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U.S.– India Joint Center for Building Energy Research and Development (CBERD)
Caring for the Energy Health of Healthcare Facilities

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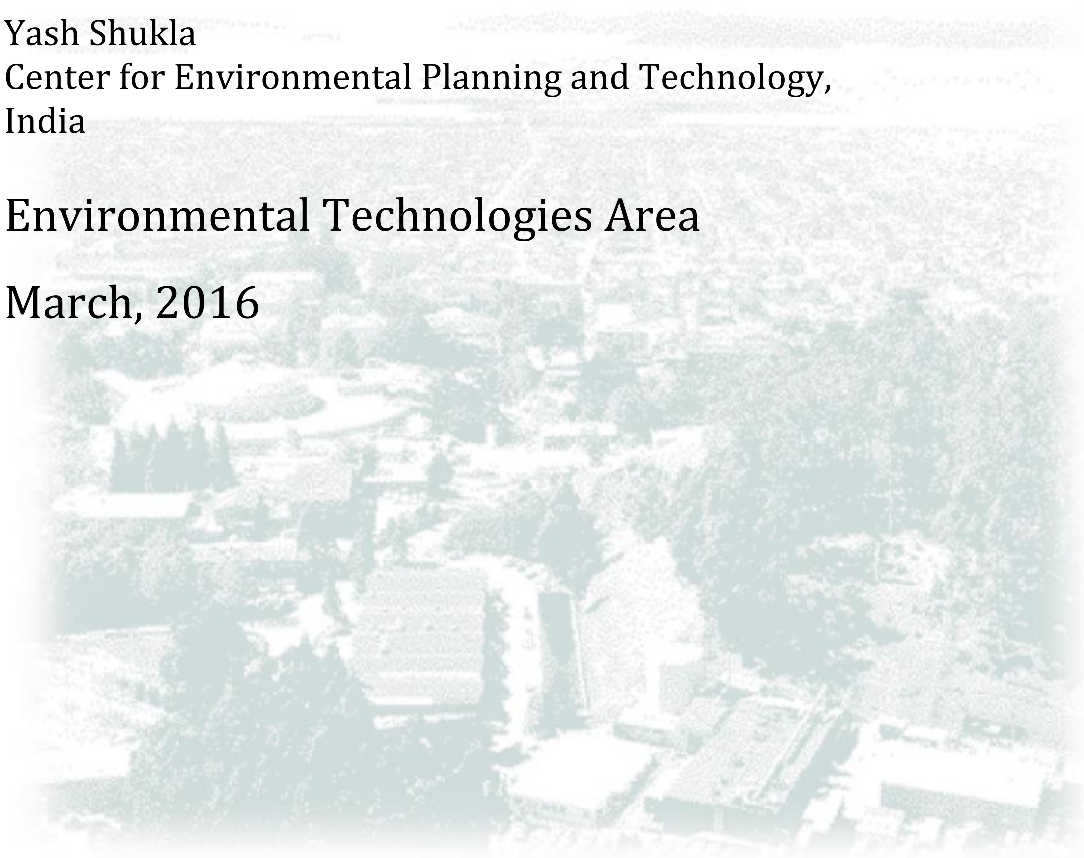

Environmental Technologies Area

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Caring for the Energy Health of Healthcare Facilities

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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 30 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. Every day, much of the energy consumed by buildings serves no purpose (Roth et al. 2005).

Building energy information systems (EIS) are commercially available systems that building owners and facility managers use to assess their building operations, measure, visualize, analyze, and report energy cost and consumption. Energy information systems can enable significant energy savings by tracking energy use, identifying consumption patterns, and benchmarking performance against similar buildings, thereby identifying improvement opportunities. The CBERD team has identified potential energy savings of approximately 2 quads of primary energy in the United States, while industry building energy audits in India have indicated potential energy savings of up to 30 percent in commercial buildings such as offices. Additionally, the CBERD team has identified healthcare facilities (e.g., hospitals, clinics), hotels, and offices as the three of the highest-growth sectors in India that have significant energy consumption, and that would benefit the most from implementation of EIS.

1.2 Discussion

There are significant barriers to energy efficiency across the building sector, such as:

1. Lack of executive mind-sharing, with the energy conversation being confined to the basement.
2. Lack of integration with legacy building management and controls systems, thayt are already usually expensive systems.
3. Heterogeneity within sectors that requires facility-wise customization, leading to high transaction costs.

The healthcare sector affords additional challenges to energy-efficiency, including:

1. Emphasis on non-energy imperatives: e.g., health delivery efficiency, exceptional patient experience, clinical excellence, space and air quality, conformance to a stringent regulatory landscape, and profitability.
2. Diversity and complexity of spaces and criticality of loads, systems, and equipment: many loads, such as acute care, ambulatory care, and outpatient/inpatient facilities, have a wide variety of functions and operations, are highly regulated, and are not deemed controllable.

3. Importance of cyber security is driven in large part by sensitivity of patient records.

However, there is a substantial energy opportunity in healthcare, especially given the increased focus on cost of healthcare provides new opportunity to recognize value of operational efficiency. Through the CBERD collaboration, the team is leveraging leapfrog opportunities in new facilities (given Indian cultural emphasis on frugality), as well as energy efficiency in existing facilities e.g. for organizations seeking operational excellence.

This report focuses on technical enablement and scale-up of energy savings through the development of readily available, simplified, standardized, and low-cost EIS packages specifically for the healthcare sector in both countries

1.2 Audience for this report

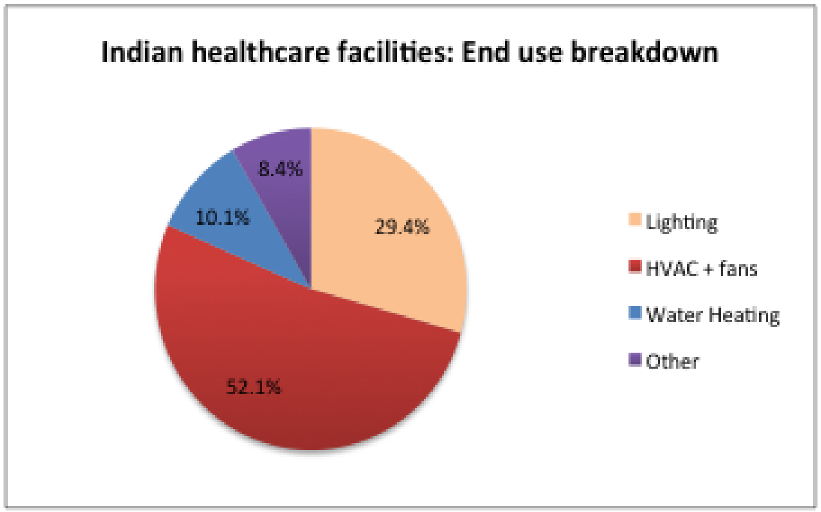
There are two primary audiences for this publication: healthcare facility owners and managers, and EIS companies and vendors.

1.3 General healthcare facilities trends

While the United States is well known for advanced medical research and treatment, India is emerging as a center for healthcare expertise and medical tourism. 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 the U.S. and India).

1.3.1 India Healthcare Energy

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). India is slated to create new facilities to house an additional 1.75 million beds by 2025, and to more than double capacity 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) for Indian hospitals ranges widely, from **28 thousand Btu per square foot per year (28 kBtu/ft^2-yr)** (88 kilowatt-hours per square meter [kWh/m^2]) for government and municipal hospitals to four times that, at **120 kBtu/ft^2-yr** (378 kWh/m^2) for private-sector, multi-specialty hospitals that may provide higher opportunities for energy savings. Heating, ventilation and air conditioning (HVAC) and lighting end uses contribute to more than 80 percent of the energy demand in India (Figure 1) (Kapoor and Kumar 2011).



(Source: Kapoor and Kumar 2010)

Figure 1: Chart showing the end-use breakdown in Indian healthcare facilities. It becomes evident that EIS packages should be targeted towards reduction in HVAC and lighting energy uses.

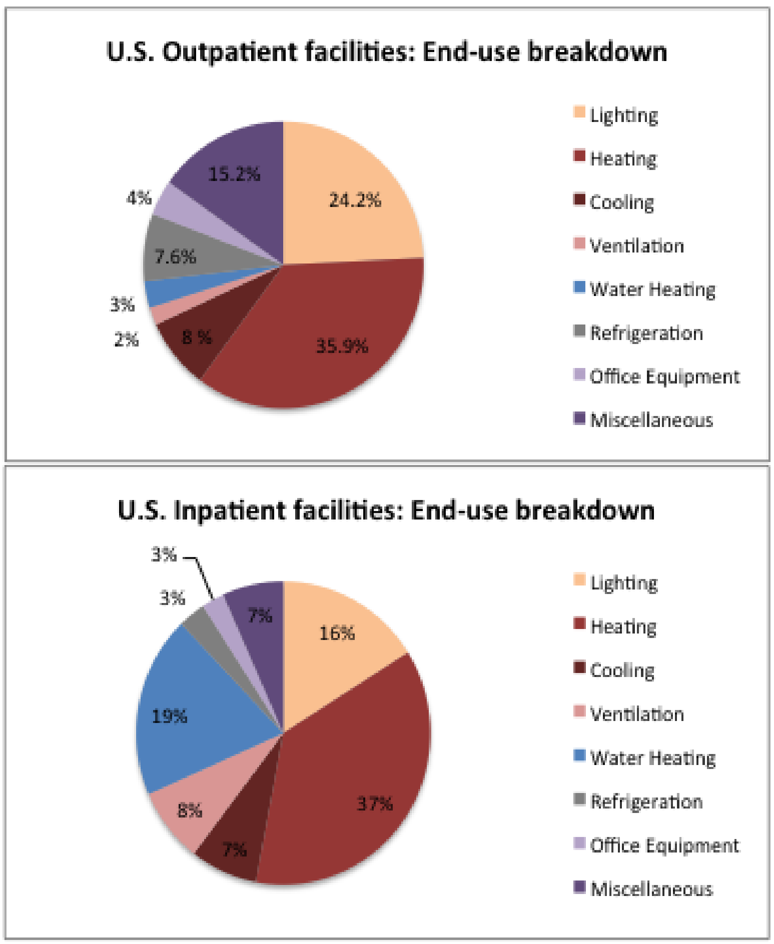
There is a trend towards increasingly higher energy use in Indian healthcare facilities; at least three factors can be attributed to this growth:

- 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 approach international standards of design and patient care. At the same time, India's healthcare system must aim to reduce costs, consume less, reduce infections, and deploy new medical technology. With energy contributing to a 5–6 percent of annual hospital operating costs, facility managers need a structured and informed approach to reduce energy use.

1.3.2 U.S. Healthcare Energy

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 acute care 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 (CBECS, 2003) Inpatient functions have significantly higher EUI than outpatient facilities. According to the U.S. Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS) 2003 modeled data, the average EUI in U.S. outpatient facilities is **94.6 kBtu/ft^2-yr** (298 kWh/m^2-yr); while the median EUI in U.S. inpatient facilities is **249.2 kBtu/ft^2-yr** (885 kWh/m^2-yr) (EIA 2003)(EERE 2012). Over half of the energy use is due to HVAC loads, driven by ventilation, thermal comfort, humidity control, filtration, and pressurization. Overall, lighting, HVAC, 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. According to another data point, the Salmon Creek hospital case study (Hatten et al. 2011), about two-thirds of the energy consumption in this in-patient facility is because of HVAC end use, while lighting is around 8 percent and water heating is 1.7 percent. There is wide variation in the sector with respect to end-use consumption breakdown.



(Source: CBECS 2003)

Figure 2: Charts showing the end-use breakdown in U.S. outpatient and inpatient facilities.

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 EIS may be a relevant technology to enable energy savings, depending on what actions are taken based on the EIS information. 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 at sufficient granularity to enable action (Figure 3). These systems can enable significant energy savings by identifying consumption patterns, tracking energy use, identifying waste, and benchmarking building energy performance against similar buildings. Approximately 100 systems are currently available with varying levels of technical capability. However, the adoption of such systems is limited to high-end markets since they tend to be custom-designed, sophisticated, and expensive. Many such systems include levels of software features and data integration, and analysis options make them difficult to navigate. This may be one barrier, among others, to more pervasive use of these promising technologies.

To combat barriers to adoption and facilitate widespread application in buildings, 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.

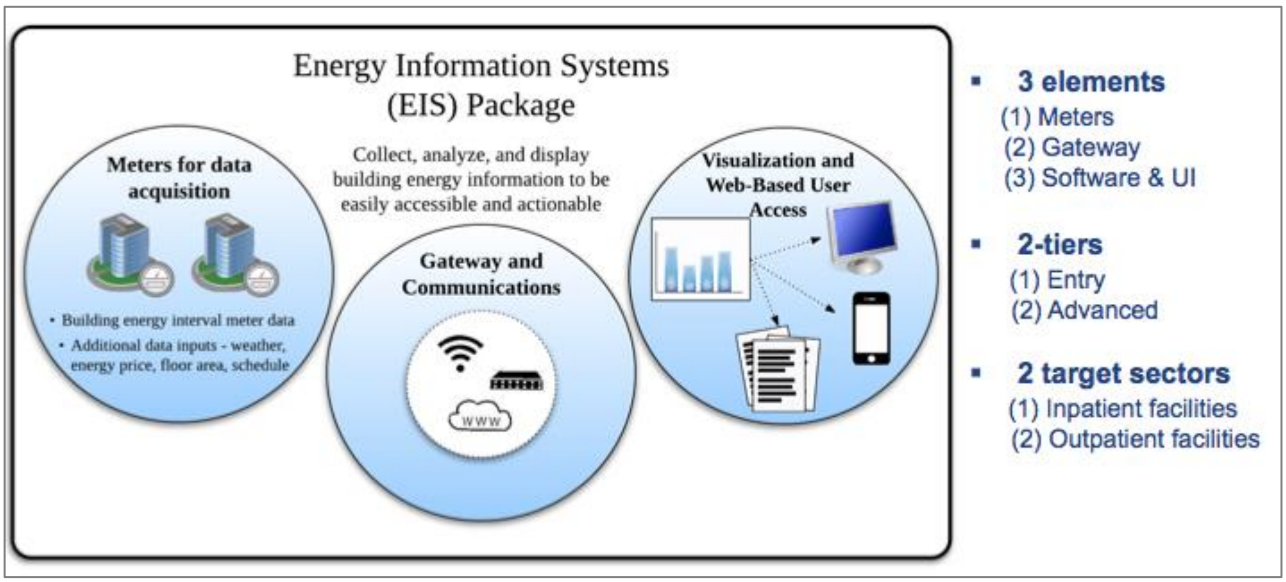


Figure 3: Energy Information Systems (EIS) consist of data acquisition sensors and interval meters, communication gateways, and performance monitoring software with a user interface. These systems collect, analyze, and display building energy data, and enable site operational efficiency.

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 initial installation, deployment, 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. Transactional cost framework

Today's market offers approximately 100 EIS solutions. However, because each building is different, these systems tend to be customized, leading to high transactional costs for procurement, installation, and operation. *Transactional cost* is defined as *costs other than the money price that are incurred in trading goods or services. Before a particular mutually beneficial trade can take place, at least one party must figure out that there may be someone with which such a trade is potentially possible, search out one or more such possible trade partners, inform him/them of the opportunity, and negotiate the terms of the exchange. All of these activities involve opportunity costs in terms of time, energy and money* (Johnson 2005).

The transaction process consists of a five steps in an existing facility, starting with a facility owner developing a curiosity for energy monitoring and ending with the facility manager using the EIS (Figure 4). These steps may be streamlined for a new facility; for example, the time taken for Step 4 may be shortened if while designing the electrical circuitry of a new facility, it is done in a way that is conducive to easy sub-metering and management.

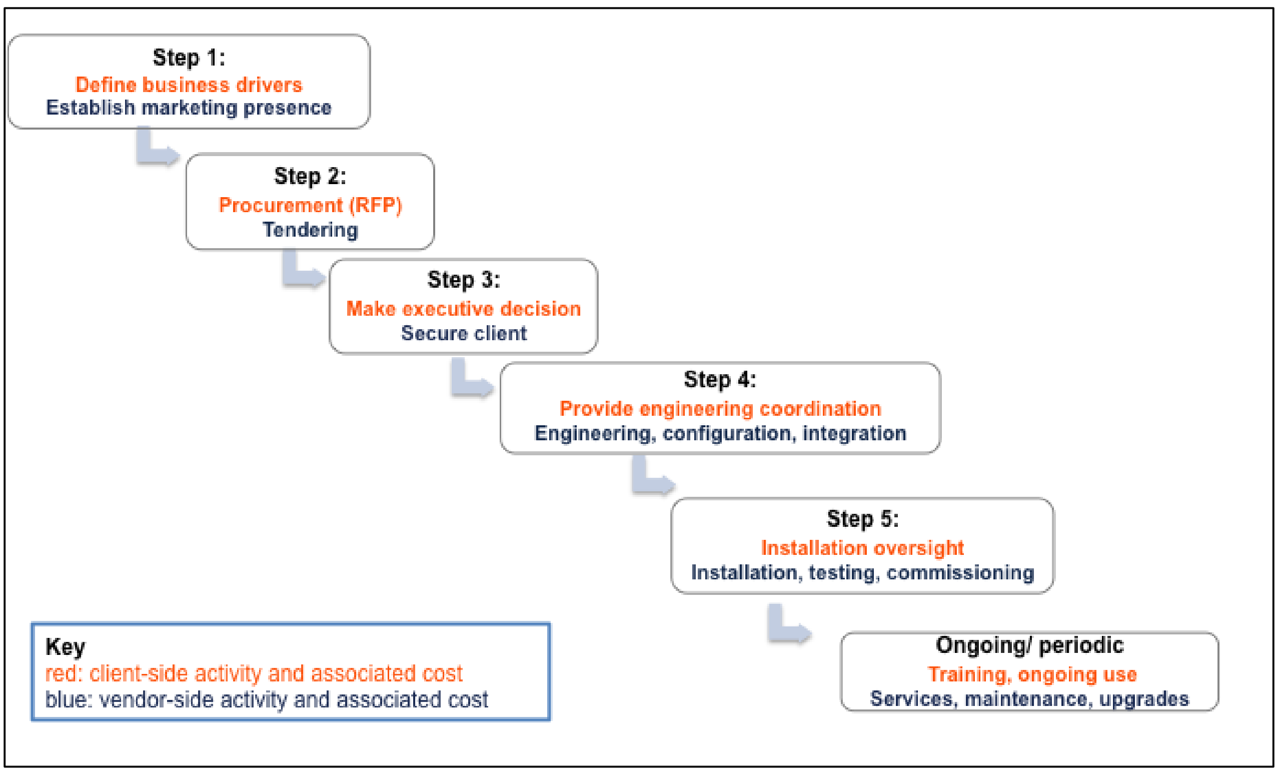


Figure 4: Transactional cost framework for the specification, installation, and use of EIS packages.

Vendor costs for these steps must be paid by 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 3–5 (i.e., securing a client, configuration, integration, installation, testing, 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 variety of healthcare facilities, with the objective of identifying common elements in an EIS package. The goal is for EIS packages to be engineered to be relevant across a range of healthcare facilities by recognizing and accommodating this heterogeneity.

Two aspects make a building sector such as healthcare highly varied: (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. This 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 the 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 subsectors. There are the core metrics such as EUI and cost/time period.

There are certain other metrics that tie back to the hospital's business drivers, but would need integration with the hospitals' patient records. These include the EUI per adjusted patient day for outpatient facilities and EUI per (occupied) hospital bed for an in-patient facility; both of these would imply data integration the hospital's patient admittance records. Given the difficulty in acquiring such data, these fall under the category of aspirational metrics.

2.2.1.3 Generating a pick list of potential loads

We then developed a list of all potential loads in a healthcare facility by end use (Figure 5), and studied the loads disaggregation in illustrative facilities (Figure 6). We then mapped non-critical end uses as being different from critical, emergency, and standby end uses. 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, presented in tables 1 and 2 in Section 3.

Typical List of Fuels and End Uses in a Healthcare Facility

1. Electricity Supply
- 1.1 Electricity grid
- 1.2 Electricity from on-site source

2. Gas/ Fuel Oil Supply

3. Steam Supply

4. Electricity Consumption
- 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 including pneumatic tube systems)
- 4.14 Plant Medical Equipment
  (clinical air compressors, clinical vacuum pumps, blowers, reverse osmosis water purification)

5. Gas/ Fuel Oil Consumption
- 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 Consumption
- 6.1 Central Cooling
- 6.2 Central Heating
- 6.3 Reheat (separation, if done at terminal units)
- 6.4 Service/Domestic Hot Water
- 6.5 Kitchen Steam-based Equipment
- 6.6 Laundry Steam-based Equipment
- 6.7 Process Steam Loads

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

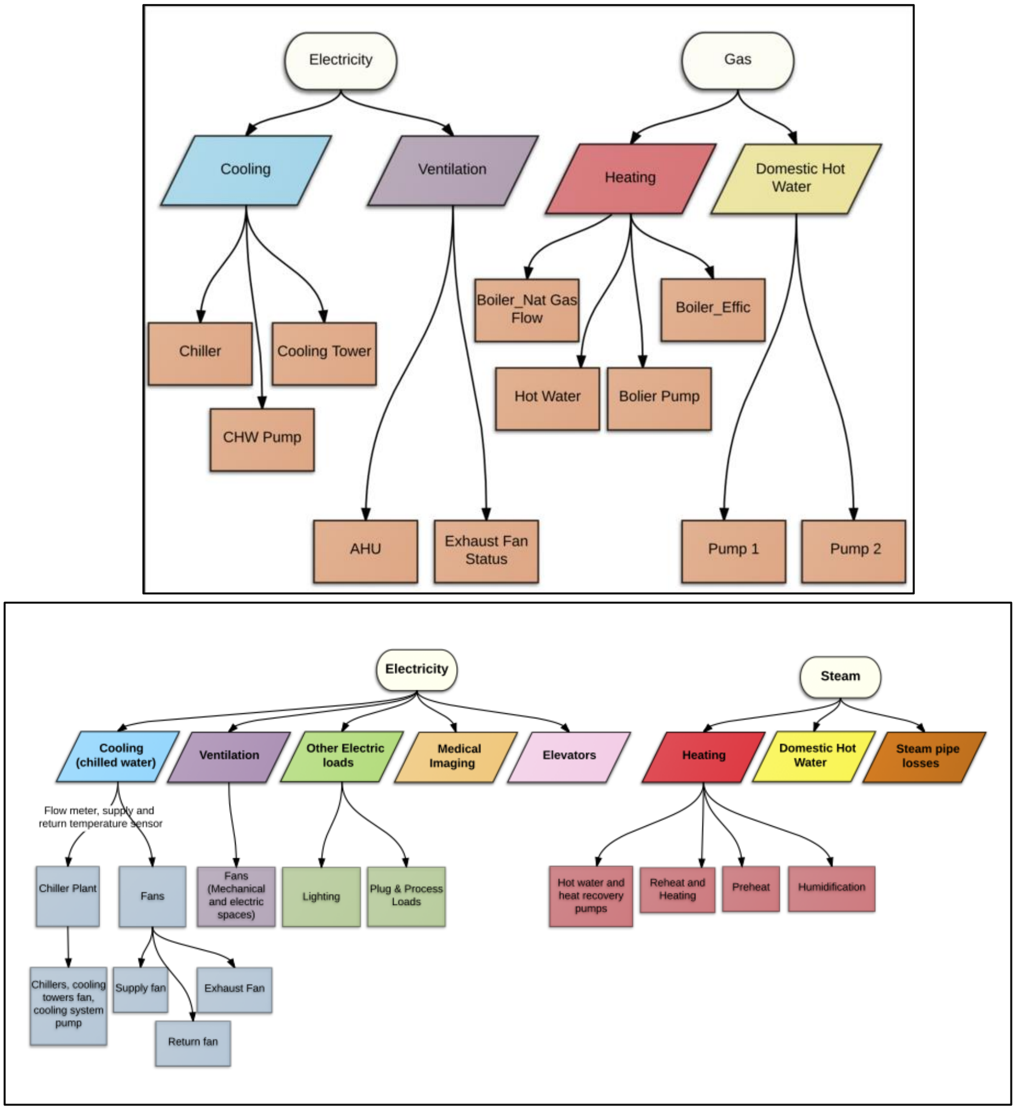


Figure 6: Measurable loads in two illustrative healthcare facilities. (Source: Black et al. 2011)

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, using previous studies (such as Black et al. 2011) and industry experience. For instance, we identified that it is 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 decision factors: contribution, actionability, and meterability.

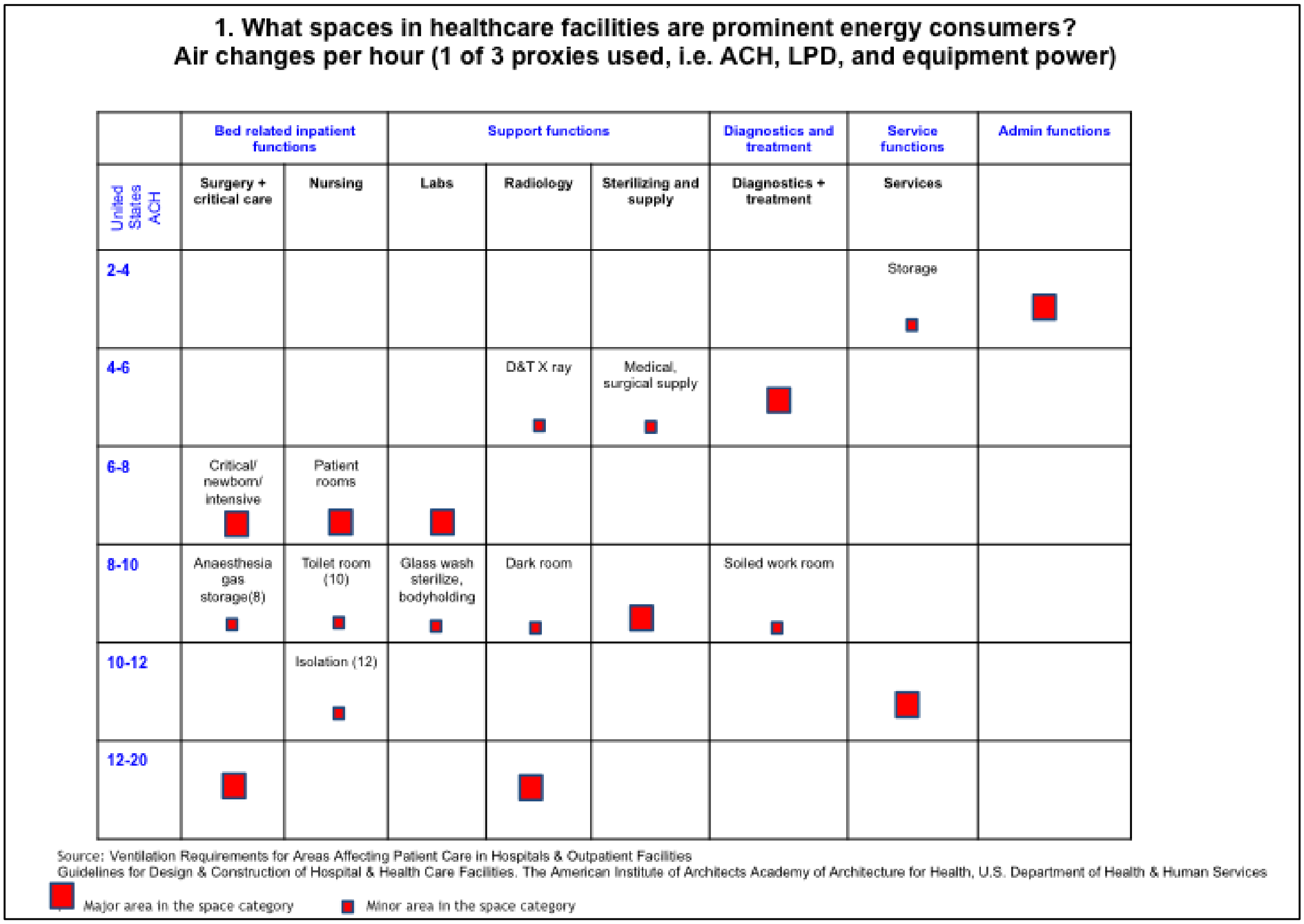
1. **Contribution:** identifying the most significant loads by size in a healthcare facility, based on three proxies: (1) air changes per hour (ACH) as an indicator of ventilation load, (2) lighting power density (LPD) as an indication of high lighting loads, and (3) equipment power, as an indicator 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. Some loads are too distributed to be easily controlled.
3. **Meterability:** determining whether the wiring provides an opportunity to disaggregate pertinent loads. While there is wide variance in the wiring design in Indian healthcare facilities, U.S. healthcare facilities are required to follow the standardized guidelines for electrical design, which may allow them to predetermine the standardized points for energy monitoring.

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.

	CONTRIBUTION Is the load a major contributor to energy consumption? ✖ Y	ACTIONABLE Is the load available to control, manage, schedule? ✖ Y	METERABLE Can the load be discretely submetered or disaggregated? ✖ Y	Selected for pick list of loads
Load 1	✖	✖	✖	Yes
Load 2	✖	✖	—	No
Load 3	✖	—	✖	No
Load 4	—			No

Figure 7: Illustrative decision framework for determining a picklist of loads.



(Source: AIA 2006)

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.

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 (figures 9 and 10).

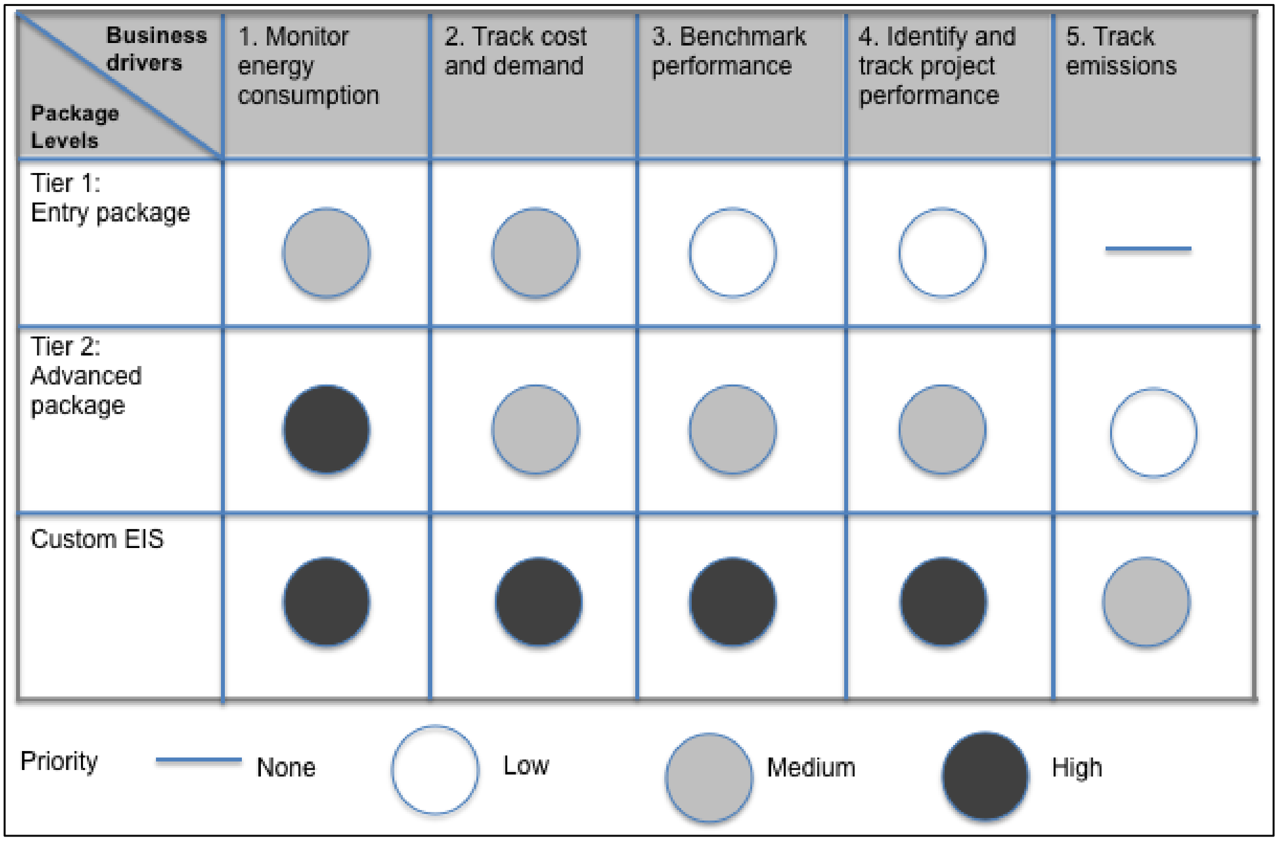


Figure 9: Entry and Advanced tier functionality, built around prioritized support provided to business drivers.

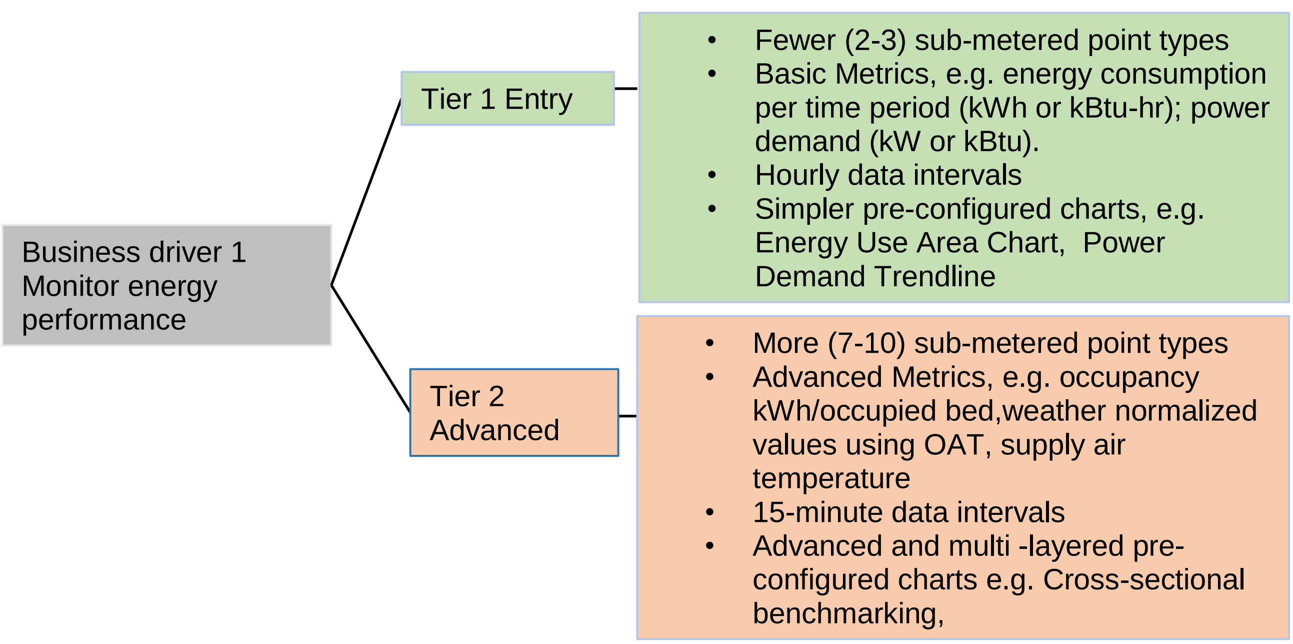


Figure 10: Illustrative example of features and functionality of EIS Packages are mapped to business drivers of healthcare facilities.

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 rapid, short-term level (daily/weekly) (Figure 11) or long-term, high-level (annual) (Figure 12) 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. Our recommended dashboards are shown in Section 3.

Building pulse at a glance: Facilities dashboard with five metrics

Primary Audience: Facility managers, engineering staff
Time scales: Daily, weekly

1. What is my whole-building **Absolute Energy Consumption?**
   - kWh or kBtu (or therm), per day or per week
     Area chart (Chart 1)

2. What is the **normalized Energy Use Intensity?**
   - kWh or kBtu (or therm) per unit square area
   - kWh/occupant (occupied bed for in-patient facilities, adjusted patient day for outpatient facilities)*
     Area chart (toggles on Chart 1)

3. How is my building performing compared to past performance, i.e., **longitudinal benchmarking?**
   - kWh or kBtu (or therm) use for given day or week versus a previous time period
     Area chart (Chart 1 variation)

4. What is the **load demand per end use** of my building; and are the end uses operating efficiently?
   -kW or kBtu/hour per length of time
   - % portion of the total energy use*
     Trendline chart (Chart 2)

5. What is the **fuel consumption and cost?**
   - kBtu/fuel per time period
   - $ per time period
     Pie chart (Chart 3)

*Tier 2 only, using inputs from patient census

Figure 11: A list of short-term questions that inform the facilities dashboard.

High-level picture:
Executive's dashboard with five metrics, with additional facilities management charts
Primary Audience: Executives, facilities managers
Timescales: Monthly, quarterly, or annually

1. What is the **fuel consumption and cost?**
   - kBtu/fuel per time period
   - $ or INR per time period
     Pie chart (Chart 1)

2. What are the **trends** for my facility's energy costs?
   - $ or INR per time period
     Trend chart (Chart 2)

3. What is my building's **energy consumption, and how is it performing over time compared to the baseline, i.e., longitudinal benchmarking?**
   - kWh or Btu per month, quarter, or year
   - kWh or kBtu/unit square area
   - kWh/occupant (occupied bed for in-patient facilities, adjusted patient day for outpatient facilities)*
     Stacked bar chart (Chart 3)

4. How is my building performing compared to other similar facilities in my portfolio, or benchmarks, i.e., **cross-sectional benchmarking?**
   Cross-sectional Benchmarking (Chart 4)

5. What is **the carbon footprint** of my facility?
   Cross-sectional Benchmarking (Chart 4)

Additionally, for facilities staff only

6. What is the **load demand per end use** of my building, and are the end uses operating efficiently?
   - kW or kBtu/hour per length if time
   - % portion of the total energy use*
     Average loads line chart (Chart 5)

7. What does an **annual snapshot** of my facility look like? Is it performing well throughout the course of a month/year?
   Whole-Building Heat map (Chart 6)

*Tier 2 only, using inputs from patient census

Figure 12: A list of high-level questions that inform the monthly/annual dashboard, targeted primarily for decision making at the owner/executive level. Additional facilities-level charts are also provided for the facilities staff.

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 1, in order to respond to that business driver, some of the important **metrics** to track are energy consumption per time period (kWh or kBtu-hr) and power demand (kW or kBtu). **Data inputs** are required to generate the metrics. These are continuously acquired from 15-minute (for Tier 2) or hourly (for Tier 1) interval data regarding energy (by fuel) use 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 a front-end user interface: an Energy Use Area Chart, a Power Demand Trendline, and a Fuel Cost and Consumption Chart. These charts are presented the Section 3.3.

Hence, for each package we determined a set of metrics, mapped to sector-specific business drivers, 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.

Table 1: Metering and gateway requirements for EIS packages.

Meters	Submetering Points	Physical Location	Communication	Measured Parameters	Accuracy and Turndown (U.S. and India)	Additional inputs
Tier 1: Electric submeters	Whole Building, major loads (spaces or end uses) such as chiller plant, fan energy	1 Main Distribution Board (DB)	- Wired between submeter and gateway, Wi-Fi between gateway (1) and remote database - RS-485 (Modbus and BACnet) output standard for India, potentially TCP/IP for U.S.	kWh, V, A	Class 1 according to IS13779 (Indian standard); 1% with 10:1 turndown (U.S. requirement)	- Bldg./space floor areas -Fuel supply cost
Tier 2 : Electric submeters	Whole Building; (spaces or end uses) - chiller plant - fan energy - inpatient room cluster - emergency eqpt./plugs/lights	1 Main DB + Representative Spaces / Floor DB	- Wired between submeter and gateway, Wi-Fi between gateway (1) and remote database - RS-485 (Modbus and BACnet) output standard for India, potentially TCP/IP for U.S	kWh, kW, V, A, Power Factor, For WB: current and voltage harmonics	Class 1 according to IS13779 (Indian standard); 1% with 10:1 turndown (U.S. requirement)	- Bldg./space areas - fuel supply cost - operating schedules - outdoor air temperature (OAT) from weather data - supply air temp (SAT) from controls system - patient census info
Tier 1 and 2: Gas submeters Primarily U.S. package	Whole Building gas; 1 major space heating load (boiler or furnace)	1 main piping location, at all boilers/ furnaces	Pulse output counting using a twister pair to gateway (e.g., AquiSuite can take pulse counting directly and convert to therms)	submeter reads out in cubic ft, data required as therms, ~100 cu ft = 1 therm	U.S. ANSI B109 standard; 1% with 100:1 turndown	
Tier 1: Oil meter	Tank-fill readings					
Tier 2: Oil meter	1	1 main location at each generator unit, providing supply and return flows	RS-485 / pulse output		1% accuracy at 10:1 turndown	
Tier 2 only: Btu submeter	cooling and heating water	at chiller and boiler plant	Scaled pulse or RS-485 (Modbus and BACnet) output standard	Btu/h	Precision matched temp. sensors, 2% accuracy 10:1 or 4% accuracy with 100:1; Standard EN 1434	

The following parameters should be measured and displayed by electric submeters:

i. Instantaneous phase voltage (V); phase-to-phase, phase-to-neutral
ii. Instantaneous phase current (A)
iii. Instantaneous apparent power (VA), active power (W), and reactive power (VAR)
iv. Maximum demand (W) over a specific time interval
v. Power factor
vi. Frequency (Hz)
vii. Active energy (kWh)

Sections 3.1 and 3.2 present descriptions of the Entry-level and Advanced-level Healthcare EIS-in-a-box packages.

3.1. The Entry EIS package

Figure 13 shows a description of the Entry tier Healthcare EIS-in-a-box package.

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. 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 based on the types of actions and interventions taken.

3.1.3 Metering and data requirements

At the Entry tier, interval meters at the whole-building load and a small, recommended set of 2–3 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 2). The software directly acquires data inputs from the meters and submeters. Additional user-supplied information that needs be configured is limited to floor area square feet for normalization by area.

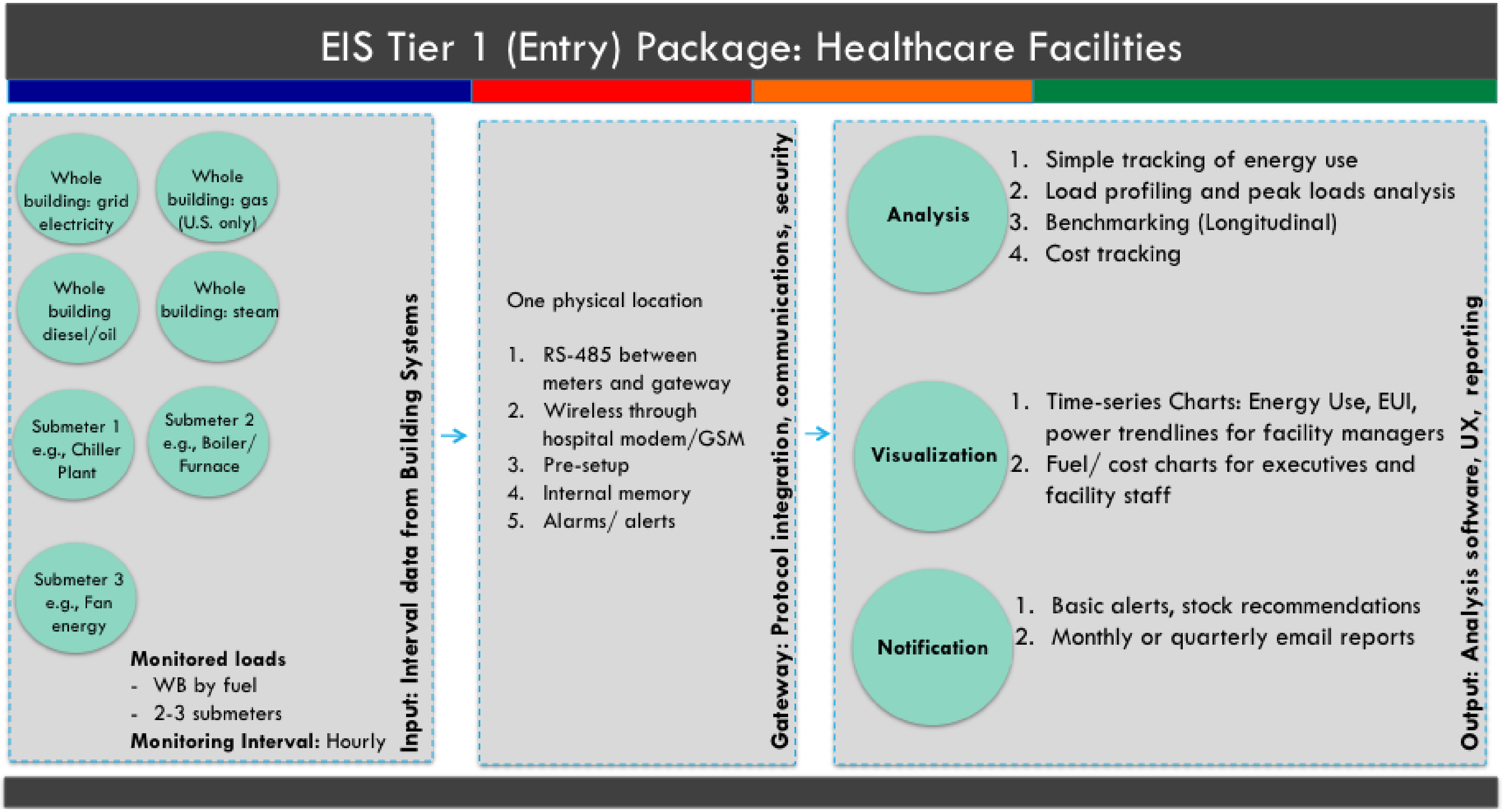


Figure 13: Entry-tier EIS package for healthcare facilities.

3.1.4. Visualization and usability

Visualization and usability consists of seven preconfigured visualization screens—three in the daily dashboard and four in the monthly/annual dashboard (figures 15 and 16)—which provide the following:

- Identification of trends and potential electricity waste 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 (INR/$) 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 a limited amount of 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 anomalies enables users to identify which big energy guzzlers they should choose to implement energy efficiency options. It also provides long-term visibility into the building's energy performance that can be used for benchmarking.

Table 2: Picklist of loads for the Entry-tier EIS package based on end uses and physical spaces in a healthcare facility.

		Whole Building	Bed related inpatient functions			Support functions			Diagnostics and treatment	Service functions	Admin functions
			Surgery + critical care	Emergency Dept	Nursing (inpatient room cluster)	Labs	Radiology + imaging	Workrms etc	D&T	Services	
			ICU	Special care/trauma							
All electricity- grid		X									
All Electricity from on-site source		X									
All gas		X									
All oil		X									
All steam											
	End Uses										
HVAC	Central cooling	X									
HVAC	Zone cooling										
HVAC	Reheat (at terminal units)										
HVAC	Pumps										
HVAC	Central Heating (furnace)	X									
HVAC	Central heating (boiler)	X									
HVAC	Fans	X									
Lights	Indoor Lighting										
Lights	Outdoor Lighting										
Plugs	Plug loads										
Plugs	Communication systems*1										
Plugs	Medical equipment *2										
Plugs	Imaging equipment (CT, MRI...)										
Process	Kitchen equipment										
Process	Laundry equipment										
Process	Process Loads for transportation *3										
Med eqpt	Plant medical equipment *4										

X pertains to recommended electric or gas meter for a Tier 1 package.

*1: IT, data network, emergency/alarms, intercom, picture archiving, CCTV, electronic health records; *2 e.g., Dialysis, radiation/inhalation/therapy; *3 Elevators, trolleys, incl. pneumatic tubes system; *4 Clinical air compressors, clinical vacuum pumps, blowers, reverse osmosis water purification)

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.

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. It provides deeper visibility and granularity in terms of *when, how much,* and *where* energy is being consumed. 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, that may enable provide savings of up to 10 percent that have been observed in office facilities. 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 occupancy (number of beds, adjusted patient days) that allow normalization and superior analytics.

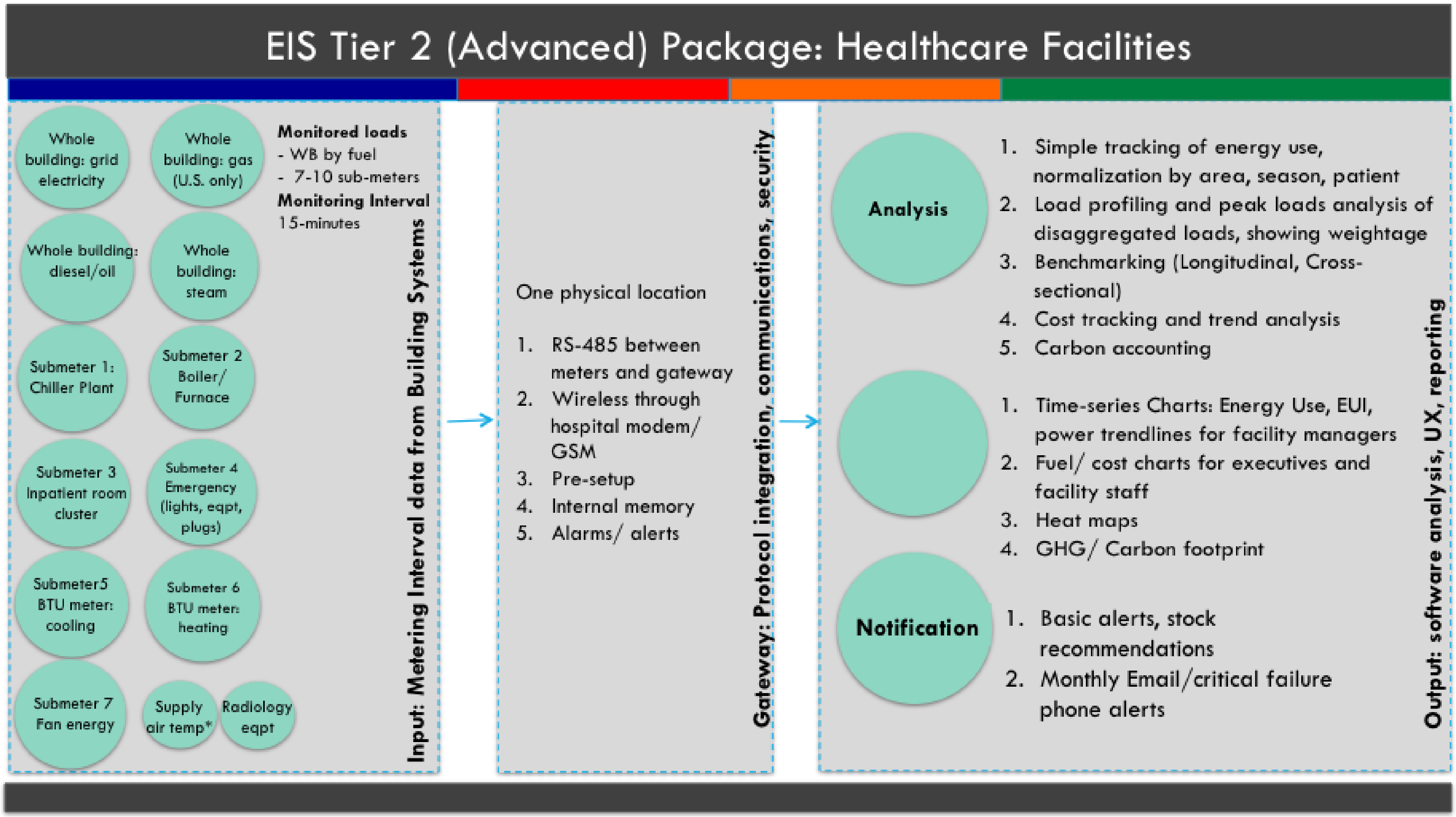


Figure 14: Advanced tier EIS package for healthcare facilities

3.2.4 Visualization and usability

The Advanced tier EIS consists of 10 preconfigured 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 as 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 8–10 recommended metering locations and provides more granular information, 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.

Table 3: Picklist of loads for the Advanced EIS package based on end uses and physical spaces in a healthcare facility.

		Whole Building	Bed related inpatient functions			Support functions			Diagnostics and treatment	Service functions	Admin functions
			Surgery + critical care ICU	Emergency Dept Special care/trauma	Nursing (inpatient room cluster)	Labs	Radiology + imaging	Workrms etc	Diagnostics + treatment	Services	
All electricity- grid		X			X						
All Electricity from on-site source		X									
All gas		X									
All oil		X									
All steam											
	End Uses										
HVAC	Central cooling	X X									
	Zone cooling										
	Reheat (at terminal units)										
	Pumps										
	Central Heating (furnace)	X X									
	Central heating (boiler)	X X									
	Fans	X									
Lights	Indoor Lighting			X							
	Outdoor Lighting										
Plugs	Plug loads										
	Communication systems*1										
	Medical equipment *2										
	Imaging equipment (CT, MRI...)										
Process	Kitchen equipment										
	Laundry equipment										
	Process Loads for transportation *3										
Med eqpt	Plant medical equipment *4										

X pertains to recommended electric or gas meter location for a Tier 1 package.

X pertains to recommended electric or gas or BTU meter location for a Tier 2 package.

*1: IT, data network, emergency/alarms, intercom, picture archiving, CCTV, electronic health records; *2: e.g., Dialysis, radiation/inhalation/therapy;
*3:Elevators, trolleys, incl. pneumatic tubes system; *4: Clinical air compressors, clinical vacuum pumps, blowers, reverse osmosis water purification

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).

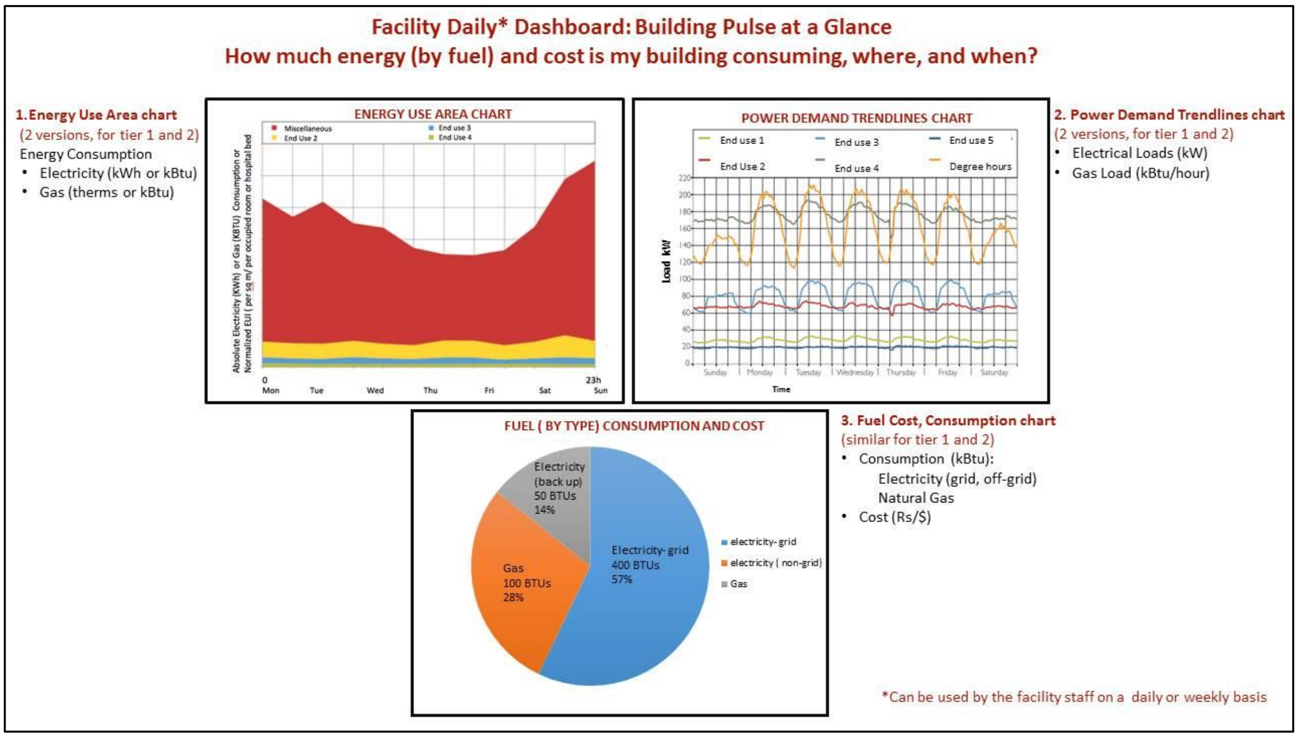


Figure 15: Facility Dashboard "Building Pulse at a glance" for EIS Healthcare packages: for daily or weekly use.

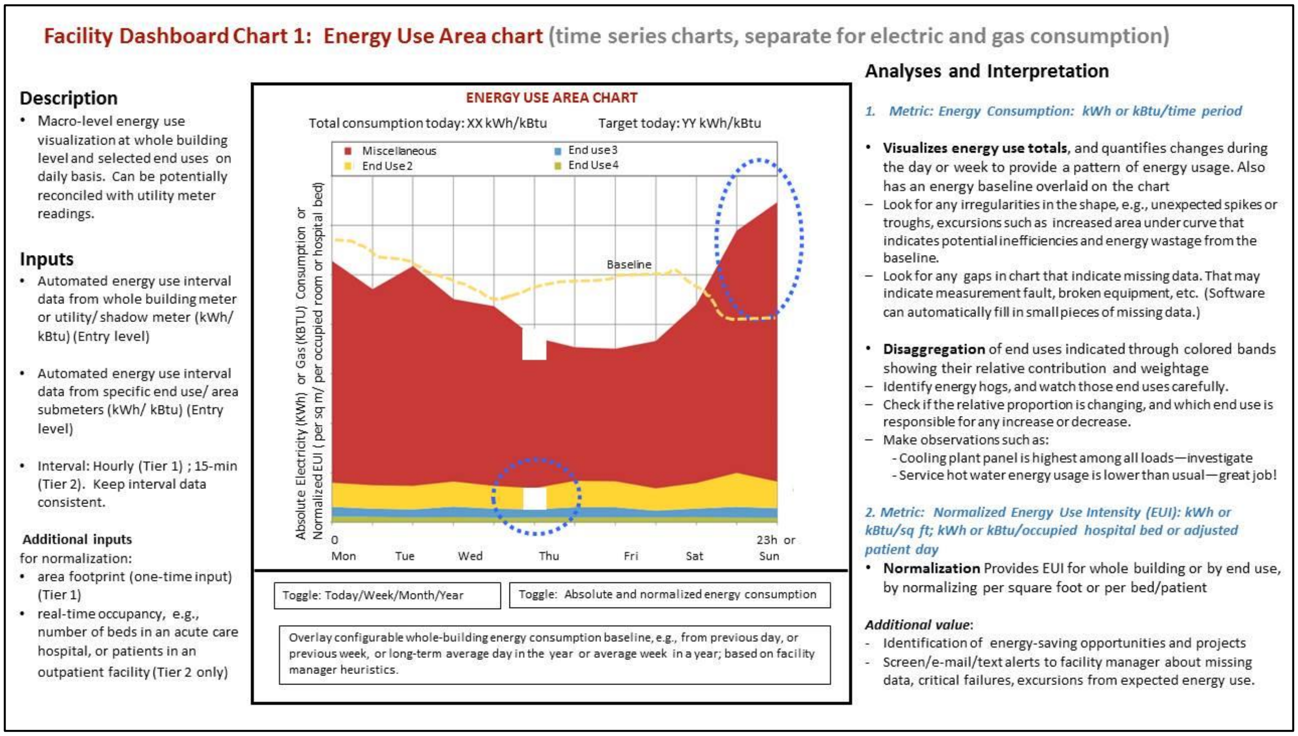


Figure 15(a): Details of Dashboard charts; Daily Chart #1 Energy Use Area Chart. Can be used for daily and weekly use using toggles. For both the Entry and Advanced Tier packages.

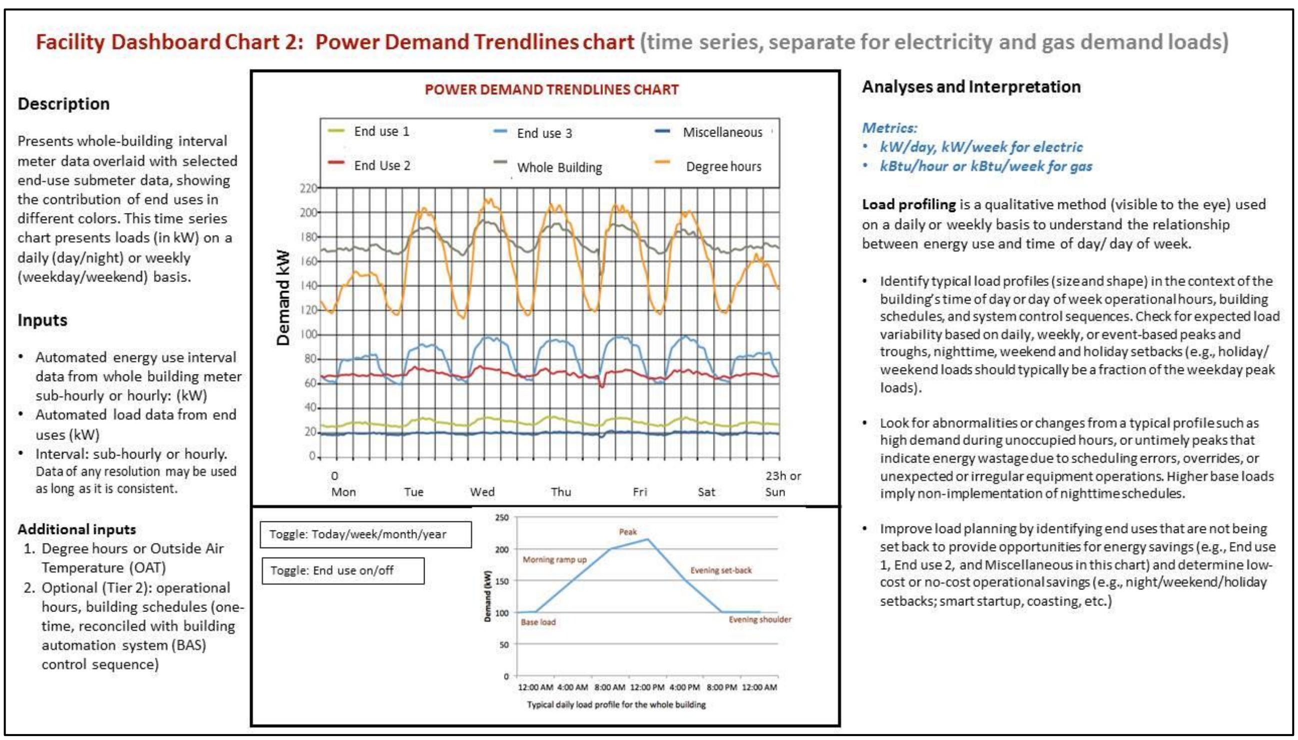


Figure 15(b): Details of Dashboard charts; Daily Chart #2. Power Demand Trendlines chart. For both the Entry and Advanced tier packages.

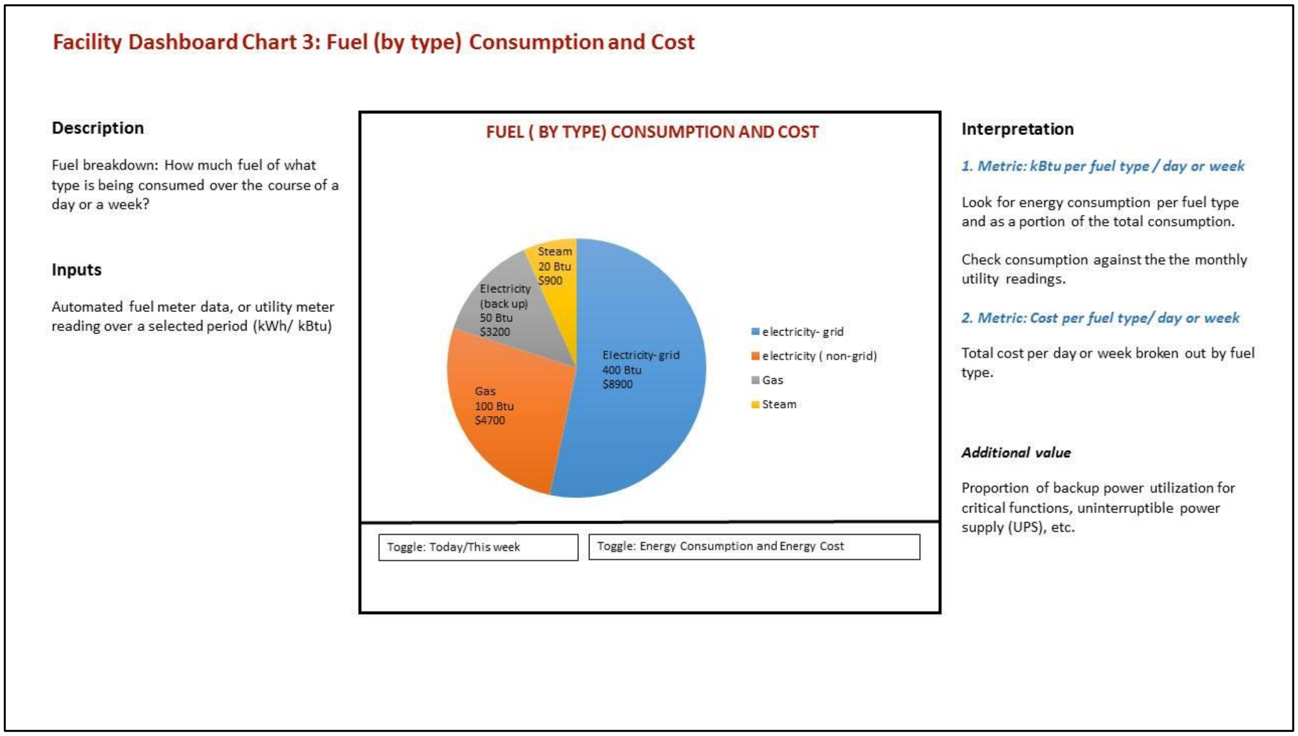


Figure 15(c): Details of Dashboard charts; Daily Chart #3. Fuel (by type) Consumption and Cost chart. For both the Entry and Advanced tier packages.

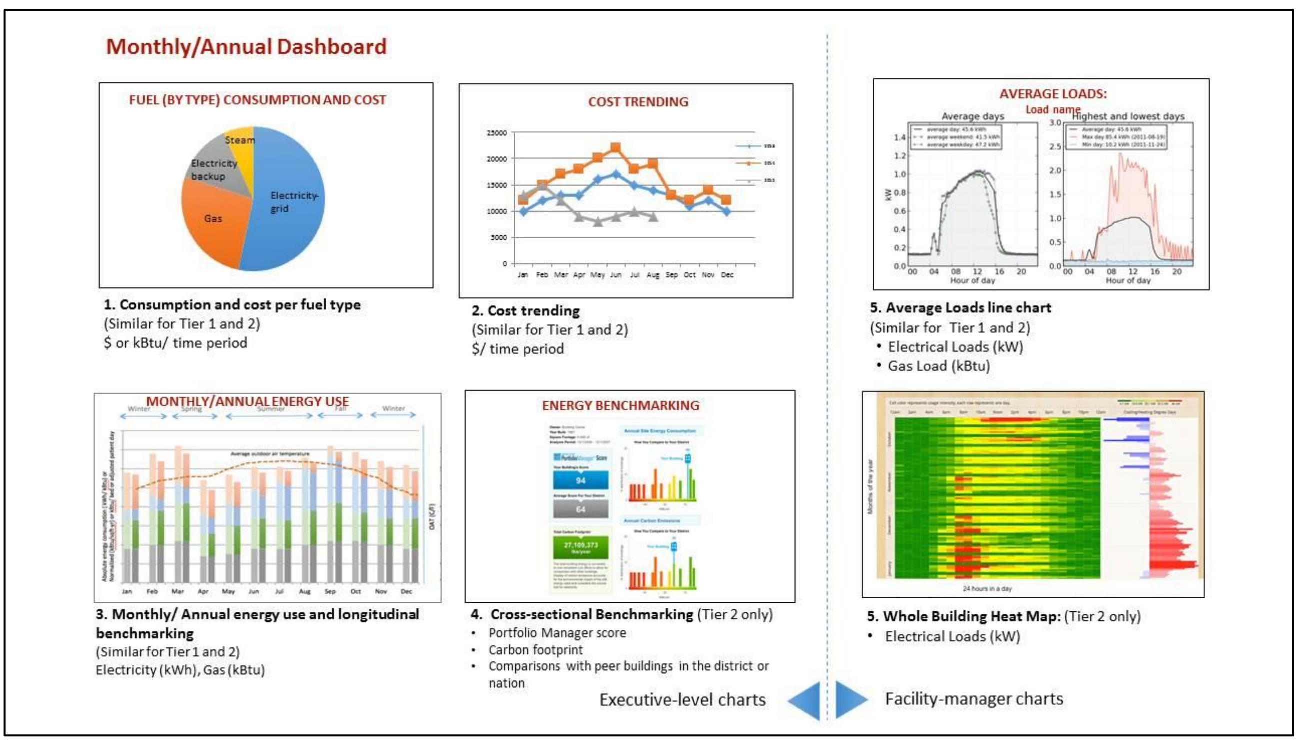


Figure 16: Monthly/Annual Dashboard for EIS Healthcare packages.

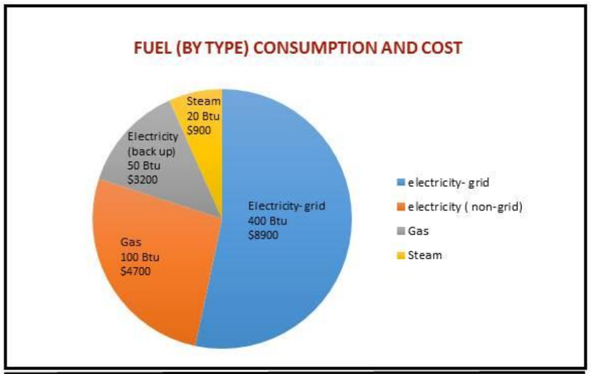
Long-Term Dashboard Chart 1: Fuel-type consumption and cost

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)



Toggle: This month / This year

Toggle: Energy Consumption and Energy Cost

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 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 backup power utilization for critical functions, uninterruptible power supply (UPS), etc.

Figure 16(a): Details of Dashboard charts; Monthly Chart 1: Fuel-type consumption and cost chart. For both the Entry and Advanced tier.

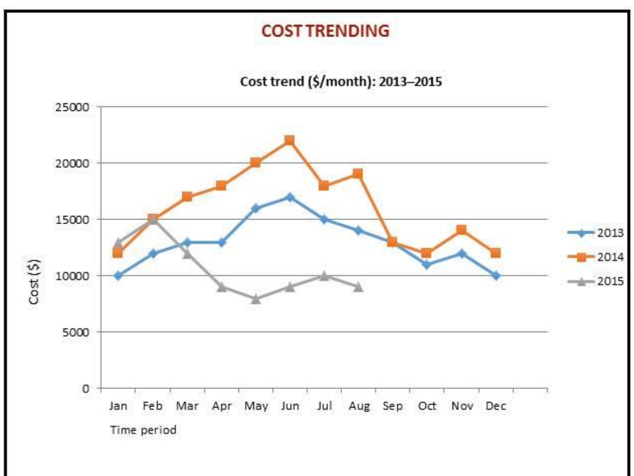
Long-term Dashboard Chart 2: Cost trending

Presentation

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

Inputs

Cost, reconciled with utility bills



Toggle: Total energy cost / cost per fuel type

Toggle time period: Over past 30 days / over season / over past 12 months

Interpretation

Key Performance Indicators (KPIs): $ or INR/month

Figure16 (b): Details of Dashboard charts; Monthly Chart 2: Cost trending chart. For both the Entry and Advanced tier.

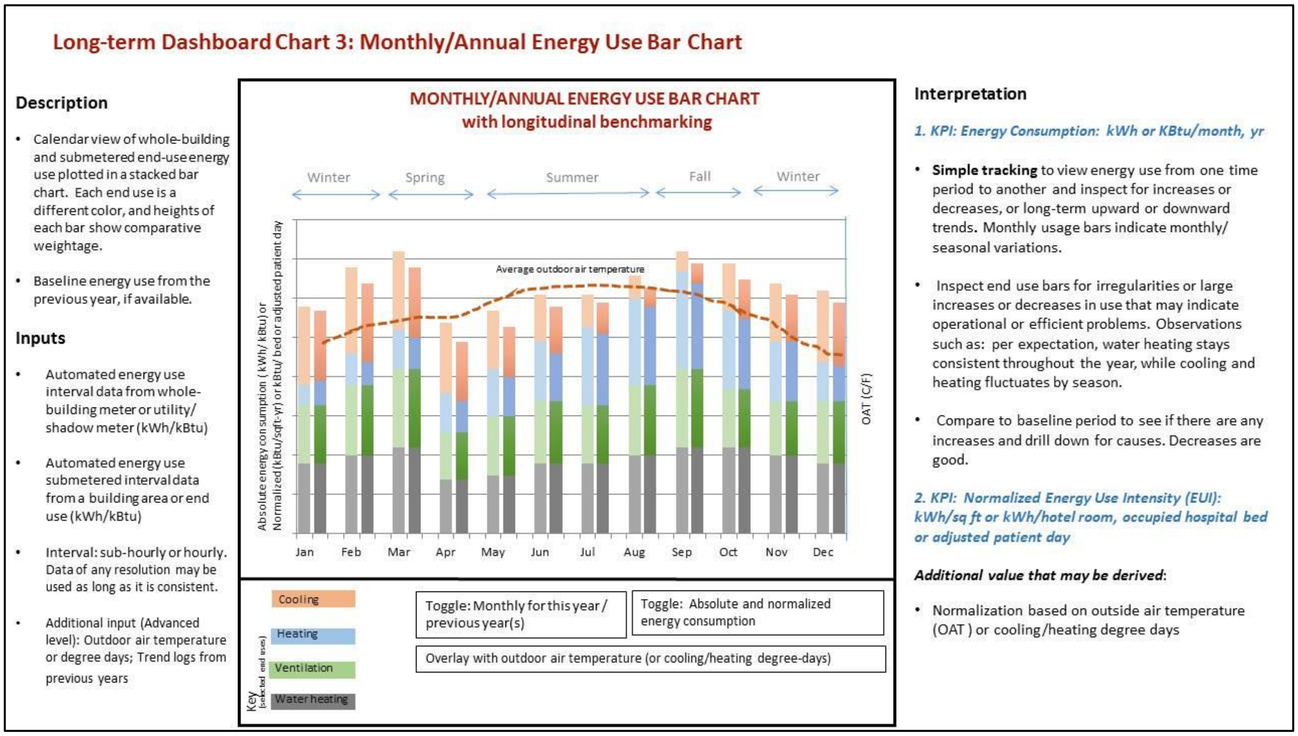


Figure 16(c): Details of Dashboard charts; Monthly Chart 3: Monthly/Annual Energy Use breakdown chart. For both the Entry and Advanced tier.

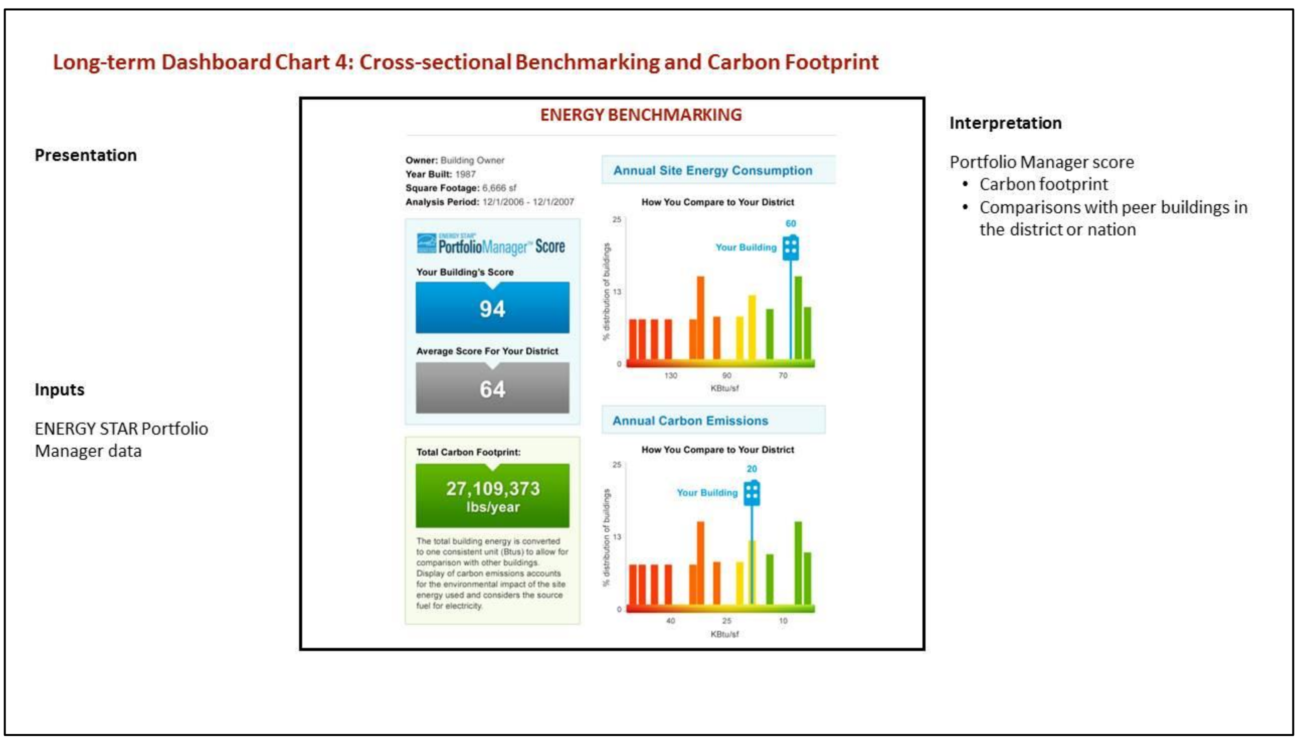


Figure 16(d): Details of Dashboard charts; Monthly Chart 4:Coss-Sectional Benchmarking and Carbon Footprint chart. For the Advanced tier.

Long-term Dashboard Chart 5: Average Loads Chart

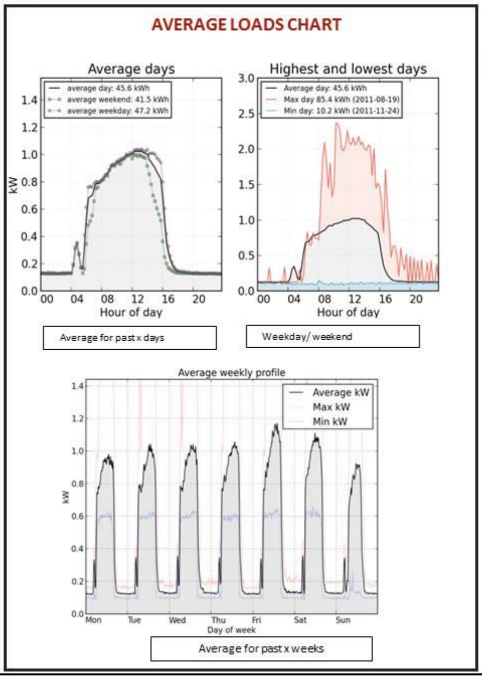
Description: Power intensity

- This chart displays the typical average daily/weekly load profile (in kW) corresponding to the building's occupancy and use for each hour of the 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

Key Performance Indicators (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 week. 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 nighttime 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(e): Details of Dashboard charts; Monthly Chart 5: Average Loads chart. For both the Entry and Advanced tier.

Long-term Dashboard Chart 6: Whole-Building Power Heat Map

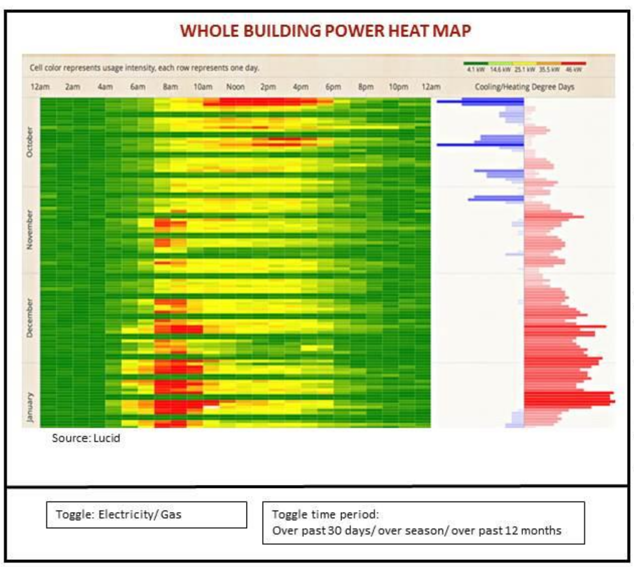
Presentation

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

Key Performance Indicator: 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 is highest at midday, e.g., 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 indicate seasonality of energy use.
- Vertical bands show consistency of scheduling and tight controls
- Make observations such as:
  - In 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 (f): Details of Dashboard charts; Monthly Chart 6: Whole-Building Power Heat map. For the 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 to encourage market adoption of the technology.

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