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Authors

Singh, Reshma
Mathew, Paul
Granderson, Jessica
et al.

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Lawrence Berkeley National Laboratory

Packaged Scalable Energy Information Systems for Hotels

Reshma Singh[1], Paul Mathew[1], Jessica Granderson[1], Yash Shukla[2], Amiya Ranjan Behera[2]

[1]Lawrence Berkeley National Laboratory; [2]Centre for Advanced Research in Building Science and Energy, CEPT University

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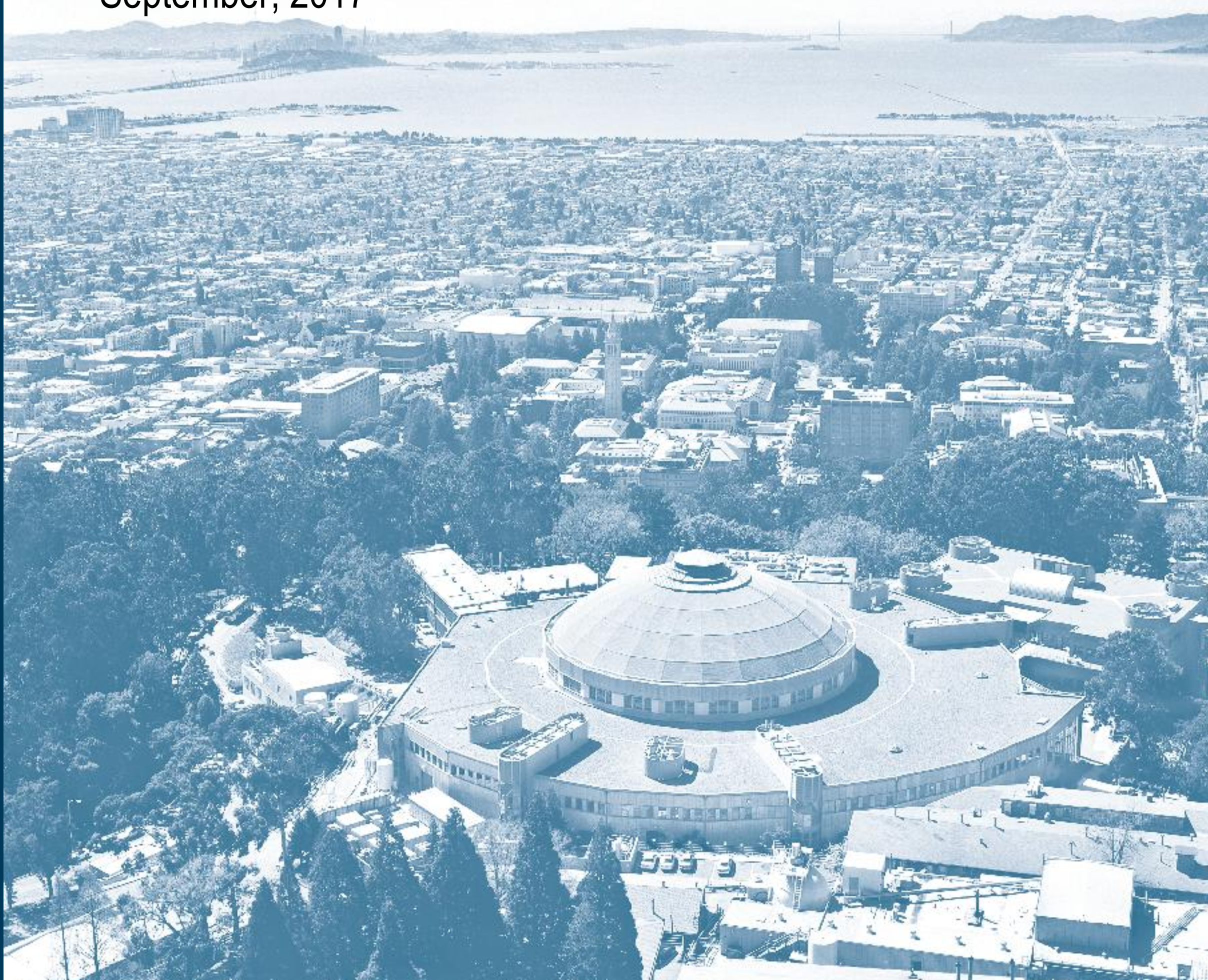

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Packaged Scalable Energy Information Systems for Hotels

Abstract

Purpose

Building Energy Information System**s** (EIS) are performance monitoring software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data. Some $60 billion is spent annually on wasted energy in U.S. buildings, and actions taken based on EIS data can enable operational energy savings of ~10 percent in the U.S. commercial sector (~2 quads of primary energy). However, EIS adoption is low due to various technical and market challenges. This paper provides technical specifications for standardized EIS packages that can help overcome barriers and accelerate scale.

Design/Methodology/Approach

A five-step process was followed:

1. Identifying business drivers as key determinants for hotel sector-specific packages
2. Addressing heterogeneity to develop standardized, tiered packages
3. Determining performance metrics for key stakeholders
4. Recommending streamlined data architecture
5. Developing visualization enabling insights and actions

Findings

Technical specifications for two tiers (entry and advanced) of EIS packages for hotels have been developed. EIS vendor, integrator, and client organization's facilities and IT staff have been considered as key stakeholders. Findings from six field demonstrations show benefits of (i) **cost-effectiveness,** through reduced transactional, first, and operational costs, (ii) **scalability,** by accommodating heterogeneity across the building sub-sector, (iii) **simplicity,** by integrating meters, gateways, and software in the package, and (iv) **actionability in organizations,** across various decision making levels.

Value

Building owners and operators can use these specifications to ease procurement and installation of EIS in their facilities. EIS software vendors can use them to develop new product offerings for underserved sectors.

Packaged Scalable Energy Information Systems for Hotels

1. Context

Although architects and engineers target energy efficiency in building design, operations of buildings differ from the design intent. Every minute, day, week, and month, in countries spanning the globe, from United States to India, large amounts of the energy consumed in buildings is not actually utilized for any purpose. For instance, one of the largest building energy loads, heating, ventilation and air conditioning (HVAC) systems often fail to meet performance expectations due to various faults, poor maintenance and controls, and improper commissioning (Roth, 2005). It is normal for building equipment to experience *operational stray* (Henderson and Waltner, 2013), where actual energy use is higher than designed. A building's actual energy use can be two to five times higher than designed (Roth et al., 2005). When the problem persists undetected over long periods of time, it can lead to an estimated 15 to 30 percent of energy wasted in commercial buildings (Katipamula and Brambley, 2005).

The business-as-usual approach of tracking energy use through monthly utility bills is typically too late (being post-facto) and too coarse (being at a whole building level) to identify causes for wastage. Optimal performance requires access to higher granularity of energy consumption data, and more timely analysis. It requires that building energy use be continuously monitored and managed to curtail operational stray, capture deeper energy and dollar savings, and attain energy performance targets.

On average, U.S. hotels spend approximately 6 percent of revenue on utilities, but historic and luxury properties may see energy costs hitting 10 percent or more (National Grid, 2004). A 10 percent reduction in energy consumption has the same financial effect as increasing the average daily room rate by $0.62 in limited-service hotels and by $1.35 in full-service hotels (ENERGY STAR, 2007). Trends from the hospitality industry show that utility costs are the second largest operational cost, after labor (Gaggioli, 2016). Some forward-thinking hotel owners use proprietary tools to capture monthly energy, waste, and water consumption data to identify trends, track performance, and compare the same against benchmarks, to inform decisions for efficiency actions for hotels in their portfolio. For instance, a large hotel chain reports that since implementing this tool in 2012, their hotels have saved $185 million in avoided costs. It also states that 75 percent of frequent travelers care about sustainability and one-third of business travelers actively seek environmentally friendly hotels—an indicator that this enterprise strategy could potentially attract clients to build up topline growth (Better Buildings, 2015).

Such trends are also relevant in emerging economies, such as In India, where the hospitality sector has been growing at a cumulative annual growth rate of 14 percent (Indian Brand Equity Foundation, 2017); major international hotel chains are planning to set up or expand significant properties within the next decade. The high growth rate of this new hospitality footprint affords a substantial opportunity for energy efficient design and operations.

The good news is that information technologies offer opportunities to reduce building energy demand and associated greenhouse gas emissions. Energy Management and Information System (EMIS) is a broad family of tools and services to manage commercial building energy use. These technologies include, for example, energy information system (EIS), equipment-specific fault detection and diagnostic systems, benchmarking and utility tracking tools, automated system optimization tools, and building automation systems. (Lawrence Berkeley National Laboratory, 2015). A key energy efficiency enabling technology are energy information systems (EIS), broadly defined as a system with performance monitoring software, data acquisition hardware, and communications used to store, analyze, and display building energy data.

Through an EIS one can access energy data to identify consumption and patterns to track energy use, manage demand charges, validate utility billing, identify waste, benchmark building energy performance, and help identify short-term and long-term goals and actions toward energy efficiency opportunities toward 20 percent savings. A cost-benefit study conducted by Lawrence Berkeley National Laboratory (LBNL) across 26 enterprises' building portfolios shows that participants achieved year-over-year median site and portfolio savings of 17 and 8 percent, respectively; they reported that this performance would not have been possible without the EIS. The median five-year cost of EIS software ownership (up-front and ongoing costs) was calculated to be $1,800 per monitoring point (kilowatt meter points were most common) (Granderson et al., 2016). Facility owners, energy and sustainability managers, and facility operators can use the data analytics provided by an EIS to drive energy efficiency, improve building performance, and save energy costs.

Larger hotels and enterprises may be able to leverage economies of scale, and with bigger infrastructure and personnel budgets are well positioned to implement customized EIS solutions. However, small- to medium-sized hotels such as high-growth business hotels remain underserved relative to efficiency services, owing to tighter margins and lack of energy management staff. In these facilities current EIS solutions can be cost-prohibitive and present a high bar for entry, limiting adoption. Hotels are a prime example of a case where the need for guest comfort and services can cause significant energy waste, and where cost-effective, easy-to-use EIS can play a critical role in achieving energy savings.

2. R&D Motivation

Despite the strong rationale for EIS as a key emerging technology that enables building energy savings, and dramatic increases in the number of EIS market offerings, several barriers impede their broad adoption.

First, enterprise decision makers typically have insufficient awareness of the energy cost and use, and the role that EIS can play in minimizing those costs. Executives can be unaware that 3 to 5 percent of their revenue is being spent on energy, or even if they do, they perceive that to be a fixed, unmanageable cost (Forbes, 2015). With such little awareness of the problem, the adoption of a solution is a challenge. Furthermore, even if owners do realize the value that an EIS can deliver, they still face a fragmented market of building energy management systems, tools, and vendors that makes it challenging to appreciate, procure and specify a relevant EIS for their building or enterprise. Enterprises are also concerned about data security.

Second, even within the hotels sector, buildings are heterogeneous. Energy Information Systems are generally customized on building-by-building basis, which is typically a time-consuming process that requires a high level of skill to configure the EIS, a robust metering infrastructure, drawing insights from data analyses, and provision of services. This customization drives up the transaction cost for an EIS.

Third, currently available EIS tend to be too complex to serve the basic needs of small- to medium-sized hotels. The operations staff are also generally not trained in the installation and use of typically sophisticated EIS and need to rely on vendor services, which creates additional ongoing costs for the organization.

From a vendor perspective, it is difficult to market and sell EIS solutions for small- to medium-sized facilities. The foremost challenge is high upfront technology cost, which is a function of the high transaction cost required to customize EIS on a building-by-building basis. If coupled with ineffective use of sophisticated EIS technologies, or high vendor cost for services, return on investment (ROI) may not prove justifiable. Factors contributing to the wide range of upfront technology costs include the number of monitored points (e.g., only whole building energy usage vs. extensive sub-metering), extent of software features, and configuration needs.

These current practices of building-wise customization and high transaction costs have led to low adoption of this innovative emerging technology in all but the largest facilities and most sophisticated campuses and enterprises. The adoption of EIS is largely limited to large organizations or buildings with large energy expenditures that justify the first and ongoing high cost of the EIS.

The motivation of this work is to overcome these challenges through design and engineering of cost-effective packaged EIS solutions that can help drive adoption, especially in underserved building sectors, in order to help curtail energy waste and enable optimal use of operational energy across the building stock. For this study, we focused on business hotels—the largest group of hotel types that primarily cater to business travelers. These are typically underserved, but with significant opportunity for energy efficient operations. We anticipate the findings are extensible to small- to medium-sized convention centers, airport hotels, and budget to mid-range service hotels.

3. Concept of a Packaged EIS

We propose simplified, low-cost EIS packages—"EIS-in-a-box"—that overcome barriers such as installation and commissioning complexity, difficulty of use, and high cost. We have developed packaged EIS broadly applicable across the hospitality sector, rather than needing high customization at a building-by-building level. We derived the technical requirements for EIS packages with three predefined components, as shown in Figure 1, namely:

(i) Data acquisition and communication through sub-meters, and gateway connectivity
(ii) Back-end software for data access, storage, and analysis
(iii) Front-end visualization and user notifications

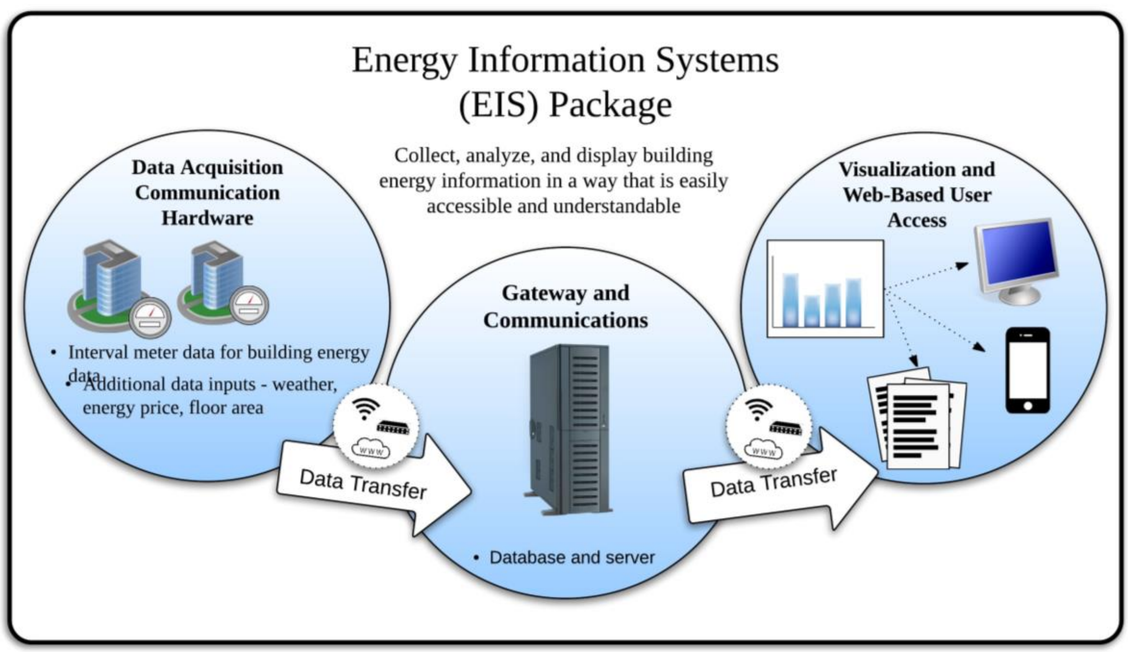

Figure 1: The three components of an Energy Information System (EIS)

Our proposed simplified, sector-specific EIS packages are detailed in subsequent sections. These packages are intended to obviate the need for customization, and enhance ease of procurement, installation and use, thereby enabling scale-up and wider adoption in the building sector.

4. Key Development Considerations

We took into account two key considerations to develop packaged EIS-in-a-box for hotels:

(i) How to **frame typical transaction costs** for the procurement, installation, and use of EIS
(ii) How to characterize **the heterogeneity** in the hospitality sector, and accommodate its influence on package hardware design and engineering

These considerations are detailed below.

4.1. Transaction cost framework

Transaction cost is defined as *costs other than the money price that is incurred in trading goods or services…and activities (that) involve opportunity costs in terms of time, effort and money* (Johnson, 2005).

The transaction process involves the time and effort required to deliver a product and service. For an EIS solution, typically there is a four-step transaction process (as shown in Figure 2) that can easily take several months or more. Each step requires time and effort that leads to overhead costs borne by the vendor that are typically passed on to the client. Through a series of structured interviews with seven EIS vendors, we determined that a significant portion of the cost is in implementing steps 1 through 3 (i.e., client recruitment, system configuration, and system integration). Our analysis showed that there exist hidden technical opportunities for reduction in transaction cost during each of these steps. For example, the time taken for steps 2 and 3 may be shortened if the electrical circuitry is viable for simple sub-metering. Additionally, metering and installation costs can be reduced significantly if a prioritization is done to select core sub-metering points based on an understanding of typically high and controllable loads. Similarly, offering value across the stakeholder ecosystem through a simple, secure system with reports and metrics targeted across facilities, Information Technologies (IT) staff, and executives can ease the buy-in process and time required for integration.

Our intent has been to comprehensively discover such opportunities and develop relevant technical requirements for packaged EIS that allow the steps to be streamlined to reduce the time, as well as first and recurring costs, for installing and operating an EIS. Our goal is that within a compressed period of transaction time (on the order of a few days) the product requirement can be fulfilled with reduced first cost (~30 percent less) for both vendors and users. Additionally, by using our user interface guidelines, in-house facility managers can be better equipped to understand the energy behavior of their facilities, conduct the first set of actions for troubleshooting, and easily operate and maintain the system, all leading to reduced operating and service costs. Beyond that, deeper vendor expertise can still be sought as needed for energy projects and upgrades. By offering an enhanced value proposition for an EIS, it is our intent that vendors and integrators experience fewer barriers to increased market penetration using existing hardware, communications devices, and distribution channels. That, in turn, should lead to better sales in higher volume, which may further lower the price point for a packaged EIS-in-a-box.

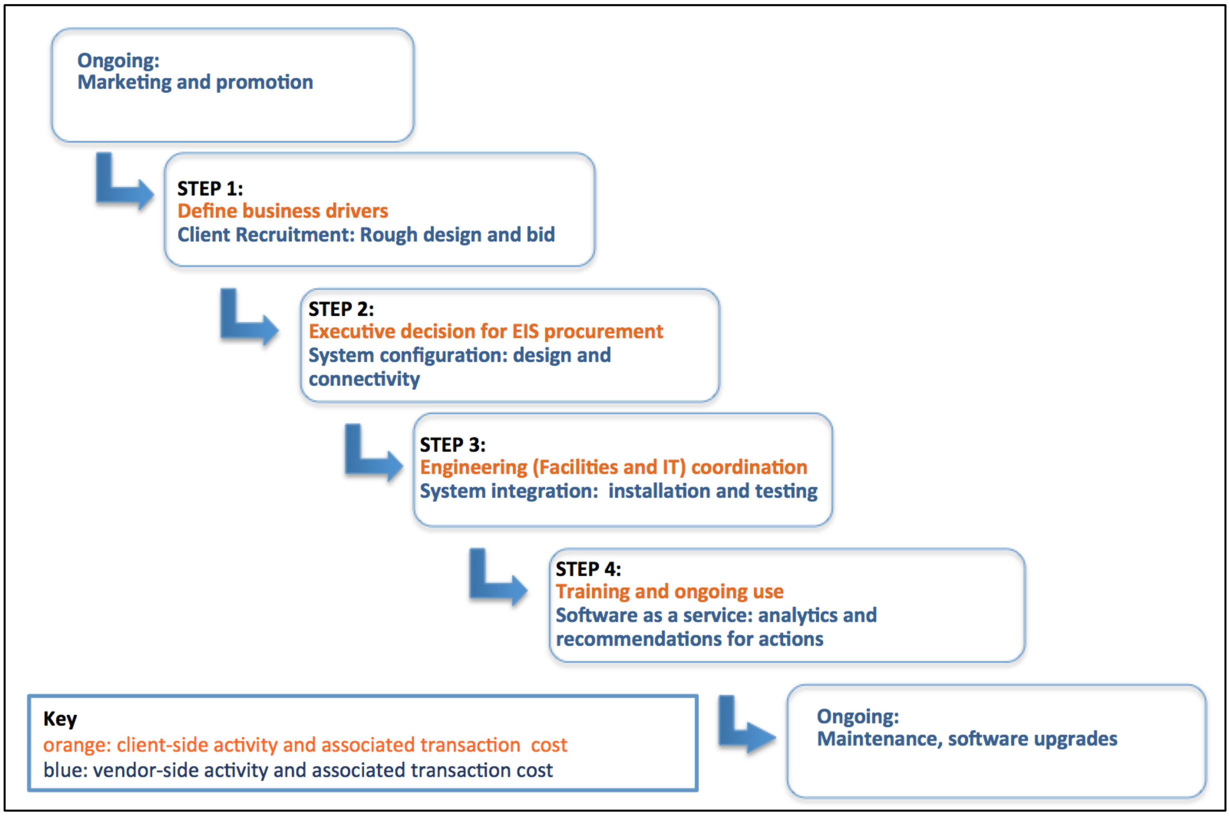

Figure 2: Typical transaction cost framework for the specification, installation, and use of an energy information system (EIS)

4.2 Heterogeneity in the hotels building sector

A second key consideration is the extent to which the energy and metering infrastructure and management approach varies from hotel to hotel. This heterogeneity affects the extent to which a packaged standardized solution can be broadly applicable. We investigated the types of hotels to understand the physical and organizational attributes that drive energy use to enable a relevant package design.

Typically, 75 percent of a hotel or motel's total energy use can be attributed to space heating, lighting, and cooling combined, with cooling and lighting alone comprising half of the building's energy consumption, as shown in Figure 3. However, there is a broad range of energy use intensity across lodging facilities, ranging from 15,000 Btu per square foot to over 300,000 Btu per square foot (U.S. Department of Energy, 2016).

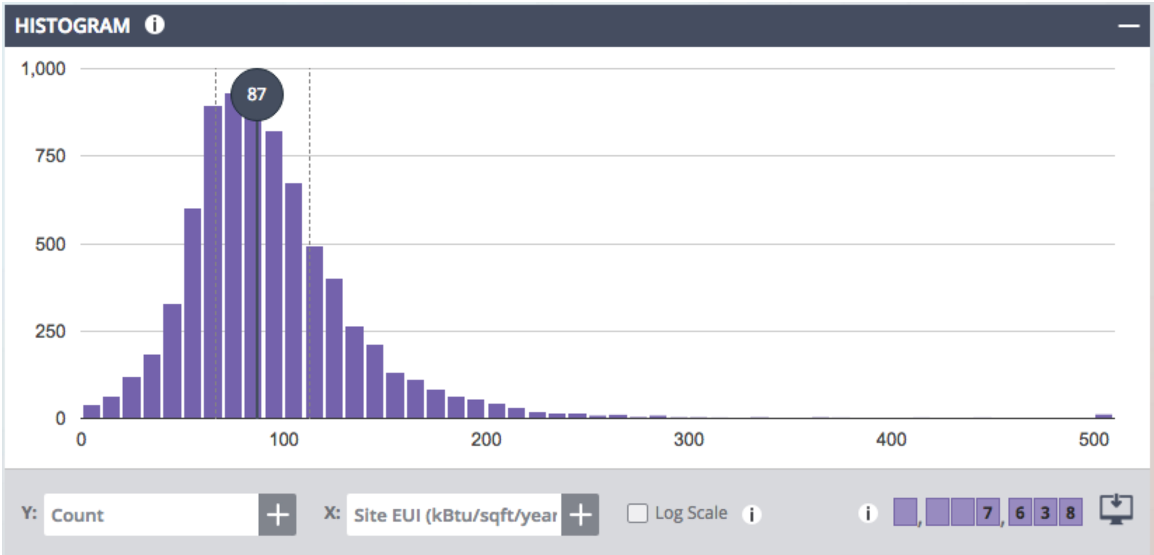

Figure 3: Screen shot from the Building Performance Database (BPD) for 7,638 U.S. hotels. Median Site EUI is 87 kBtu/sf. 25th, 75th percentiles are 66 and 113 kBtu/sf, respectively. (Source: U.S. DOE, 2016)

4.2.1 Mapping physical infrastructure

There is wide diversity in hotel facilities, classified by parameters such as size of the hotel, target markets, level of service, and ownership, as shown in Figure 4. These parameters are significant determinants for the physical design and operations of hotel facilities, and thereby a key consideration to assess how and where an EIS may help impact energy use. Another important consideration is to analyze and understand potential saving opportunities and EIS design in new construction, as compared to those possible in existing facilities.

Classification of Hotels				
Physical attributes			**Organizational attributes**	
Classification by size	**Classification by target market**	**Classification by location**	**Classification by levels of service**	**Classification by ownership and affiliations**
• Small hotels: up to 25 rooms • Mid-sized hotel: 26-99 rooms • Large hotels over 100 rooms	• Business • Suites • Transit • Extended Stay • Services apartments, • Resorts • Bed and Breakfast • Heritage • Boutique • Casino hotels • Convention centers	• City/Downtown • Suburban • Airport • Highway motels • Floatels	• World class • Mid-range • Budget	• Independent hotels • Chain hotels • Time share • Condominium hotels

Figure 4: Heterogeneity in the hotels building sector, based on physical and organizational attributes

4.2.2 Organizational characteristics and business drivers

Organizational considerations in developing the packaged EIS included factors such as the value attributed to energy, and staff motivation and skill available to take energy-related decisions and actions. Even within an organization, a diversity of stakeholders have influence, ranging from facilities staff operating on a day-to-day level, and IT staff who take decisions regarding the information technology infrastructure, to facilities executives and sustainability managers who may make investment and high-level decisions. While facilities staff may consider building automation systems important for primarily building operations and management, the value of energy efficiency is often far from being fully appreciated or visible, or perceived as being business-relevant. Understanding and being responsive to organizational business drivers and needs is a key precursor for an effective EIS.

These considerations were taken into account during the design of the packaged EIS and are detailed in the next section.

5. Approach to Determine Specifications for Packaged EIS

We followed a five-step process to determine the specifications:

- Step 1: Determining business drivers for the building sector as the core determinants for the package
- Step 2: Addressing heterogeneity of facilities through a tiered package structure
- Step 3: Identifying metrics for key stakeholders and decision makers for which data would be derived
- Step 4: Recommending a “picklist of loads” for controlling data cadence
- Step 5: Forming insights and actions based on data analysis presented in simplified user interfaces

Each step is detailed in the sub-sections that follow.

5. 1 Determining business drivers for hotels

Through a literature review of trends related to facility energy use in hotels, and interviews with industry collaborators, we identified five business drivers for hospitality organizations. These drivers, and their impact on the design of an EIS package is detailed below:

(i) **Monitor energy performance of their facility.** To address this driver, an EIS should provide near real-time time-series information on facility energy use and quantify changes in energy use over time.

(ii) **Track cost and demand** to understand the financial implications of energy use, and wastage; identify base and peak demand, and assess system size and efficiency of mechanical equipment. An EIS should support the establishment and monitoring of utility budgets and costs, and develop annual energy reports.

(iii) **Benchmark energy performance t**o have an effective yardstick for demand, efficiency, and energy use targets by comparing the facility’s energy performance against a peer. Hence an EIS should perform “cross-sectional benchmarking.” Second, it should benchmark the facility against itself, (i.e., validate the energy performance against the design intent, initial commissioned operations, or base period of performance). Hence, an EIS should perform “longitudinal benchmarking” (Granderson et al., 2013).

(iv) **Identify and track energy efficiency projects.** An EIS should to provide information to identify, understand, and mitigate risks of undertaking energy efficiency measures, track persistence in savings through any implemented projects, and track improvements over time.

(v) **Be environmentally sustainable and compliant** to track greenhouse gas emissions, for instance for benchmarking or carbon disclosure program reporting and city energy disclosure ordinances. An EIS may provide this option.

Once we identified the business drivers for hotel organizations, we mapped features and functionality of packaged EIS to address these drivers. There are operational or cost metrics associated with these drivers. Our goal for EIS-in-a-box packages is to provide information relevant to operational performance metrics pertinent for the facilities staff, as well as cost metrics that tie back to the topline revenue and profit, pertinent for executive-level decision-making. The EIS should acquire energy data from consistent sub-metering points to feed into the analyses for performance and cost metrics. Further, the EIS should provide effective visualization to make the energy information accessible, optimum, reportable, and actionable. This logic flow for the design of packaged EIS is shown in Figure 5.

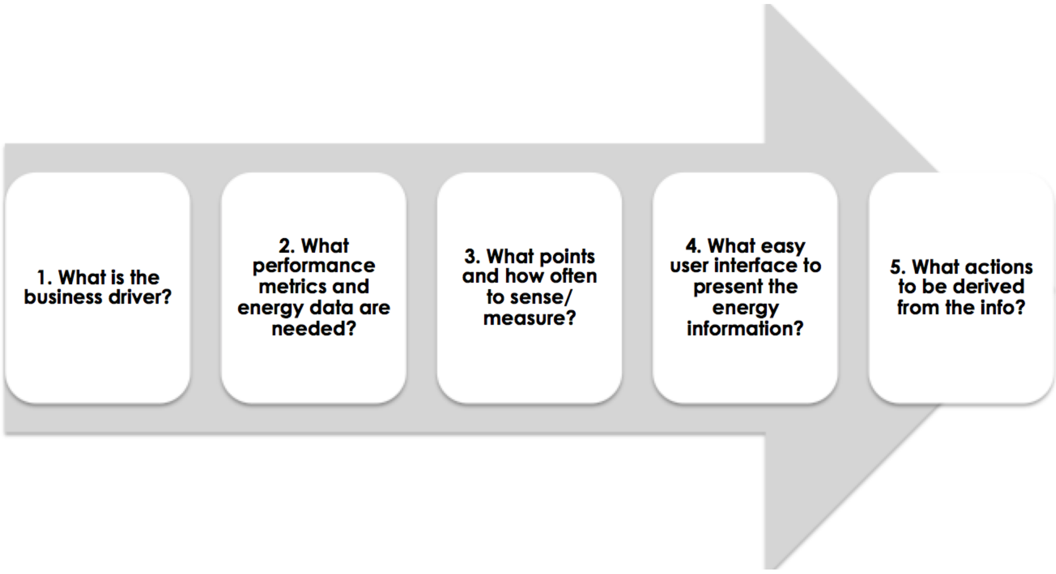

Figure 5: Logic flow for developing a packaged EIS-in-a box based on prioritized business drivers for a building typology

5.2 Addressing heterogeneity through a tiered package structure

As mentioned earlier, hotel facilities and organizations are heterogeneous, and their staff posses varying levels of skills and motivation to save energy. To address this heterogeneity, we developed two distinct tiers of EIS packages: Entry (Tier 1) and Advanced (Tier 2). These tiers represent a light-touch and medium-touch approach respectively, to provide technology options that are commensurate with organizational skills and motivation. The difference between the two tiers lay in their objectives, target user/audience, and features and functionality—relative to the Entry tier, the Advanced tier marks an increase in complexity, cost, and energy savings potential.

The Entry Tier 1 EIS package for hotels offers organizations that traditionally have little or no visibility into their building energy footprint, and whose building managers who have extremely limited time and resources, to obtain only the most important information. The Entry Tier 1 package is a “foot in the door" to familiarize users with installation, use, and benefits of a simple EIS. In such organizations, a monthly utility bill may be the only currently available energy use information, which is post-facto.

On the other hand, organizations that recognize the value of energy and provide some resources for their building managers to monitor their building's energy usage may be better served through an Advanced Tier 2 solution. This is targeted toward hotel owners and managers who have a higher awareness and interest in the benefits of energy efficiency and carbon accounting, and the ability to spend investment dollars and staff resources commensurately.

Figure 6 shows, for each key business driver, how the Tier 1 and Tier 2 packaged EIS solutions compare with the custom EIS offerings common in today's market. We note that users could begin with Tier 1 and evolve its capabilities to a Tier 2 level over time, as their needs change from "introduction to quick energy wins" to " best practices for ongoing maintenance of energy performance."

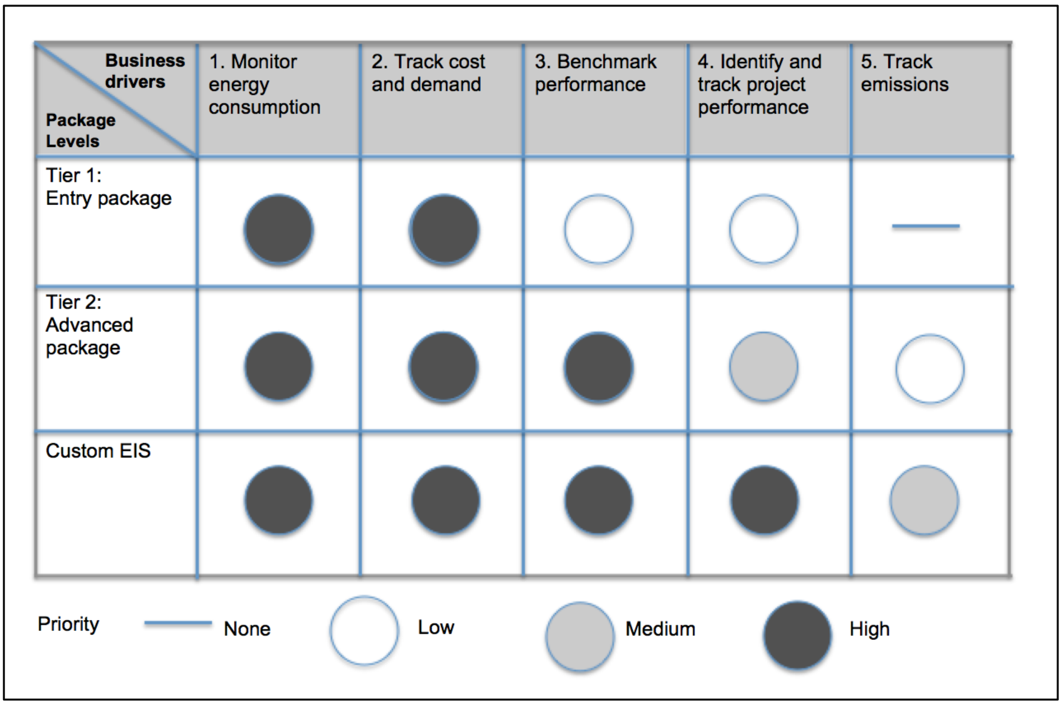

Figure 6: Entry and Advanced tier functionality, built around prioritized support provided to business drivers

5.3 Identifying metrics for key stakeholders and decision makers

In the spirit of making energy information visible and valuable across the hotels' stakeholder ecosystem, we identified two primary types of users for the packaged solution: (1) facility managers who track energy granularly at a daily or sub-daily basis, and (2) management/executives who would view energy and its financial implications quarterly or annually (at a minimum). Further, we identified the two types of audiences' critical questions and metrics of interest, to track and report on a rapid, short-term basis (daily/weekly) (Figure 7) and a long-term (quarterly/annual) basis (Figure 8). We generated recommended daily and annual dashboards with easy-to-use charts. Our recommended dashboards targeting these two audiences are shown in Section 6: Results.

Building Pulse at a Glance: Facilities Dashboard with Five Metrics
Primary Audience: facility managers, engineering staff
Timescale: daily, weekly

1. What is my hotel's whole-building **Absolute Energy Consumption?**
   - kWh or kBtu (or therm) per day or per week
2. What is the **normalized Energy Use Intensity** of my hotel facility?
   - kWh or kBtu (or therm) per unit square area
   - kWh/room or per occupant*
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
4. 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
   - % Portion of the total energy use*
5. What is the **fuel consumption and cost?**
   - kBtu/fuel per time period
   - $ per time period

*Tier 2 only, using building occupancy inputs

Figure 7: A list of questions and metrics that inform the facilities daily/weekly dashboard

High-level Picture: Executive Dashboard with Five Metrics, with Additional Facilities Charts
Primary Audience: executives, facilities managers
Timescale: monthly, quarterly, or annually

1. What is the **fuel consumption and cost?**
   - kBtu/fuel per time period
   - cost per time period
2. What are the trends for my facility's energy costs?
   - cost per time period
3. What is my building's **energy performance,** and how is it performing over time compared to baseline**, i.e., longitudinal benchmarking?**
   - kWh or Btu per month, quarter, or year
   - kWh or kBtu/unit square area
   - kWh/room or per occupied room*
4. How is my building performing compared to other similar facilities in my portfolio, or benchmarks, i.e., **cross-sectional benchmarking?**
   - kBtu/fuel per time period, or per unit square area, or per occupant*
   - cost per time period
5. What is **the carbon footprint** of my facility?
   - Metrics tons or pounds of carbon dioxide (CO_2) per year

Additionally, for facilities staff

6. What is the **load demand per end use** of my building, and are the systems operating efficiently?
   - kW or kBtu/hour per time period
   - % portion of the total energy use
   - kW/ton*
7. What does an **annual snapshot** of my facility look like? Is it performing well throughout the course of a month/year?
   - kW or kBtu/hour per time period

* Tier 2 only

Figure 8: 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.

5.4 Determining a pick-list of loads to monitor in the EIS

A key approach for package design is simplification, i.e., paring down the extraneous hardware, removing any superfluous data collection, and streamlining the data analysis and visualization without adding any sophisticated new algorithms and techniques. The optimization of data collection is also driven not just by simplicity of use, but also by the emerging challenge of too much data, as can be encountered in custom EIS implementations. On one end of the spectrum are legacy meters, read 12 times a year to track consumption post-facto. At the other end, smart meters barrage readings at 15-minute intervals, providing 35,000 meter readings a year. This amount of data is an opportunity for data interrogation, however, it is costly data overload, and our target segment would find it virtually impossible to gain insights relevant to them, given their typical lack of data analysis experience.

Measuring every end use load and piece of equipment in a hotel building would require hundreds of metering points, which would be neither practical nor cost effective. Hence, only prioritized loads were recommended to be monitored, to provide the relevant data to feed into the pertinent metrics required for the business drivers.

Our aim was to reach an 80-20 solution, i.e., select approximately 20 percent of core measurement points in a hotel building necessary to provide 80 percent of the most critical information necessary for energy-based decision making. In order to select the core metering points to measure loads or end-uses, we developed a decision framework determined by following three selection criteria:

(i) **Is the load large?** Answering this question helped to identify the most significant loads by size in an office facility. For example, space heating and cooling loads typically account for one-third to one-half of a hotel's energy use.

(ii) **Is it a discretionary load/end-use?** It is important to characterize loads in a facility that can be controlled, managed, or scheduled by the facility manager (or even the occupant) versus loads that that are too indispensable (e.g., Uninterruptible power supply, UPS) or are too regulated or distributed to be flexibly controlled or managed. For instance, a hotel conference room or business center that is used only at certain times may be easy to schedule. Lobby lighting, however, is not a discretionary load to schedule, since lighting would be required continuously for hotel operations. On the other hand, lighting may be *controllable*, and able to be dimmed or tuned based on operations and occupancy.

(iii) **Is the load reasonably measurable?** Analyses must determine whether the electrical design provides an opportunity to sub-meter certain points, or even disaggregate data through subtraction or back-calculation, i.e., virtual load. While there is more variability in the wiring design in some hotel portfolios, many portfolios are required to follow the guidelines for electrical design, which allow predetermination of standardized points for energy monitoring.

Using this decision framework we assessed which electrical points scored high on all three decision criteria. An example is space-cooling loads in hotels: cooling loads typically account for a *significant contribution* to the energy use, and cooling is potentially able to be scheduled in a business hotel room based on occupancy, thus making it *discretionary*. Finally, HVAC loads are often on an independent circuit, making them *measurable* (sub-meterable). Hence, space cooling is prioritized as a core monitoring point. Another example is lighting. Even in situations where lighting is not disaggregated from plug loads at the panel level, there still is value in obtaining data from the mixed lighting-plus-plugs panel.

Using this method, we derived a picklist of loads (See figures 11 and 12 in Section 6: Results). This picklist is a set of core recommended energy-monitoring points for a hotel facility, and can be further broken down if the building is owner-occupied or leased. This picklist would be further used to inform technology users about the types of meters and gateways and the associated analysis and visualization that are essentially the technical requirements for the EIS package. By creating this predefined package of EIS components, we aim to reduce the usual transaction costs borne from developing custom EIS configurations on a facility-by-facility basis.

5.5 Forming insights and actions

Based on the questions to be answered in the short-term (Figure 7), we developed a daily/weekly dashboard, and based on the questions to be answered in the long-term (Figure 8), we developed a quarterly/annual dashboard. These dashboards enable facility staff to monitor and answer pertinent questions quickly and succinctly, conduct actions, and to send reports up the management chain to the executive level. Each package provides guidance on how to interpret energy data and relay information from each energy consumption analysis. Flexibility is built in for a suggested picklist of loads, incremental configuration of charts, and associated notifications based on whether it is pertinent to an Entry or Advanced package.

Common reasons for initiating energy-related upgrades in hotels and motels include customer complaints, corporate sustainability policies, frequent equipment malfunctions and shortened equipment lifetime due to years of deferred maintenance, piecemeal additions to buildings, and internal changes to existing spaces that have not been accompanied by corresponding changes to heating and cooling systems. Other reasons are previous attempts to reduce energy use by inappropriate measures, such as covering vents, and major pieces of capital equipment or building elements, such as a boiler or a roof, that are nearing the end of their useful life (ENERGY STAR, 2015). These are usually cost-intensive, one-time upgrades. What we propose through the ongoing use of an EIS is a staged approach that can reveal no-cost or low-cost opportunities that are mostly incremental, and enable persistent savings on energy costs through load reduction strategies.

Facility operators can follow a staged approach and assess the impact of each upgrade through EIS energy use tracking. This staged approach is listed below, and is shown in Figure 9:

(i) **Schedule loads:** This involves turning off and on loads based on predetermined schedules, such as tracking and ensuring that HVAC settings in lobbies, offices, and other such peripheral and back rooms are at minimum settings during hours of low use. This strategy helps to keep the peak-to-baseload ratio high, so that off-hours setbacks are aggressively maintained for energy savings during those hours. Scheduling can be effective if there is pre-known information regarding occupancy, events, or any evening, nighttime, off-peak, or seasonal variations.

(ii) **Control loads:** The basis of ongoing controls may be occupancy, outdoor air temperature, grid pricing, and other such measures. Examples include: using demand control ventilation for areas with variable occupancy, using economizers for free cooling when the weather is appropriate, and setting laundry hot water to 120° Fahrenheit—an optimal temperature for all hot water uses outside of the kitchen—where codes are specific about water temperature. For hallways, a simple recommended strategy is to use a combination of scheduled lighting and dimming plus occupancy-sensor controls after hours. Another example is to reduce the amount of overnight lighting used in the guest hallways by dimming controls. The results are not only energy savings but also the unforeseen benefit of fewer noise complaints from other guests, since hallway conversations linger for a shorter time (ENERGY STAR, 2016).

Beyond these in-house actions around scheduling and controlling loads, here may be additional actions required that warrant external contractor or vendor support, such as the following:

(iii) **Repair equipment:** If, despite scheduling and controlling loads, the equipment shows energy waste, this may indicate the need for component, equipment, or system repair.

(iv) **Audit building/systems:** Beyond all the previous approaches, if the whole building or a system shows energy waste, it calls for executive decision making around deploying an energy audit for a deeper dive to investigate causes and further determine potential energy efficiency projects.

(v) **Upgrade systems, equipment, and appliances:** This would be a last resort, to deploy capital resources into a physical system upgrade. The EIS will track energy costs before and after the energy efficiency projects, such as replacement with energy efficient, ENERGY STAR-labeled appliances, replacement with high-intensity fluorescent (HIF) lighting for parking lots and outdoor applications, or HVAC upgrades.

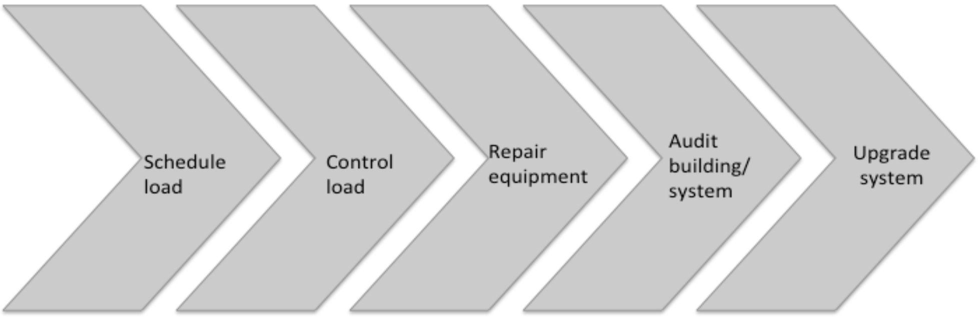

Figure 9: Staged approach to energy savings based on EIS analytics

Additional practices such as hotel reservation best practices can be followed aggressively; these can include booking rooms in clusters and renting last the cooling- or heating-intensive areas, such as rooms on top floors, at building corners, and facing west (in summer) or north (in winter). Best housekeeping practices such as covering heated swimming pools, turning off all lights, closing drapes, and setting temperatures to minimum levels in unoccupied rooms will save energy, and that will be reflected in the EIS's energy use tracking.

6. Results

The packaged EIS solutions have three components: energy meters, communications gateways, and software with a user interface. The hardware components, such as sub-meters and gateway, are specified for each tier, and are selected from off-the-shelf products that comply with the specifications, as shown in Figure 10. An important first-order supply-side interval metering is recommended for whole building electric, natural gas, other fuel and standby power. This should be followed by sub-metering of selected points and locations that are identified through the "picklist of loads" as detailed in Section 5.4 above. The whole building and systems/end-use sub-metering information acquired feeds into metrics-oriented visualization, and can help trigger action toward delving further into a certain fuel or end-use. Thus, software analysis and visualization is defined for each tier.

Section 6.1 and 6.2 describe the Entry Tier 1 and Advanced Tier 2 EIS packages.

Meters	Sub-metering Points	Physical Location	Communication Gateway	Measured Parameters	Accuracy and Turndown (U.S. and India)	Additional Inputs
Tier 1: Electric sub-meters*	Whole Building, 2–3 major loads (spaces or end uses) such as chiller plant, fan energy	1 Main distribution board (DB)	Wired between sub-meter and gateway, Wi-Fi between gateway (1) and remote database RS-485 (Modbus and BACnet) output standard for India; TCP/IP for U.S.	kWh, V, A	Class 1 according to IS13779 (India standard); 1% with 10:1 turndown (U.S. requirement)	-Bldg./space areas - Fuel supply cost
Tier 2: Electric sub-meters*	Whole Building, 7–10 major loads (spaces or end uses) such as: - chiller plant - fan energy - emergency equipment/ plugs/lights	1 Main DB + Represent-ative Spaces / Floor DB	Wired between sub-meter and gateway, Wi-Fi between gateway (1) and remote database RS-485 (Modbus and BACnet) output standard for India; TCP/IP for U.S.	kWh, kW, V, A, Power Factor, For WB: current and voltage harmonics	Class 1 according to IS13779 (India standard); 1% with 10:1 turndown (U.S. requirement)	Tier 2 - Bldg./space areas - Fuel supply cost - Operating schedules - Outdoor air temperature (OAT) from weather data
Tiers 1 and 2: Gas sub-meters 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., pulse counting and convert to therms)	Sub-meter reads out in cubic ft, data required as therms	U.S. ANSI B109 standard; 1% with 100:1 turndown	
Tier 2: Btu sub-meter	Water cooling and heating	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	

Figure 10: Metering and gateway requirements for EIS packages

6.1 EIS Tier 1, Entry package

Audience: The EIS Tier 1 Entry package (Figure 11) is targeted toward hotel owners and managers who have an interest in understanding their buildings' energy utilization, but have low skill and time. An entry-level "foot in the door" EIS package can familiarize a user with the installation, use, and benefits of a simple EIS based on information about when and how much total electricity is being consumed and wasted, primarily at the whole building level. This is a solution that most optimizes sub-meters and dashboards that can identify low-hanging fruit for energy savings. It would have an arguably lower energy savings potential, on the order of 3 to 5 percent at a whole building level. The EIS Tier 1 Entry package provides an introduction to the organization on quick energy wins.

Data Requirements: Interval meters at whole building and sub-meter levels for 2 to 3 critical points from the picklist of loads, selected on the basis of significance and controllability of the loads and ease of metering it. These loads can be at the end-use level (e.g., HVAC and all lights and plugs), for critical equipment (e.g., chiller plant). No additional user-supplied information is required.

Visualization and Functionality: Two to five preconfigured charts in visualization dashboards, as shown in Figures 13 and 14, to provide information for the features provided below:

- Simple tracking of energy consumption (KWh) to identify ongoing use and electricity wastage, to inform energy efficiency actions.
- Load profiling of critical loads (KW). These data can be provided from hourly interval metering.
- Longitudinal benchmarking to provide visibility into long-term building's energy trends, including tracking whole building energy savings after implementation of energy efficiency projects
- Tracking fuel costs that help with reconciliation of electricity billing costs and identify variances in cost versus actual consumption.

A simple level of analysis can usually be carried out in-house. Notifications, such as basic alerts and stock recommendations, are provided to the facility manager, and standard monthly or quarterly reports are provided to executives. Actions such as scheduling and controls for main sub-metered end-uses and equipment can be conducted in-house. As needed, infrequent vendor support would be required for recalibration of meters, software upgrades, and the like.

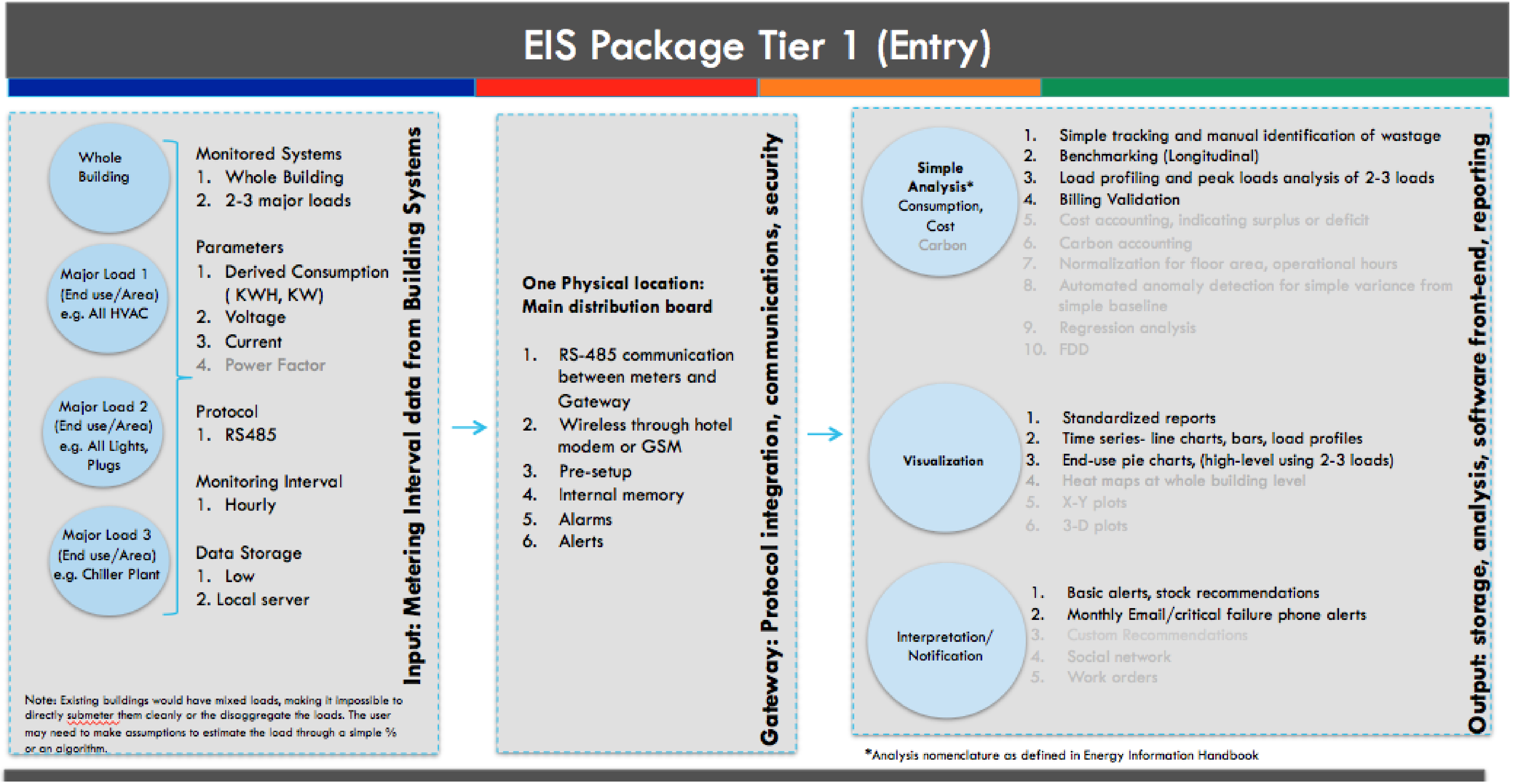

Figure 11: High-level overview of a Hotel EIS Tier 1 Entry Package. The left column recommends a picklist of loads, the middle column defines a simple communication gateway, and the right column provides the analysis and visualization functionality.

6.2 EIS Tier 2, Advanced package

Audience: The Tier 2, Advanced-Level package (Figure 12) is targeted toward hotel owners and managers who have a relatively higher awareness and interest in energy efficiency and carbon accounting to spend investment dollars and staff resources commensurately.

This is a more complex, granular package than the Entry level. The Advanced Package consolidates data from a few more interval meters and provides deeper visibility and analytics in terms of when, how much, and where electricity is being consumed and wasted. All other things being equal, this enables higher energy savings than the Entry-level package—up to ~10 percent—since it takes advantage of more extensive sub-metering to better pinpoint the reasons for use and waste. The cost is correspondingly higher because of additional metering requirement, higher functionality software, and/or ongoing vendor 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.

Data requirements: Interval data is recommended from up to 7 to 8 end-uses or major areas. Their selection is based on the picklist of loads. Beyond Entry level metering, other points such as outdoor lighting, air handlers, elevators, and major areas such as common areas and guest room blocks are recommended. Additional user-supplied information is also suggested to be configured into the EIS, such as operating schedules, building/ zone square feet areas, and designed occupancy (number of rooms, event schedule) that allow for normalization to provide superior analytics.

Visualization and Functionality: Six to ten advanced visualization screens are recommended. In addition to the charts provided in the EIS Basic package, there are charts depicting cost accounting, carbon accounting, and heat maps, as well as end-use pies, as illustrated in figures 13 and 14. In addition to the functionality and benefits of the Tier 1 Entry package, the Tier 2 Advanced package provides the following:

- Higher granularity and visibility into energy consumption (KWh) and load profiling (kW) of up to 7 to 8 major loads. 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) and can identify when and where the energy saving opportunities are with respect to time and the load category (i.e., scheduling, changes in load profile).
- Cross-sectional benchmarking with respect to a peer group such as a portfolio or other similar hotels. Benchmarking provides comparative information that reveals the need for improvement in energy performance; helps set energy targets; prioritizes energy efficiency projects, and tracks progress toward those targets.
- Cost accounting in terms of reporting electricity costs against the budget, indicating a surplus or deficit.
- Sustainability/GHG tracking, by providing carbon accounting analysis and reports.

Built-in notifications, such as email/phone alerts and some custom recommendations are also recommended in the Advanced package. The usability could be a conveniently handled through a hybrid model of of in-house analysis and specific vendor-provided services. Vendor services can include support, training, and upgrade; as well as cost of any data storage in the cloud based or vendor-site local server.

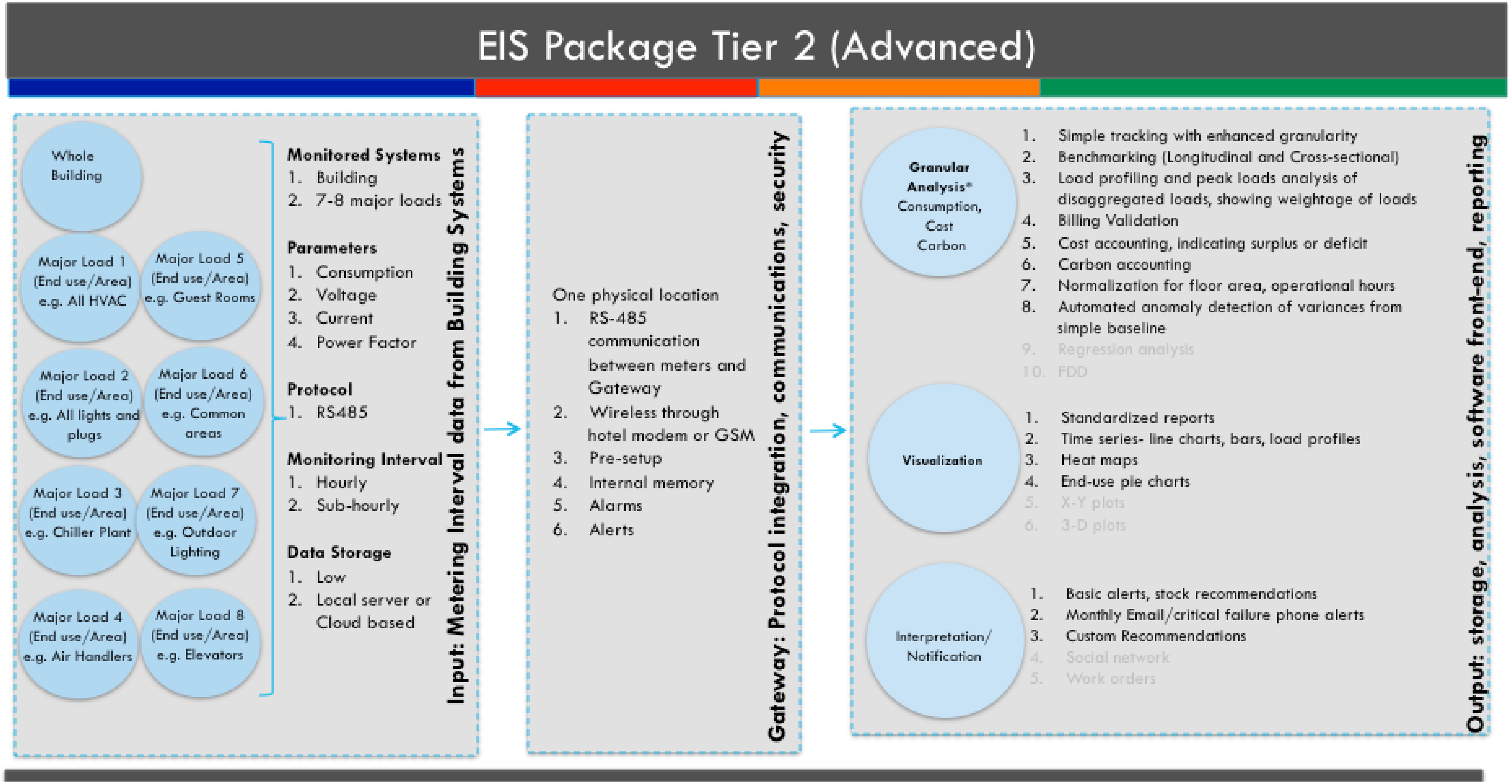

Figure 12: High-level overview of a Hotel EIS Tier 2 Advanced Package. The left column recommends a picklist of loads, the middle column defines a simple communication gateway, and the right column provides the analysis and visualization functionality.

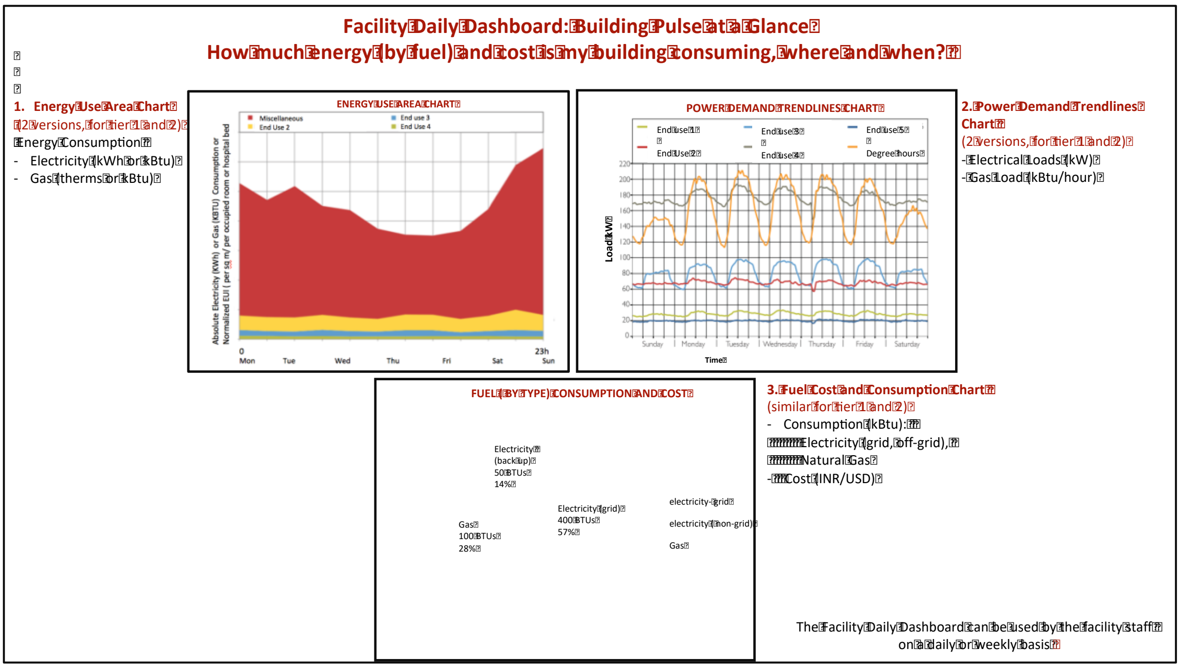

Figure 13: High-level overview of daily/weekly dashboard, “Building Pulse at a Glance” for facilities staff

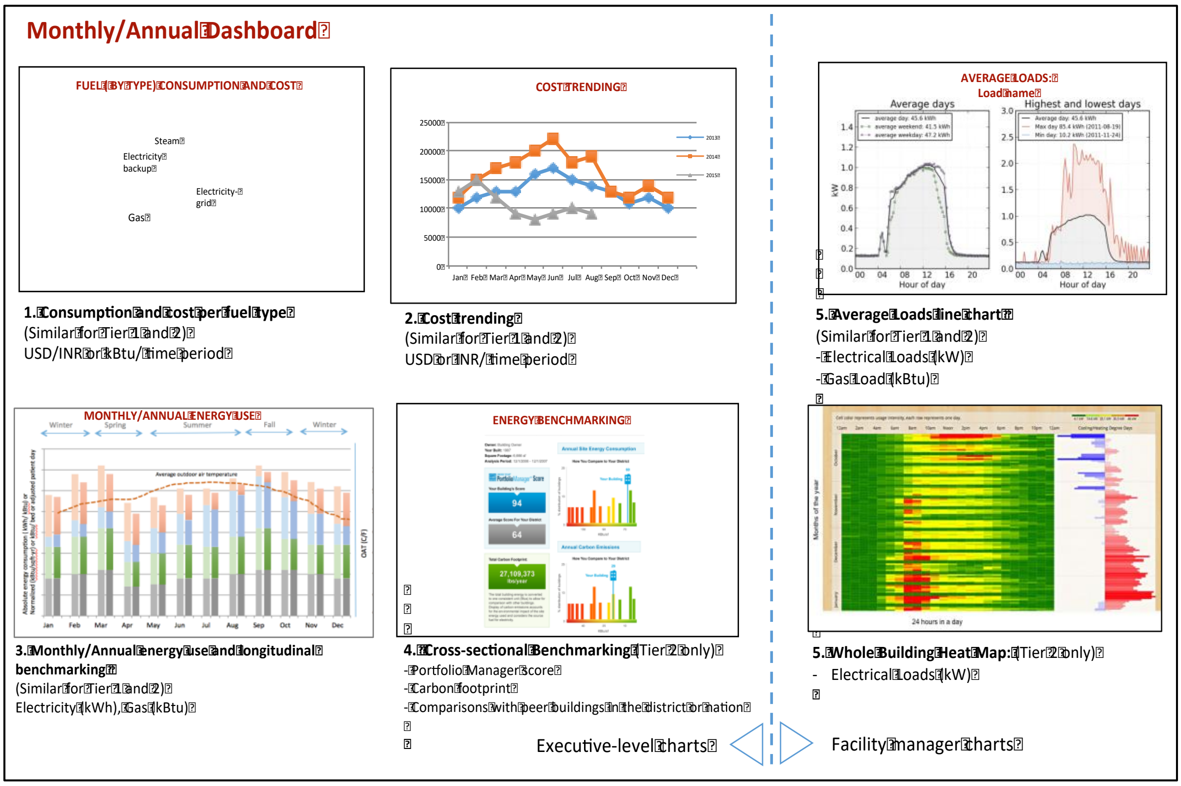

Figure 14: High-level overview of Monthly/ Annual dashboard for both executives and facilities staff

6.3 Trade-offs between functionality and greater adoption

There is a trade-off between functionality and broader adoption: Figure 15 shows the range of organizational and technical factors addressed in the two tiers of EIS packages. The tiered EIS-in-a-box packages do not provide the accuracy, granularity, and customized features of expensive custom energy information and management systems (EMIS) solutions used by some large buildings and portfolios. However, their value is in the 80-20 solution, i.e., they provide adequate functionality for energy savings in small- and medium-sized facilities, simplicity of use, actionable dashboards, and cost-effectiveness through first and operational cost reduction. We believe that the Tier 1 Entry EIS is a minimum requirement for all hotel facilities, and the Tier 2 Advanced EIS is best practice within a limited cost.

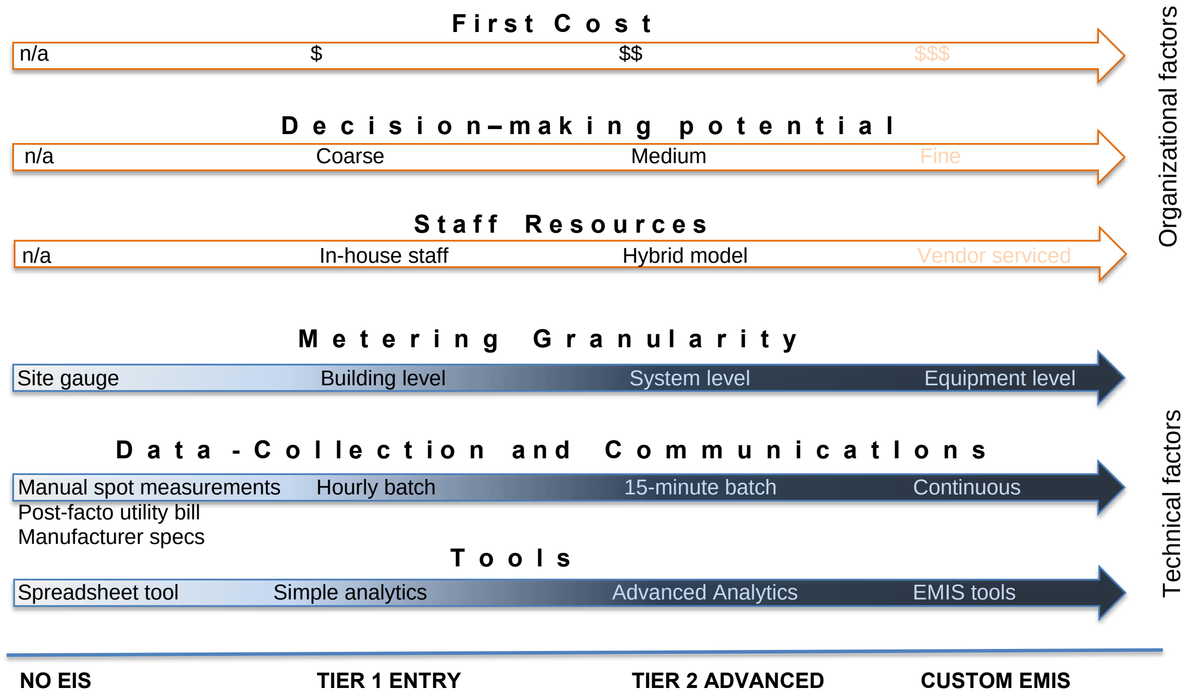

Figure 15: The two tiers of EIS-in-a-box provide trade-off between functionality and broader adoptability

7. Results

In a context where $60 billion is spent annually on wasted energy in U.S. buildings (Forbes, 2015), it is critical to manage building energy use to achieve up to 20 percent savings enabled by EIS (Granderson et al., 2016). A key technical response to help overcome the scale and adoption challenge for EIS is the development of packaged solutions that address the current pain points around specifying, procuring, installing, and using the EIS. Our packaged EIS-in-a-box solution provides the following benefits:

- **Cost-effectiveness,** by helping to reduce first costs (i.e., transactional costs, hardware costs) as well as ongoing operational costs. This can help ease the sales cycle for vendors (especially for new or tough-to-penetrate markets) and make procurement and operations cost-effective for users. To test our assumptions around reduction of transaction costs, we conducted vendor interviews and found that packaged EIS can help bring down cost by up to 30 percent of custom solutions (Singh et al., 2017).

- o **Scalability,** by development of an optimum EIS that takes into account the specificity of the hotel sector rather than being too generic (all types of buildings) or too specific (customized on a per-building basis); also by engineering EIS packages to accommodate heterogeneity across hotel buildings. Its replicability across the organization's building portfolio and scalability establishes a broader market applicability of the systems. These EIS hotels packages are intended to be relevant across a range of facilities by recognizing and accommodating the heterogeneity within this target segment.
- o **Simplicity,** through ease of use, procurement, and installation. EIS packages are engineered for the uncomplicated integration of the three main components (i.e., meters, gateways, and software) into preset configurations as two recommended tiered EIS-in-a-box packages. The uncluttered hardware and streamlined data architecture and cadence helps curtail unnecessary data management. Technical simplification of products and their usability is a real need and a path toward scalable deployment.
- o **Actionability in the organization,** through alignment with business drivers and metrics that are relevant across various levels of organizational decision making. For the facilities staff in the basement checking the near-time, daily, or weekly pulse, it enables data-derived actions in the facilities operations. For executives, valuable energy information presented with the relevant energy and sustainability metrics at quarterly/annual time frames can help inform facility and energy investments within their larger decision-making framework.

The EIS package technical requirements that were developed in this work provide details for the three components—metering, gateways, and software/user interface—that are integrated into two tiers. The recommendations are specific, but allow flexibility in the prioritized selection of points for energy monitoring, reporting, and granularity of data acquisition, analysis, and actionable information display.

Energy Information Systems packages significantly improve on the business-as-usual practice for energy measurement of post-facto utility bill information, or for single-point-in-time information such as spot measurements, site gauges, manufacturer specifications, and assumptions. The core EIS information is intended to provide knowledge that is actionable across various types of decision makers in an organization, as well as across organizations in the offices sector. The packages rely on buy-in across various stakeholders, including upper management commitment for investment in these packaged solutions, as well as early involvement of IT staff to help overcome security, data maintenance, big data management, and installation hurdles. The packages rely upon training of in-house staff while leveraging the technical skills of systems integrators as necessary in the process. In this way, the design of the packages considers the EIS vendor, integrator, and client organization's facilities and IT staff as crucial partners in the successful installation of an EIS and persistent savings through its use. Finally, advantages such as standardization of packages also may help with interoperability and security standards in the near future.

While these EIS packages do not provide all 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 who might otherwise be unable to practically leverage the technology. While sacrificing some of the granularity or accuracy, the value of the EIS-in-a-box is derived through their ease of use and adoption. The sector-specific packages can be a factor in market transformation that could allow building owners and managers to easily procure, install, and operate a system to monitor their energy usage, identify areas for improvement and cost savings, and encourage market adoption of the technology.

While this paper focuses on the hotel sector, our methodology spans three building sectors (hospitals, hotels, and offices) across two countries that are among the world's top energy consumers, namely the United States and India. Vendor interviews have been conducted to study typical transaction costs and project cost savings from EIS-in-a box packages across these building typologies. These packages are being field-demonstrated in six buildings in India and a key next step is to assess the efficacy of the packages and the effectiveness of data-driven decision making through the packages.

In conclusion, the research question we investigated was: How can we effectively design building energy information system packages that can overcome technological and market barriers to attain significant energy savings for high-consuming building sectors? Through streamlining and integrating the metering, communication, and visualization components of an EIS, it is possible to significantly reduce transaction costs, provide a relevant amount data for energy-based decision making, and drive significant energy savings through these adaptable and adoptable packaged EIS-in-a box solutions.

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