energy. 2012. "2011 Buildings Energy Data Book."

U.S. Energy Information Admininistration 2003. "Commercial Buildings Energy Consumption Survey (CBECS)." *Consumption & Efficiency*.

Facilities Guidelines Institute. 2014. *2014 FGI Guidelines for Hospitals and Outpatient Facilities*. 2014th ed.

Gudwani, Ayushi, Palash Mitra, Ankur Puri, and Mandar Vaidya. 2012. "India Healthcare : Inspiring Possibilities , Challenging Journey (Prepared for Confederation of Indian Industry)."

Indian Brand Equity Foundation. 2015. "Indian Healthcare Industry Analysis." http://www.ibef.org/industry/healthcare-presentation.

Institute of Electrical and Electronics Engineers. 2007. "Electric Systems in Health Care Facilities." Vol. 2007.

Kapoor, Ravi, and Satish Kumar. 2011. "Energy Efficiency in Hospitals Best Practice Guide." *Development*. New Delhi.

Mazzetti. 2015. "Personal Communication with Walt Vernon."

Roth, Kurt W, Detlef Westphalen, Michael Y. Feng, Patricia Llana, and Louis Quartararo. 2005. "Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential." *U.S. Department of Energy*.

Thamba, Varun, Divyanshi Gupta, Syed Ibrahim, and Arokia Manoj Kumar. 2012. "Demand Forecast of Hospitals in India."

Literature Review

Askin, Elisabeth, and Nathan Moore. 2014. *The Health Care Handbook: A Clear and Concise Guide to the United States Health Care System*. First Edit. Washington U in St. Louis.

Black, Douglas R, Judy Lai, Steven M Lanzisera, Kristen D Parrish, and Brett C Singer. 2011. "E RNEST O RLANDO L AWRENCE Healthcare Energy Efficiency Research And Development Environmental Energy Technologies Division" (500).

Bonnema, Eric, Shanti Pless, and Ian Doebber. 2010. *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*. *Journal of Healthcare Engineering*. Vol. 1. doi:10.1260/2040-2295.1.2.277.

Dey, Mrinmoy. 2013. "Infrastructure - Healthcare Injecting Growth." *SEL* 1: 60–65.

U.S. Energy Information Admininistration. 2003. "COMMERCIAL BUILDINGS ENERGY CONSUMPTION SURVEY (CBECS)." *Consumption & Efficiency*.

Facilities Guidelines Institute. 2014. *2014 FGI Guidelines for Hospitals and Outpatient Facilities*. 2014th ed.

Granderson, J. 2013. "Energy Information Handbook: Applications for Energy-Efficient Building Operations:" 298. doi:LBNL-5272E. http://escholarship.org/uc/item/03z8k1v3.pdf.
Granderson, Jessica, and MA Piette. 2009. "Building Energy Information Systems: State of the Technology and User Case Studies."

Gudwani, Ayushi, Palash Mitra, Ankur Puri, and Mandar Vaidya. 2012. "India Healthcare : Inspiring Possibilities , Challenging Journey (Prepared for Confederation of Indian Industry)."

Hatten, Michael, Houten BozVan, Heather Burpee, and Joel Loveland. 2011. "Targeting 100! - Energy Use and Model Calibration Study: Legacy Salmon Creek Medical Center Vancouver, Washington - Advanced Energy Efficient Building Technologies for High Performance Hospitals - Study Hospital Report." *Energy*.
Hospitals, Energy Efficient. "Energy Efficient Hospitals – Visiting the Realities."

Indian Brand Equity Foundation. 2015. "Indian Healthcare Industry Analysis." http://www.ibef.org/industry/healthcare-presentation.

Institute of Electrical and Electronics Engineers. 2007. "Electric Systems in Health Care Facilities." Vol. 2007.

Kaiser. 2015."Kaiser Integrated Care Continuum." Brochure

Kapoor, Ravi, and Satish Kumar. 2011. "Energy Efficiency in Hospitals Best Practice Guide." *Development*. New Delhi.

Mazzetti. 2015. “Personal Communication with Walt Vernon.”
National Renewable Energy Laboratory. 2011. “Guide Healthcare Energy Metering Guidance Low-Cost / No-Cost Metering with Existing Resources Recommended Steps for Hospitals □.”

Pat Lydon. 2015. “Finding and Funding an EMIS System - Legacy Health.”

Roth, Kurt W, Detlef Westphalen, Michael Y. Feng, Patricia Llana, and Louis Quartararo. 2005. “Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential.” *U.S. Department of Energy*.

Schneider Electric. 2011. “Designing a Metering System for Small and Medium-Sized Buildings.”

Sheppy, Michael, Shanti Pless, and Feitau Kung. 2014. “Healthcare Energy End-Use Monitoring Healthcare Energy End-Use Monitoring” (August).

Singer, Brett C, Jennifer L Coughlin, and Paul a Mathew. 2009. “Summary of Information and Resources Related to Energy Use in Hospitals – Version 1.0. LBNL-2744E.” *Facilities* (October 2009).

Singer, Brett C, Paul Mathew, Steve Greenberg, William Tschudi, Dale Sartor, Susan Strom, Walter Vernon, Mazzetti Nash, and Lipsey Burch. 2009. “Hospital Energy Benchmarking Guidance - Version 1 . 0.” *State Government* (October).

Taddonio, Kristen. 2014. “Better Building Alliance Update for Healthcare.”

Appendices for

CARING FOR THE ENERGY HEALTH OF HEALTHCARE FACILITIES

SEPTEMBER 30, 2015

CEPT University : Auroville CSR : IIIT Hyderabad : IIT Bombay : IIM Ahmedabad : MNIT Jaipur;
Lawrence Berkeley National Lab : Oak Ridge National Lab : RPI New York : UC Berkeley : Carnegie Mellon University

Appendix 1: Categorization of Healthcare facilities in U.S. and India

U.S. Healthcare Facilities : three categories

Inpatient (Hospitals)

Patient gets admitted to a medical facility for at least one night

General Acute Care

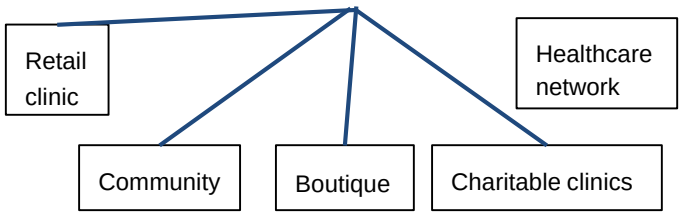
- Multi-specialty hospitals
  e.g. Cedar-Sinai LA
- Academic medical centers (research and teaching)
  e.g. Mass General, Brigham
- Community hospitals
  e.g. Kaiser, Sutter
- Critical access hospitals (1332, for rural communities, <25 beds
  e.g. .Healdsburg Distt Hospital, Sonoma

Specialty Care

- By specialty e.g..children's, cardiology, oncology, birthing centers
- acute psychiatric e.g. mental health and rehab institutions

Outpatient care or "ambulatory care" (Clinic)

Patient is examined, diagnosed or treated at a medical facility but stays less than 24 hours



General OP

- Surgical (Emergency department ED, Urgent Care Center (UCC); for suturing, abscess drainage etc
- Medical office Building (MOB), physician's offices
- Diagnostics & Labs
- Imaging centers, e.g. mammograms

Specialty OP

- Behavioral health e.g OP Rehab, psychiatric centers
- Ambulatory Surgery Center (ASC): for procedures - colonoscopy, endoscopy, dialysis, cataract removal
- Non physician services: dentists, OB/GYN, chiropractors, podiatrists, physical therapists, optometrists
- complementary & alternative medicines: acupuncture, homeopathy etc

"Post acute care" (long-term-care) (aka Skiled Nursing)

Nursing care and assistance with daily living

- Skilled nursing long term care (US has 1.7 million beds, 3-30 days stay)
- Long term acute care hospitals (US has 420 hospitals)
- Inpatient rehab facilities (US has 1166 hospitals, for strokes, fractures etc)
- Hospice care
- Medical hotels (rare in US, unlicensed

US Trends towards:
Outpatient and urgent care functions, and shorter patient stays
High service levels and quality of delivery, energy use and wastage

Askin E. and Moore N (2014). The Health Care Handbook - A Clear and Concise Guide to the United States Healthcare System. Washington University in St. Louis Press; Mazzetti response to LBNL Survey

India Healthcare Facilities : three categories

Inpatient
14% CAGR

Hospitals (Government/ Private/ Trust-run)

General Tertiary care level
- Multi-specialty hospitals: Apollo, Max, Fortis, Manipal, Wockhardt, 1000 beds
- Teaching hospitals 500 beds+ e.g. AIIMS, Christian Medical College
- District hospitals ~250 beds
- Subdivision/tehsil taluka hospitals <100 beds
- Primary Health Centers <10 beds

Specialty tertiary care level

- Cardiology (CAGR 18%) e.g. Escorts, Birla Heart Center
- Oncology (CAGR 16%) e.g, Health Care Global, Tata)
- Diabetes (CAGR 19%) e.g. Dr Mohuns, Chennai
- Laparoscopy, Urology e.g. RG Stone
- Ophthalmology: Vasan Eye Care, Aravind

Medical tourism

Medi city: Medanta cardiac medicity, Gurgaon, Aster Medicity Kochi

Outpatient care or "ambulatory care"
8% CAGR , mostly in diagnostics

General
Primary Health Centers
Community Health Centers

Specialty

- Diagnostics:
  Imaging (30%), pathology (70%)
- Daycare Surgery
- Clinics and Polyclinics
- Dispensaries

"Post acute care"
Nursing care and assistance with daily living

- Nursing Homes
- long term acute care hospitals
- inpatient rehab facilities

Indian Trends towards:
Medical tourism
Acute inpatient care
Multispecialty
Aspirational higher service levels leading to higher energy use and wastage

Mapping spaces in US and Indian (high-end) healthcare facilities

	Bed related inpatient functions			Outpatient related functions			Diagnostics and treatment	Service functions		Administrative functions	Research and teaching
United States	**Nursing area** Patient rooms, toilets, labor and delivery, intensive care	**Surgery + critical care** *ICU	**Patient rooms** Inpatient towers	**Labs** Anatomical, pathology and clinical pathology	**Radiology + imaging**	**Workroom** Clean/ soiled	**Diagnostics + treatment** Exam rooms. medical office	**Services** Housekeeping, food services and kitchen		**Ancillary** Pharmacy, waiting/admin	
India	**Nursing** Patient room, toilet, intensive care, protective isolation,infectious isolation + anteroom,labor/delivery/recovery/post partum, patient corridor)	**Surgery and critical care** (operating rooms - all OA and recirculated air), delivery rooms, recovery rooms,nursery suite, trauma room and anesthesia)	Wards	**Ancillary** (Radiology - surgical, critical care , D&T, Labs, autopsy, non refrigerating body holding room and pharmacy)			**Diagnostic and Treatment** (Examination room, medication and treatment room, physical therapy and soiled workroom/holding, clean workroom/holding)	**Sterilizing and Supply** Sterilizer equipment room; soiled or decontamination; cleaned workroom and sterile storage and equipment storage	**Services** Food prep center and general laundry	**Administration** Admission rooms and waiting rooms	

Appendix 2: Understanding the prominent energy demand in healthcare facilities

Three proxies are used

1. Air changes per hour (ACH)
2. Lighting Power Density (LPD)
3. Equipment Power

1. What loads are the prominent energy guzzlers for healthcare facilities?
ACH (1 of 3 proxies used: ACH, LPD, and equipment power)

	Bed related inpatient functions					Outpatient related functions			Diagnostics and treatment	Service functions	Administrative functions	Research and teaching
United States ACH	**Nursing area**	**Surgery + critical care** *ICU	**Specialized care/trauma**	**Patient rooms** (inpatient towers)	**Autopsy and mortuary services**	**Labs**	**Radiology + imaging**	**Workroom**	**Diagnostics + treatment**	**Services**	**Ancillary**	
4-6				■				■	■	**Storage area (2)** ■	**Patient Corridor (2) Pharmacy (4)** ■	
6-8	■	■				■			**X-ray (6)** ■			
8-10	**Toilet room (10)** ■					**Glass wash, sterilize (10)** ■	■					
10-12	**Isolation (12)** ■	**X-ray (15)** ■			■			■		■		
12-20		■	■									

AIA, Academy of Architecture for Health and the U.S Department of Health and Human Services "Guidelines for Design & construction of Hospital and Health Care Facilities". retrieved from http://www.filterair.info/pdf/aia%20dhhs%20ventilation%20requirements%20for%20areas%20affecting%20patient%20care%20in%20hospitals.pdf

Chart based on Energy guzzlers for US (based on ACH)

Outpatient → Inpatient

Nursing Facilities →

		Ancillary			Administration	Diagnostics and Treatment		Skilled Nursing	Sterilizing & surgical supply		Services		Inpatient Nursing		Surgery and Critical care	
	United States ACH	**Labs** (Anatomical,pathology and clinical pathology,pharmacy)	**Radiology + imaging** (X ray (diagnostics & treatment; X-ray surgery & critical care; darkroom)	**Autopsy** (autopsy, non refrigerating body holding room)	(main lobby, medical records, business offices,waiting/admin)	(Exam, medication room, therapy)	Bronchoscopy, sputum collection pentamidine admin, soiled workroom or soiled holding	(Resident room, corridor,toilet room, resident gathering	Sterilizer equipment, sterile storage and equipment storage)	**Medical surgical supply** (soiled, clean workroom, sterile storage)	(Food prep; warewashing, laundry;linen trash chute janitor's closet, bathroom)	Support spaces (Soiled room ; hazardous materials;	**Patient rooms** (Inpatient wards/private rooms, newborn nursery,labor/delivery/recovery/postpartum	**Nursing area** (Protective, Airborne infection isolation, toilets)	**Specialized patient** (Burn units, treatment, Newborn, recovery room, intensive care, treatment)	**Surgery + Procedures** (operating rooms, ER incl waiting rooms, triage and Radiology waiting
Low	2							**resident room**			**Dietary and clean linen storage**			**Corridor**		
Low	4- 6											**clean work room**				
Low	6-8															**Anesthesia,Gas Storage(6-8)**
Medium	8-10	**Glass washing, Sterilizing (10)**	**Darkroom, if present**					**Bathing room**								
High	10-12						**Procedure,bronchoscopy (12)**									
High	12-20		**X ray-surgery/Critical care (15)**				**Endoscopy (15)**									**ER waiting, Triage, radiology waiting room (12) Trauma,Laser eye room(15) Surgical room;operating rooms; delivery (20)**

ASHRAE 2010. Standard 90.1 (IP Edition) Energy Standard for Buildings Except Low-Rise Residential Buildings (ANSI Approved; IESNA Co-sponsored)

Chart based on Energy guzzlers for India (based on ACH)

Outpatient → Inpatient

		Administration	Diagnostics + treatment		Ancillary			Service	Sterilizing & supply	Inpatient Nursing		Surgery & critical care	
	India	(Waiting/admitting rooms)	Bronchoscopy, sputum collection and pentamidine admin, soiled workroom or soiled holding	(Examination room, medication and treatment room, physical therapy, clean workroom or clean holding)	**Labs** (Anatomical,pathology and clinical pathology, pharmacy	**Radiology** (X ray (diagnostics and treatment) X-ray (surgery and critical care and darkroom)	**Autopsy** (Labs, autopsy, non refrigerating body holding room)	(Food preparation; laundry)	(Sterilizer equipment room; soiled or decontamination room; clean workroom and sterile storage and equipment storage)	**Patient wards** (Inpatient wards and private rooms, intensive care patient corridor, labor/delivery/recovery/post partum, recovery room)	**Nursing area** (protective isolation,infectious isolation + anteroom,toilet)	**specialized patient/trauma recovery** (nursery suite, trauma room)	**Surgery + critical care** (operating rooms, anesthesia, delivery room)
Low	**2**												
Low	**4-6**									Patient corridor (4)			
Low	**6-8**												recovery room, Anesthesia storage
Medium	**8-10**				Lab sterilizing, glass washing	Darkroom			sterilizer equipment room		toilet		
High	**10-12**												
High	**12-20**					X-ray surgical and critical care							

Kapoor, R. Kumar, S. (March 2011). Energy Efficiency in Hospitals: Best Practice Guide. New Delhi, India. Adapted from NBC 2005 and ASHRAE Handbook 2007 HVAC Application.

Lighting Power Density (LPD) for U.S.

Outpatient

Inpatient

Nursing Facilities

		Ancillary			Administration	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
	LPD (W/ft² & W/m²)	**Labs** (Anatomical,pathology and clinical pathology, pharmacy	**Radiology + imaging** (X ray (diagnostics and treatment; X-ray surgery and critical care and darkroom)	**Autopsy room** (autopsy, non refrigerated body holding room)	(main lobby, medical records, business offices,waiting/admin)	**Diagnostics + treatment** (Exam, medication room, MRI room,therapy dept)	Bronchoscopy, sputum collection and pentamidine admin, soiled workroom or soiled holding	Resident room, corridor,toilet room, resident gathering	Sterilizer equipment, sterile storage and equipment storage, utensils)	**Medical surgical supply** (soiled, clean workroom, sterile storage)	(**Food preparation**; warewashing, laundry;linen and trash chute janitor's closet, bathrooms)	**Support space** (Soiled room ; hazardous materials;	**Patient rooms** (Inpatient wards/private rooms, newborn nursery,labor/delivery/recovery/postpartum	**Nursing area** (Protective, Airborne infection isolation, toilets)	**Specialized patient** (Burn units, treatment, Newborn, recovery room, intensive care, treatment)	**Surgery + Procedures** (operating rooms, ER incl waiting rooms, triage and Radiology waiting
Low	0-1 W/ft² 0.0-0.98W/m²										-Laundry (0.60/6.5)		-Patient Room (0.62/6.67) -Corridor (0.89/9.68)	-Nurse Station (0.87/9.36) -Nursery (0.88/9.47)		
Medium	1-2 W/ft² 0.99-1.99 W/m²	Labs (1.81/19.48)	-Radiology and Imaging (1.32/14.21)		-Waiting Room(1.07/11.51)	-Physical Therapy (0.99/10.65) -Pharmacy (1.14/12.27) -Exam treatment (1.66/17.86)				-Medical Supplies(1.27/13.67)					-Recovery (1.15/12.37)	-Operating Room (1.89/20.34)
High	2-3 W/ft² 1.99-3.0 W/m²															-Emergency (2.26/24.32)

ASHRAE 2010. Standard 90.1 (IP Edition) Energy Standard for Buildings Except Low-Rise Residential Buildings (ANSI Approved; IESNA Co-sponsored)

Lighting Power Density (LPD) for India

Outpatient

Inpatient

Nursing Facilities

	Ancillary			Administration	Diagnostics + treatment		Sterilizing & supply	Services	Inpatient Nursing		Surgery & critical care	
LPD (W/ft² & w/m²)	**Labs** (Anatomical,pathology and clinical pathology, pharmacy	**Radiology** (X ray (diagnostics and treatment) X-ray (surgery and critical care and darkroom)	**Autopsy** (Labs, autopsy, non refrigerating body holding room)	(Waiting/admitting rooms)	Bronchoscopy, sputum collection and pentamidine admin, soiled workroom or soiled holding	(Examination room, medication and treatment room, physical therapy, clean workroom or clean holding)	(Sterilizer equipment room; soiled or decontamination room; clean workroom and sterile storage and equipment storage)	(Food preparation; laundry)	**Patient wards** (Inpatient wards and private rooms, intensive care - ICU, patient corridor, labor/delivery/recovery/postpartum, recovery room)	**Nursing area** (protective isolation,infectious isolation + anteroom,toilet)	**specialized patient/trauma recovery** (nursery suite, trauma room)	**Surgery + critical care** (operating rooms, anesthesia, delivery room)
0-1 W/ft² 0.0-0.98W/m²		-Radiology and Imaging (0.4/4.3)		-Waiting Room (0.79/8.6)		-Physical Therapy (0.9/9.7)	-Storage (0.9/9.7)	-Laundry (0.6/6.5) -Restrooms (0.9/9.7)	-Patient Room (0.1/7.5)		-Nursery Suite (0.6/6.5)	-Recovery (0.8/8.6)
1-2 W/ft² 0.99-1.99 W/m²	-Labs (1.4/15.1) -Pharmacy (1.2/12.9)	-Exam Treatment (1.5/16.1)					-Medical Supplies (1.4/15.1)		-Corridor (1.0/10.8)		-Nursing Station (1.0/10.8)	
20-30 W/ft² 1.99-3.0 W/m²												-Operating Room (2.2/23.7) -Emergency (2.7/29.1)

Balbir Saxena Marg,Hauz Khas.(2009). *Energy Conservation Building Code (ECBC) User Guide.* Bureau of Energy Efficiency. New Delhi, India.

Legend
Peak , Average Nameplate, * = Typical Laboratory Equipment **=Laboratory Equipment that can be categorized under Medical Equipment

Power used by Medical and Laboratory Equipment in U.S.

	Ancillary			Administration	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
Watt (W)	**Labs** (Anatomical,pathology and clinical pathology, pharmacy	**Radiology + imaging** (X ray (diagnostics and treatment X-ray surgery critical care, darkroom)	**Autopsy room** (autopsy, non refrigerated body holding room)	(main lobby, medical records, business offices,waiting/admin)	**Diagnostics + treatment** (Exam, medication room, MRI room,therapy dept, pharmacy)	Bronchoscopy, sputum collection and pentamidine admin, soiled workroom or soiled holding	Resident room, corridor,toilet room, resident gathering	Sterilizer equipment, sterile storage and equipment storage, utensils)	**Medical surgical supply** (soiled, clean workroom , sterile storage)	(Food preparation; warewashing, laundry;linen and trash chute janitor's closet, bathroom)	**Support space** (Soiled room ; hazardous materials ;	**Patient rooms** (Inpatient wards/private rooms, newborn nursery,labor/delivery/recovery/postpartum	**Nursing area** (Protective , Airborne infection isolation, toilets)	**Specialized patient** (Burn units, treatment, Newborn, recovery room, intensive care, treatment)	**Surgery + Procedures** (operating rooms, ER incl waiting rooms, triage and Radiology waiting
Low 0-99	-Analytical Balance* 7/7 (7) -Orbital Shaker 16/16 (100) -Function Generator 29/29 (58) -Oscilloscope 38/38 (72) -Optical Microscope 65/63 (330) -Electrochemical analyzer* 45/44 (50) -Rotary Evaporator 74/73 (75) -Centrifuge* 89/87 (138)	-X-ray System N/A/82 (250)			- Hysteroscopic Pump 35/34(180)							-Blood Pressure Meter 33/29 (180)	- ECG/RESP 54/50 (1440)		-Pulse Oximetry 21/20 (72) -Harmonical Scalpel **60/59** (230)
Medium 100-199	-Flame Photometer 107/105 (180) -Spectrophotometer 122/121 (200) -Fluorescent Microscope 144/143 (150)				-Stress Treadmill 198/173 (N/A)										-Anesthesia System **177/166** (250) -Blood Warmer **204/114** (360) - Electrosurgery 147/**109** (1000)
High 200+	-Spectro Fluorometer405/395 (340) -Thermocycler 965/641(1840) -Tissue Culture 1178/1146 (2346)				**MRI, Linear accelerators, CT scan**				-Blanket Warmer 504/221 (500)			- Ultrasound System 1063/1050 (1800)	-Vacuum Suction 337/302 (621)	- Incubator** 461/451(515)	--Laser Sonics **256/229** (1200) -Endoscope 505/596 (1688)

Power used by Medical and Laboratory Equipment in India

Outpatient

Nursing Facilities

Inpatient

Legend
Peak , Average, (Nameplate)
* = Typical Laboratory Equipment
**=Laboratory Equipment that can be categorized under Medical Equipment
Note: Chart is based on Average Heat Gain

	Ancillary			Administration	Diagnostics + treatment		Sterilizing & supply	Services	Inpatient Nursing		Surgery & critical care	
Watt (W)	**Labs** (Anatomical,pathology and clinical pathology, pharmacy	**Radiology** (X ray (diagnostics and treatment) X-ray (surgery and critical care and darkroom)	**Autopsy** (Labs, autopsy, non refrigerating body holding room)	(Waiting/admitting rooms)	Bronchoscopy, sputum collection and pentamidine admin, soiled workroom or soiled holding	(Examination room, medication and treatment room, physical therapy, clean workroom or clean holding)	(Sterilizer equipment room; soiled or decontamination room; clean workroom and sterile storage and equipment storage)	(Food preparation; laundry)	**Patient wards** (Inpatient wards and private rooms, intensive care - ICU, patient corridor, labor/delivery/recovery/postpartum, recovery room)	**Nursing area** (protective isolation,infectious isolation + anteroom,toilet)	**specialized patient/trauma recovery** (nursery suite, trauma room)	**Surgery + critical care** (operating rooms, anesthesia, delivery room)
Low 0-99	-Analytical Balance* 7/7 (7) -Orbital Shaker 16/16 (100) -Function Generator 29/29 (58) -Spectronics 31/31 (36) -Oscilloscope 38/38 (72) -Optical Microscope 65/63 (330) -Electrochemical analyzer* 45/44 (50) -Rotary Evaporator 74/73 (75) -Centrifuge* 89/87 (138)					-Hysteroscopic Pump 35/34 (180)			-Blood Pressure Meter 33/29 (180)	-ECG/RESP 54/50 (1440)		-Pulse Oximetry 21/20 (72) -Harmonical Scalpel 60/59 (230)

Power used by Medical and Laboratory Equipment in India

Outpatient

Nursing Facilities

Inpatient

Legend
Peak , Average, (Nameplate)
* = Typical Laboratory Equipment
**=Laboratory Equipment that can be categorized under Medical Equipment
Note: Chart is based on Average Heat Gain

	Ancillary			Administration	Diagnostics + treatment		Sterilizing & supply	Services	Inpatient Nursing		Surgery & critical care	
Watt (W)	**Labs** (Anatomical,pathology and clinical pathology, pharmacy	**Radiology** (X ray (diagnostics and treatment) X-ray (surgery and critical care and darkroom)	**Autopsy** (Labs, autopsy, non refrigerating body holding room)	(Waiting/admitting rooms)	Bronchoscopy, sputum collection and pentamidine admin, soiled workroom or soiled holding	(Examination room, medication and treatment room, physical therapy, clean workroom or clean holding)	(Sterilizer equipment room; soiled or decontamination room; clean workroom and sterile storage and equipment storage)	(Food preparation; laundry)	**Patient wards** (Inpatient wards and private rooms, intensive care - ICU, patient corridor, labor/delivery/recovery/postpartum, recovery room)	**Nursing area** (protective isolation,infectious isolation + anteroom,toilet)	**specialized patient/trauma recovery** (nursery suite, trauma room)	**Surgery + critical care** (operating rooms, anesthesia, delivery room)
Medium 100-199	-Flame Photometer 107/105 (180) - Spectrophotometer 122/121 (200) -Fluorescent Microscope 144/143 (150)					-Stress Treadmill 198/173 (N/A)						-Anesthesia System **177**/**166** (250) -Blood Warmer **204**/**114** (360) - Electrosurgery 147/**109** (1000)
High 200+	-Spectro Fluorometer 405/395 (340) - Thermocycler 965/641(1840) -Tissue Culture 1178/1146 (2346)	-X-ray System 534/480 (1725)					-Blanket Warmer 504/221(500)		-Ultrasound System 1063/1050 (1400 continuous; 1800 intermittent)	-Vacuum Suction 337/302(621)	-Incubator** 461/451 (515)	--Laser Sonics **256**/**229** (1200) -Endoscope 605/596 (1688)

Appendix 3: A framework for the prioritization of monitored loads

Three factors:

1. Consumption
2. Actionable
3. Meterable

Matrix of Loads

FACILITY SPACES →

END-USES ↑

	WB	Ancillary			Ad min	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
	Whole Bldg	Labs e.g. glass wash, steril.	Radio-logy + imagi.	Autopsy room		D&T Exam Room	Special procedures	(US only)	Sterillizer Eqpt etc	Medical surgical supply (US only)	Food prep; laundry	Support space (US only)	Patient rooms nursery, LDRP	Nursing area (isolation ward)	Specialized patient	Surgery + Procedure
BY END LOAD (Separate Electricity, Gas, Steam based loads)																
Central heating (furnace)																
Central heating (boiler)																
Reheat (if at done at terminal units)																
Central cooling (chiller plant)																
Zone Cooling																
Vent.																
Zone vent. (exhausted directly)…																
Etc																

	WB	Ancillary			Adm	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
	Whole Building	Labs esp. glass wash, sterilize	Radiology + imaging	Autopsy room		D&T Exam Room	Special procedures	(US only)	Sterilizer equipment etc	Medical surgical supply (US only)	Food prep; laundry;	Support space (US only)	Patient rooms nursery, LDRP	Nursing area (isolation ward)	Specialized patient	Surgery + Procedures
BY END LOAD																
Central heating (furnace)	y	y y			y y Only if furnace separated between MOB and acute care								y y	y n	y n	y y OP only eg I3 OSHPD small outpatient surgery
Central heating (boiler)		y y			y y Only if boiler separated between MOB and acute care								y y	y n	y n	y y OP only eg I3 OSHPD small outpatient surgery
Reheat (if at done at terminal units)	y n	y y OP w manual override	n		y y	y y OP w manual override	y y OP w manual override	y y resident spaces + gathering	y y	y n	y y *California Board of Health	y y	y y	y n	y n	y y OP only eg I3 OSHPD small outpatient surgery
Central cooling (chiller plant)	y y	y y	n		y y Only if chiller plant is separated between MOB and acute care								y y	y n	y n	y y OP only eg I3 OSHPD small outpatient surgery
Zone Cooling	**NA**	y y OP w manual override	n		y y OP only	y y OP w manual override	y y OP w manual override	y y resident spaces + gathering	y y	y n	y y *California Board of Health	y y	y y	y n	y n	y y OP only eg I3 OSHPD small outpatient surgery

	WB	Ancillary			Adm	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
	Whole Building	Labs esp. glass wash, sterilize	Radiology + imaging	Autopsy room		D&T Exam Room	Special procedures	(US only)	Sterilizer equipment etc	Medical surgical supply (US only)	Food prep; laundry;	Support space (US only)	Patient rooms nursery, LDRP	Nursing area (isolation ward)	Specialized patient	Surgery + Procedures
BY END LOAD (contd)																
Ventilation	y y	y y		n	y y Can you have a central ventilation system in a healthcare facility?								y y (unoccupied - 0 ACH; OSHPD 25% reduction)	y n		y y Unoccupied spaces to maintain pressure relationship
Zone ventilation (exhausted directly)		y y Needs direct exhausting in Labs	y n Needs direct exhausting in darkrooms	n			y n	y y	y y ? Needs direct exhasuting in equipment rooms					y n Needs direct exhasuting in toilets	y y n Needs direct exhasuting in Isolation rooms	y y Unoccupied spaces to maintain pressure relationship

	WB	Ancillary			Adm	Diagnostics and Treatment		Skilled Nursing	Sterilizing & supply		Services		Inpatient Nursing		Surgery and Critical care	
	Whole Bldg	Labs esp. glass wash, sterilize	Radiology + imaging	Autopsy room		D&T Exam Room	Special procedures	(US only)	Sterilize eqpt etc	Medical surgical supply (US only)	Food prep; laundry;	Support space (US only)	Patient rooms nursery, LDRP	Nursing area (isolation ward)	Specialized patient	Surgery + Procedures
Service HW	y y	y y	y y	n	NA	y y	y y	y y	y y		y y		y y	y n	y n	y n
Lighting Indoor	y y	y y (OP only)	y y	n	y y OP only	y y	y y	y y	y y	y y	y y	y y	y y	y n	y n	y n
Lighting Outdoor	y y	NA														
Plug loads receptacle	y y (OP only)	y y (OP only)	y y If quickly calibrated	n	y y OP only	y y	y y	y y	y y	y y	y y	y y	y y	y n	y n	y n
Medical Eqpt	y y (OP only)	y y (OP only)	y y	n	NA	y y	y y	y y	NA				y n	y n	y n	y n
Imaging Eqpt	y y (OP only)	NA	y y	NA											y n	y n
Process Loads cooling towers, refrigeration elevators	y y (OP only)	y y (OP only)	y y	n	y y OP only	y y	y y	y y	y y	y y	y y	y y	y y	y n	NA	

Appendix 4: Technical Requirements mapped to Business Drivers

	EIS package tier	Key analysis Frequency	Data from interval Metering	Additional User Inputs	Metrics	EIS technical software : Data inputs/ streams	EIS technical software requirement: Data analysis	EIS technical software requirement: Data visualization	EIS technical software requirement Intrepretation/ Notification
What exactly to do you want to know? Sub-points are EIS functionality		**How often do you need to know this?**	**At what location(s) does information need to be gathered?**		**What measure is reqd?**	**What type of data inputs are reqd?**	**How do you process the raw info?**	**How do you communicate the analyzed info?**	**What type of interpretation can be derived? What type of alerts can be had?**
1.CONSUMPTION: CONTINUOUS MONITORING OF ENERGY PERFORMANCE									
1.1 ONGOING TRACKING ELECTRICITY USAGE Trending and Viewing building energy consumption (KWh) and loads (KW). **Questions are: Visibility- Where, when and how is the building consuming electricity**	**1** **Objective: Get visibility into electricity consumption- When and where is elecricity being used and how much is being used**	Hourly	WB, 2-3 Critical Loads by end use or major area		WB Electricity and major load sub-metered electricity; KWh and KW	_EIS will extract continuously monitored interval data (15-minutes or hourly) on electricity usage from whole building meter and panel submetered loads or zones _ EIS will extract data about continuous loads and peak loads	_EIS will track readings using the same interval from multiple meters in order to provide **simple tracking** of electricity consumption and loads. Data of any resolution may be used as long as it is consistent. _EIS will provide **trend analysis** of historical data going back recommended intervals. _EIS will provide WB/ critical load daily or weekly **load profiling** with day time and night time demand loads	_Time series charts: EIS will provide visualization of electricity interval data at WB level and major load level (y-axis) at sub-monthly intervals (x- axis). These can be line, bar _ Load segmentation chart disaggregating at the level of the critical 2-3 loads monitored	and loads _ Monthly usage bars indicate monthly/ seasonal variations _Screen/ Email/ phone alerts to facility manager about missing data and for critical failures _ Standard monthly summary reports
	2 **Objective: Get visibility into electricity consumption- Provides increased granularity of where, when and how you use it**	Hourly	WB, 7-8 Major Loads by end use or major area	~Building size, Zone areas, ~Operating schedules (diurnal, weekly, seasonal)	KW KWh/ m2 KWh/ season			_ More granular time series charts based on submetered data from 7-8 loads. _ Time series overlays of different selected time periods to compare to a user-defined base periods _Load segmentation charts (e.g.pie charts or stacked bars) EIS will provide recommended end use level breakout of electricity usage _Plots of energy usage trends over recommended periods of time (See Section 2.1 Longitudinal Benchmarking) _EIS will calendar view of the daily 24-hour period time of day plots as visually discernable (qualitative) patterns. Analyses such as changes in load profiles, load variability, daily or event-based peaks and troughs, nighttime, weekend, holiday setbacks _ EIS will provide heat map of energy consumption, indicating the level of hourly or sub-hourly energy usage across a selected time period using different colors	_ Indicates simple increases or decreases in electricity for current period, and past periods. _ Disggregates loads to metered levels and reveals comparitive weightage of loads- i.e. which loads are energy intensive, and which ones are not.
	3 **Objective: Get visibility into energy consumption- Provides increased granularity on how much you use and when you use it-and in addition, where you are buying it from.**	15-min	Custom metering: Potential meters are _ WB, RE meter, DG meter; _ Gas meter _ Submeters for as many loads and as many locations, _ Equipment level meters for critical/ energy intensive equipment	~Occupancy (Room occupancy, Numbers of events or guests) ~Weather/location information e.g. Outside Air Temperature (Deg C) ~ RH for hvac (%) ~Equipment type for plugs ~Equipment run time (#hours) ~Component count (#units)	KW KWh/ m2 KWH/person KWh/ season KWh/ cooling degree day, heating degree day KWh/equipment			_Beyond Level 2 at a more granular level, such as sub-system or equipment level electricity use _Charts indicating disaggregated electricity supply	_Peak load analysis reveals magnitude of peak, including "Most likely maximum load". Can help inform system sizing in retrofit projects _ Supply side optimization (where to buy the electricity at what time) and potentially modulate energy allocation to various end uses and equipment _ Real time dashboard for energy consumption. Can imclude the provision of a public kiosk to allow occupants and visitors to view hotel electricity consumption

	EIS package tier	Key analysis Frequency	Data from interval Metering	Additional User Inputs	Metrics	EIS technical software : Data inputs/ streams	EIS technical software requirement: Data analysis	EIS technical software requirement: Data visualization	EIS technical software requirement Intrepretation/ Notification
What exactly to do you want to know? Sub-points are EIS functionality		**How often do you need to know this?**	**At what location(s) does information need to be gathered?**		**What measure is reqd?**	**What type of data inputs are reqd?**	**How do you process the raw info?**	**How do you communicate the analyzed info?**	**What type of interpretation can be derived? What type of alerts can be had?**
1.CONSUMPTION: CONTINUOUS MONITORING OF ENERGY PERFORMANCE									
1.2 DETECT VARIANCES IN CONSUMPTION AND IDENTIFY SAVINGS OPPORTUNITIES Questions are: What is the expected energy performance of the building? Is it performing the way it should? How much is the variances and wastage; How to determine operational /retrofit savings opportunities?	**1. Manually identify wastage at whole building and critical loads level**	Hourly	WB, 2-3 Major Loads by end use or major area		WB Electricity and major load sub-metered electricity; KWh and KW				**_ Manual detection of variances in consumption and loads:** Unexpected spikes or troughs (+/- x% deviation from a pre-defined consumtion band can be manually investigated for scheduling or other errors at the WB and 2-3 loads level
	2 Identify electricity wastage at whole building and granular loads level, and identify savings opportunities	Hourly	WB, 7-8 Major Loads by end use or major area	~Building size, Zone areas, ~Operating schedules (diurnal, weekly, seasonal)	KW KWh/ m2 KWH/person KWh/ season	_ EIS will extract interval data on electricity consumption at the sub-metered level for major loads, with flexibility by system or zone. _ EIS will extract data about continuous loads and peak loads	_ Eis will provide **normalization** Based on floor area and operations schedule _ EIS will provide a **simple baseline**, and will track variances in consumption- min,max, annual/ monthly average _ EIS will provide WB and selected end use peak load analysis normalized to floor area , base-to-peak analysis, peak load duration	_ Time series with simple baseline overlay	**_Semi-automated anomaly detection:** Abnormalities/ changes in time series load profiles indicate WB and end-use level energy wastage due to scheduling/ operating errors. e.g. based on time of day (e.g. night setback, morning peaks) or other patterns such as high usage during unoccupied hours, or unexpected peaks or overrides. Low cost or no-cost operational savings identification e.g. Night/Weekend/holday setbacks; Smart startup, Coasting, Reveals ***operational*** energy savings potential. _ Higher base loads imply non-implemetation of night time schedules. Reveals energy savings potential even though day-night differntial in hotels may not be as high as in offices _EIS identifies what factors strongly correlate with deeper savings
	3 Identify electricity usage trends and wastage at whole building and granular loads and equipment level. Drill down into causes and potential solutions for abnormal energy use	15-min or hourly data for daily or weekly load ; seasonal inspection	3 Custom metering	~ Occupancy (Room occupancy, Numbers of events or guests) ~Weather/location information e.g. Outside Air Temperature (Deg C) ~ RH for hvac (%) ~Equipment type for plugs ~Equipment run time (#hours) ~Component count (#units)	KW KWh/ m2 KWH/person KWh/ season KWh/ cooling degree day, heating degree day KWh/equipment		_ EIS will provide normalization for variations in climate (seasonality, weather), occupancy (room occupancy/ events), square footage and time of day _ EIS wil provide model baseline energy consumption modeling, i.e. characterize/predict typical or expected energy usage based on factors such as weather (degree days/outside air temperature), occupancy, time of day/week, and other energy drivers. One path is through regression analysis using Outside Air Temperature (OAT) ~EIS will provide peak load analyis based on peak load duration and peak demand charges	_EIS will provide plotted representations to look for usage trends, and unusual (+/- x %) deviations against the model baseline that indicate good or bad changes from predicted value.	**_Fully automated anomaly detection through pre-defined algorithms**: If usage doesn't reflect the model baseline Abnormalities/ changes in load profiles can be automatically detected. These indicate system level or equiment level electricity wastage due to irregular equipment operations e.g boiler on during summer nights, equipment cycling etc . Reveals energy savings potential. e.g. Economizing, Peak demand management _ EIS will indicate (based on a decision tree) which equipment requires Fault Detection and Diagnostics (See Section 1.5.2) _ EIS will provide early alerts/ alarms/ error notifications for wastage or variances for exceeding peak load with respect to the budget.
1.3 Lighting systems: Track lighting system energy use in terms of effectiveness of control or scheduling	**3 Validate and improve ligting system performance**	hourly/weekly profile, monthly inspection	3 WB, 7-8 Major Loads by end use or major area By lighting control zone, or critical portions encompassing many zones	_Schedules: Lighting Schedule Occupancy schedule Event schedule _ Light levels: Daylighting levels Artificial Light level (lux) _Info about Automated, manual control and daylighting controls _Area of lighting zone	Lighting electricity: Lighting power efficiency (%) W/sf	Sub- Metered lighting demand; total installed lighting power for: ~ 3-5 indicator spaces ~Regularly used spaces, ~Occasional use spaces ~Car parking spaces ~Outdoor Lighting	_EIS will track lighting energy use profile follows schedule (on-off-dimming); Check that power efficiency is maintained (W/sf). _EIS will determine Lighting power efficiency (%) of the sub-metered area _ EIS will trend Lighting efficinecy over time.	Lighting power efficiency time series plots revealing outcomes of manual control, occupancy sensing, evening and night-time variations, daylighting controls, illuminance setpoints	_Profiling lighting load and zones/ area sof larger lighting electricity consumption _Check that lighting energy use intensity is maintained (W/sf). _ For Indicator spaces or regularly used spaces, ensure that lighting energy use profile follows schedule _For Occasional use spaces Ensure that lighting energy use profile reflects level of use; ~Outdoor lighting and Parking: Ensure that lighting is turned off during daylight hours _ Report lighting fixture/ lamp failure

	EIS package tier	Key analysis Frequency	Data from interval Metering	Additional User Inputs	Metrics	EIS technical software : Data inputs/ streams	EIS technical software requirement: Data analysis	EIS technical software requirement: Data visualization	EIS technical software requirement Intrepretation/ Notification
What exactly to do you want to know? Sub-points are EIS functionality		**How often do you need to know this?**	**At what location(s) does information need to be gathered?**		**What measure is reqd?**	**What type of data inputs are reqd?**	**How do you process the raw info?**	**How do you communicate the analyzed info?**	**What type of interpretation can be derived? What type of alerts can be had?**
1.CONSUMPTION: CONTINUOUS MONITORING OF ENERGY PERFORMANCE									
1.4 HVAC system- 1.5.1 Track HVAC system electricity consumption: Identify and reduce operational inefficiencies in heating, cooling and ventilation ; Ensure that energy use profile reflects level of use, seasonality and weather;	**3 Validate and improve HVAC system performance**	hourlyor sub-hourly profile	Custom metering	Integrate with BAS:info about TR Sub-system and equipment schedules: Chiller plant, boiler, AHU	HVAC electricity; gas, steam	Power needed to produce heating or cooling; produced heating or cooling load. (note: Zonal system performance is hard to measure because of distribution losses. Extract inputs directly from chiller plant)	_Thermal efficiency for Heating (boiler) _Power efficiency (kW/TR) for Cooling (chiller, pump, cooling tower) _Power efficiency (W/cfm) for Ventilation (3-5 AHUs, split units)	_ Plots for sub-system efficiency e.g. Chiller power efficiency _ X-Y plot (with Outside Air Temperature)	_Eis will profile HVAC load and zones/ areas of larger electricity consumption such as chiller plant and AHU
1.5.**1 Fault Detection and Diagnosis (FDD).** Detect faults early and diagnose their causes to prevent damage and energy wastage	3	15 minutes	Custom metering	Integrate with BAS		Air temp.& pressure, airflow rate, VFD speed from	_EIS will determine fault either through visual inspection or through automated process. For automated process, EIS will run **Fault detection and diagnostics** algorithms that weigh the probability of faults, list causes. FDD is a tool to automatically identify HVAC system or equipment level faults, and sometimes isolate root causes. FDD can comprise of expert rules or physical/ statistical models _EIS will determine the occurrence of a fault in HVAC equipment, isolate it for type, location and time of detection; and identify the size and behavior.	_ EIS will provide diagnostics dashboard with location, source and cost of faults	_EIS will detect and provide early automated alerts for faults and failures in meters, communications and front-end. _EIS wil provide corrective recommendations to fix the fault
1.5.2 Provide Equipment level tracking	3	15 minutes		Integrate with BAS		_Chiller plant (chiller, pump, cooling tower) _Ventilation (AHU) _ Heating (boiler)		_Plots overlaying measured efficiency vs manufacturer nameplate; Equipment operational (e.g. chiller) savings after any retrofits; Equipment (e.g. boiler) efficiency vs part load capacity,	_For Heating (boiler): Check that thermal efficiency is maintained (%) _For Cooling (chiller, pump, cooling tower): Ensure that energy use profile reflects level of use, seasonality and weather; Check that power efficiency is maintained (kW/TR) _For Cooling ensure that energy use profile reflects level of use, seasonality and weather; Check that power efficiency is maintained (W/cfm) _For Ventilation: Upto 3-5 AHUs and/or split units- Ensure that energy use profile reflects level of use, seasonality and weather; Check that power efficiency is maintained (W/cfm)
1.6 Plugs/Process Loads Track plugs and process loads	3 Validate and improve Plug/process loads system performance	15 minutes	Custom metering	Integrate with BAS Level of utilization based on occupancy and periods of use					Ensure that energy use profile reflects level of use; Check that power efficiency is maintained.
1.7 **Track Cooking energy use**	3	daily profile	Gas meter	Level of utilization based on occupancy and periods of use	Cooking Fuel				EIS will Identify unusual use relative to sales

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What exactly to do you want to know? Sub-points are EIS functionality		**How often do you need to know this?**	**At what location(s) does information need to be gathered?**		**What measure is reqd?**	**What type of data inputs are reqd?**	**How do you process the raw info?**	**How do you communicate the analyzed info?**	**What type of interpretation can be derived? What type of alerts can be had?**
2. BENCHMARK: COMPARE BUILDING/PORTFOLIO ENERGY PERFORMANCE									
2.1 Longitudinal Benchmarking: Assess long-term upward /downward trends, i.e.overall energy performance IN COMPARISON TO ITSELF	**1**	annual total, seasonal	WB, 2-3 Major Loads by end use or major area		WB Electricity and major load sub-metered electricity; KWh and KW	Eis will extract WB electrical consumption data, and formulate a base period benchmark	EIS will provide **longitudinal benchmarking** at WB level, i.e. comparing energy usage in a fixed period to a baseline period of the same length, i.e. base-period benchmark. Either a base year, or normalized to square footage, or occupancy	EIS will provide plots. Can be static reports, or with dynamically accessible functions e.g. heat maps	EIS will provide longitudinal benchmarking, i.e. compare electricity cost in fixed periods (day/week/month/year) at the buildingand/or system against past performance. Identification whether energy use is remaining static, improving or deteriorating with time. Identify energy saving oportunities
	2		WB, 7-8 Major Loads by end use or major area		KW KWh/ m2 KWH/person KWh/ season	Eis will extract system level electrical consumption data and formulate a base period system benchmark	Additional bechmarking at the system level		
	3		Custom metering		KW KWh/ m2 KWH/person KWh/ season KWh/equipment	Eis will extract critical eqpt electrical consumption data and formulate a base period equipment benchmark	Additional bechmarking at the equipment level		
2.2 Cross-sectional Benchmarking **Assess overall efficiency potential and performance relative to peers**	**3**	annual total, seasonal	WB, 7-8 Major Loads by end use or major area		KWh/ m2 KWH/person	Annual electricity use; Gross floor area; peer group selection	EIS will normalize electricity use for occupancy and floor area, and compare to peer buildings (**cross-sectional benchmarking**) from the vendors database, or any future national data set.	EIS will place the building on a sliding scale of peer group buildings' energy performance	_ EIS will provide ranking how the building is performiing wrt the peer group as a percentile _ EIS will identify targets for potential energy retrofits _EIS will be used to track progress towards the target

	EIS package tier	Key analysis Frequency	Data from interval Metering	Additional User Inputs	Metrics	EIS technical software : Data inputs/ streams	EIS technical software requirement: Data analysis	EIS technical software requirement: Data visualization	EIS technical software requirement Intrepretation/ Notification
What exactly to do you want to know? Sub-points are EIS functionality		**How often do you need to know this?**	**At what location(s) does information need to be gathered?**		**What measure is reqd?**	**What type of data inputs are reqd?**	**How do you process the raw info?**	**How do you communicate the analyzed info?**	**What type of interpretation can be derived? What type of alerts can be had?**
3. TRACK ELECTRICITY COST and MANAGE DEMAND CHARGES									
3.1 **Validate billing accuracy:**	1	By billing period (typically monthly)	WB, 2-3 Major loads by end use or major area	Cost per unit for electricity (as an estimated flat rate Rs/unit) _ Manually entered bill amount	$			EIS will calculate and visualize electricity costs using site-specific tariffs or estimated flat rates Rs./energy unit.	Reduce likelihood of accounting errors Ensure that cost is consistent with consumption; Identify discrepancies/unusual changes in billing; Ensure that rate is consistent with contract. i. EIS will identify when a utility bill is late, a billing period has been missed, or a particular expense double billed. ii. EIS will identify when a payment has been posted by the utility in the wrong amount
3.1 **Cost accounting** (Note: for other non-hotel typologies this may be split into two, based on who the cost is attributable to, i.e. owner or tenant)	3	By billing period (typically monthly)	WB, 7-8 Major Loadsby end use or major area	Estimated flat rate per unit for electricity	$		c. EIS will chart and report energy costs against budget, indicating surplus/deficit.	_EIS will visualize WB annual cost, monthly summary of daily cost, and potentially compare year to day with the same period last year (through overlays) _ EIS will compare total or daily system costs by percentage such as in a pie chart, t We will not have complete pie in level 2	Weightage of $ wastage can help prioritize conservation actions
	3	Interval data-monthly, hourly, 15-min	Custom metering	Estimated flat rate per unit for electricity, disaggregated into Utility, RE and DG	$	EIS will allow for recording system or component cost accounting	_EIS will identify cost structure of the utilty bill e.g. energy charge, Time Of Use charge, other charges. _EIS will identify billing from private distributors such as for green energy, chilled water (in case of district cooling), steam. _ Eis will track any energy waste for the submeters, convert to waste utility costs		
3.3 Proactively manage the energy budget	**3**	By billing period (typically monthly)	Custom metering 1 WB interval meter, DG meter, RE meter, 10-12 Major loads	_Manual budget _Integration with accounting system	$	Additional inputs such as construction of new buildings, changes in occupancy, and utility rate escalations.	. _EIS will trend cost data based on historical usage trends, weather patterns and cyclical occupant needs _ EIS will upload billing information to a centralized enterprise database such as the financial/accounting system.	EIS will report energy costs against budget, indicating surplus/deficit.	_ EIS will help manage decisions about what source to buy the electricity and at what time _ EIS will help in decision making about what allocatio of energy budet towards various end uses, areas and equipment

	EIS package tier	Key analysis Frequency	Data from interval Metering	Additional User Inputs	Metrics	EIS technical software : Data inputs/ streams	EIS technical software requirement: Data analysis	EIS technical software requirement: Data visualization	EIS technical software requirement Intrepretation/ Notification
What exactly to do you want to know? Sub-points are EIS functionality		**How often do you need to know this?**	**At what location(s) does information need to be gathered?**		**What measure is reqd?**	**What type of data inputs are reqd?**	**How do you process the raw info?**	**How do you communicate the analyzed info?**	**What type of interpretation can be derived? What type of alerts can be had?**
4. IDENTIFY, TRACK AND VALIDATE ENERGY EFFICIENCY PROJECTS TO SET AND ATTAIN ENERGY TARGETS									
4.1 Set performance targets and identify EE opportunities and their forecasted cost (new buildings and retrofits)	3	annual, monthly	Custom metering		cash flow ($); IRR (%)	Simple tracking, Cost accounting	EIS will consolidate historical energy use data- using simple tracking, cost accounting etc	EIS will provide intuitive dashboards to unearth low/no-cost savings to allow prioritized and actionable information on building energy performance, to help formulate EE projects	This provides info to prioritize capital investment.
4.2 Verify savings from energy improvement projects based on measured performance	3	annual, monthly	Custom metering	Pre and post-period energy and cost data	cash flow ($); IRR (%)	IRR equation inputs for costs	EIS or associated spreadsheet will calculate Internal Rate of Return (IRR)*, i.e. expected profit or rate of growth for a given efficiency measure. IRR is the rate at which NPV=0	EIS will generate IRR, NPV and cash flow tables or plots.Higher the IRR better the project .	Verify savings and impact of project
5. PROVIDE CARBON ACCOUNTING AND MINIMIZE CARBON EMISSIONS									
Ability for GHG reporting for building energy use and on-site emissions	3	monthly, annual, total	WB, 7-8 major loads by end use or major area	Emissions factor that is customer identified or from regional databases		EIS will extract data from desired site, reporting time period and emissions units		_ EIS will generate report on carbon emissions as a total quantity, This information can exported with aim of achieving compliance with internal sustainability initiatives or public registries country/regional emissions targets	

THE END