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Barriers to Energy Efficiency in Hospitals: Building a Better Business Case for Sub-Metering

chris davies
cdavies@clarku.edu

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Barriers to Energy Efficiency in Hospitals: Building a Better Business Case for Sub-Metering

Christian Davies

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Master's Capstone Project

Greg Trencher, Ph.D.
Chief Instructor

Will O'Brien, J.D. & M.B.A.,
Chief Instructor

Abstract

The natural world finds itself placed in an ever more precarious position as climate change is continually exacerbated by the burning of fossil fuels. Achieving greater energy efficiency in resource intensive industries has emerged as part of the immediate solution to this problem, a solution which can be financially, environmentally, and socially beneficial. Healthcare is one such industry where energy efficiency has high relevance. With hospitals operating 24/7 and energy intensive equipment running all day long, the healthcare industry offers high potential for successful building energy efficient retrofits. Yet it also faces many unique barriers. This paper identifies some of the most prevalent barriers to the industry by presenting the results of a sub-metering consulting project conducted at the University of California San Diego (UCSD) Medical Center. Through constructing a baseline for energy consumption and drawing on a variety of academic resources, the project was able to build a successful business case for sub-meter installation, the first step to better energy management in any large organization.

Academic History

Author: Christian Davies

Date: March, 2015

B.S Geography

Source: Southern Illinois University, Carbondale, Illinois

Date: March, 2015

Occupation and Academic Connection since date of Baccalaureate degree:

Sustainability Project Coordinator - Worcester Hannover Theatre

Environmental Defense Fund Climate Corps Fellow - University of California San Diego

Graduate Recruitment Assistant - Clark University

Marketing Research Assistant for Professor Keith Coulter, Ph.D. - Clark University

English Teacher, New Languages – Barcelona Spain

International Development, Community and Environment Fellow - Clark University

Dedication

I would like to dedicate this work to the members of my cohort and my faculty advisors who have each helped me to pursue my passions in their own way.

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1: Introduction

The phrase “The cleanest kilowatt is the one not used” has recently gained popularity in conversations about the importance of energy efficiency in building infrastructure. Yet the full truth is that the kilowatt not used is also the cheapest, and most socially beneficial to existing and future generations. Energy efficiency equates to doing more with less, maximizing output while reducing input costs, reducing resource consumption for future generations and saving money for today, tomorrow, and years to come. Energy efficient technologies for buildings offer proactive approaches that directly address the triple bottom line, a key tenet of sustainability, and something which has been historically overlooked in the process of doing business.

About 81.5% of the commercial buildings in the U.S. were constructed before 2000 (U.S. Energy Information Administration, 2016). While there has been solid growth in the construction of new energy efficient buildings, the larger pool of older existing buildings presents a unique financial, social, and environmental opportunity for energy efficient retrofitting (Eames, Dixon, May, & Hunt, 2013). In terms of overall sustainability, energy efficiency projects in buildings return an average of \$2 for every \$1 of spending, offer improved conditions for occupants, and could reduce CO² emissions needed to achieve climate security from energy by two-thirds (Institute for Building Energy Efficiency, 2012).

Within the general commercial building stock, healthcare facilities offer a great opportunity and challenge for significant energy improvement. Such facilities account for more than 8% of the total commercial energy use in the United States (U.S. Department of Energy, 2016). Their large energy consumption stems from the cost of running energy intensive equipment, often 24/7. For hospital management, this energy consumption is made worse by constantly rising energy costs. Yet this also means preventative measures and efficiency projects can be incredibly lucrative. Estimates show that \$1 saved on energy by a non-profit hospital is equivalent to producing \$20 in revenue. Furthermore, reducing energy use by 5% can increase for-profit hospitals' earnings by as much as penny per share (Health Research & Educational Trust, 2014).

While the financial payoff of energy efficiency projects can be substantial, there are often barriers to their implementation, financial and otherwise. The primary goal of this paper is to identify what specific barriers to energy efficiency projects exist in hospitals, and to offer a case study for building better financial business cases to address some of these barriers for sub-metering. In exploring these topics, this paper will draw from a case study where the author worked at the University of California San Diego Medical Center to analyze the potential benefits of sub-metering.

2. Literature Review

2.1 Barriers to Energy Efficiency in Hospitals

Utility costs for water, gas, and electricity are constantly on the rise, and the cost of organizational operations steadily increase as a result. Energy efficient technologies are the most cost effective and easiest way to lower utility costs at large organizations (Energy Star, 2016; International Energy Agency, 2008). The benefits extend beyond directly lower utility use. Energy efficient properties are more valuable than their less efficient counter parts, occupants tend to be more comfortable, and utility companies themselves save money through reduced transmission costs, decreased risk, avoided line losses, and other operational benefits (Lazar & Colburn, 2013). Given the obvious benefits of energy efficiency, it seems strange that organizations often overlook energy efficiency as a viable strategy for cutting costs.

For a variety of reasons hospitals face unique, and complicated barriers to pursuing energy efficiency projects that are not always found in other buildings that comprise the commercial building stock. The largest barriers tend to be economic and related to hospital funding (Evergreen Economics and SBW Consulting, 2015). Secondly organizational barriers related to hospital management and strategy are seen as interfering with energy efficiency projects (Singer & Tschudi, 2009). Thirdly, regulatory and legislative barriers can negate many options for energy efficiency projects (Cleveland & Irwin, 2013). Finally, the physical

and operational considerations of day to day facilities management in hospitals create additional concerns for energy efficiency projects (Cleveland & Irwin, 2013). Bearing in mind that sometimes these barriers are interrelated, the following sections unpack each, followed by a review of existing literature on the subjects.

Economic Barriers

In one survey of 288 healthcare facilities departments worldwide, 45% of respondents indicated that a lack of internal capital budget was the primary barrier to pursuing energy efficiency projects. The next most important factor was insufficient return on investment (ROI), listed by 21% of respondents, and uncertainty of ROI, listed by 13% of respondents (Institute for Building Efficiency, 2010). This should come as no surprise considering that in any organization there is competition for capital. This competition can lead to energy efficiency investments being overlooked (U.S. Department of Energy, 2015). In another survey of 29 facilities managers from hospitals across in the Midwestern United States, 44% indicated that lack of funding was the primary reason for not investing in Energy Management Software (Evergreen Economics and SBW Consulting, 2015). Finally, in a Survey of hospitals in Ontario, lack of internal funding was identified by 55% of hospitals as a serious barrier to implementing energy efficiency projects (Ontario Hospital Association, 2006). These economic barriers can often stem from organizational barriers, which are covered next.

Organizational Barriers

Hospitals are concerned with patient care first and foremost. Strategically speaking, since upper management tends to be more concerned by issues of profitability, healthcare reform, and clinical care changes, energy efficiency is often shifted to the backburner (Cleveland & Irwin, 2013). Additionally, energy efficiency projects and medical equipment tend to compete in the same capital pool. In such situations, it is highly unlikely the energy efficiency project will be given priority to medical equipment directly supporting the hospital's main line of business (Massachusetts Energy Efficiency Advisory Council, 2015). Hospitals also tend to have a highly risk adverse culture in their operation. Management may not be willing to experiment with energy efficiency projects for fear that such projects will impact their ability to provide medical services (Singer & Tschudi, 2009). Overall, many hospitals seem to be generally unclear as to how energy efficiency will contribute to their overall organizational mission (Northwest Energy Efficiency Alliance , 2015; Evergreen Economics and SBW Consulting, 2015).

Regulatory Barriers

All buildings are subject to local building codes. While these codes do not present a major barrier in many circumstances, there are times in which they create substantial complications. In regions with more stringent seismic codes, like California, the permitting and assessment process for building retrofits can make many retrofit projects cost

prohibitive (Cleveland & Irwin, 2013). Even if a project is not expected to trigger seismic codes when it is initiated, there is always the possibility that it will break seismic regulations during implementation (Cleveland & Irwin, 2013). Problems also arise during participation in energy efficiency programs offered via utilities. Financial incentives for energy efficiency are often offered through state governments or utility companies. For the latter, cost recovery and business models can make participation in energy efficiency projects, like demand response or construction of combined heat and power systems difficult or infeasible (U.S. Department of Energy, 2015).

Physical/Operational Barriers

Operationally speaking, hospitals run 24/7 and deal with vulnerable populations. This can make accessing areas in need of energy retrofits tedious and dangerous (Health Research & Educational Trust, 2014). There is rarely a good time to enter an area to make substantial renovations. HVAC improvements are often particularly difficult in hospital environments. Hospitals need to maintain equal air pressure in all their patient rooms. If one patient room has a lower air pressure, the air from other rooms will flow into it, potentially exposing them to a host of dangerous viruses. This consideration makes some HVAC technology infeasible and makes the implementation of other HVAC improvements very difficult (Cleveland & Irwin, 2013).

2.2 Building the Case for Sub-Meters

While it seems that financial constraints present the largest barrier to energy efficiency in hospitals, it is clear that there are a variety of other barriers to implementing energy efficiency projects. To circumvent these barriers, hospitals need to make a greater effort in using data driven approaches to strategic decision making. This can be achieved through the installation of sub-meters for efficiency project measurement and verification. Given that hospitals in particular seem so focused on financial barriers, literature that addresses the financial justification of sub-meters prior to installation is extremely valuable. That being said, there is relatively little literature that places an emphasis on building financial cases for sub-metering, which can be an expensive undertaking.

Most of the literature that does exist tends to overlook the problem of building the financial justification for sub-meter installation. It instead focuses on the benefits that are achieved post sub-metering. This is not surprising as sub-meters do not reduce energy consumption, they only track it. Still, the data gathered by sub-meters can be used extensively in the identification of potential building retrofits and project measurement and verification. In many ways, sub-meters do produce a financial payback through project identification though this is can be hard to quantify. Literature that addresses their monetary savings tends to provide only vague estimates of savings by sub-meter end use. Most of the literature usually focuses more on justifications by usefulness of sub-meters, rather than their financial solvency.

Economic Justification

The economic justification for sub-metering is perhaps the most difficult argument to make. The U.S. Department of Energy (DOE) has done extensive research pertaining to the economics of sub-metering, and much of their work was used in justifying meters in the following case study. Ultimately the DOE suggests using the estimates provided by the following table to select an appropriate level of savings for a sub-metering project.

TABLE 1: METER SAVINGS BY END USE

Use of Meter	Potential Savings
Installation of Meters	0 - 2% (the "Hawthorne Effect") ¹
Bill Allocation	2.5 – 5% (Improved awareness)
Building tune-up	5 – 15% (Improved awareness, operational and maintenance improvements)
Continuous Commissioning	15 – 45% (Improved awareness, operational and maintenance improvements, project accomplishment, continuing management attention)

(U.S. Department of Energy, 2006)

This table demonstrates that depending on what the meters are used for, various levels of savings can be expected through project selection. As the table indicates, meters can also be used to identify opportunities for building tune up and maintenance which can reduce

¹ The Hawthorne Effect, better known as the observation effect, is any noticeable decrease in energy use after meter installation from a raise in occupant awareness.

energy use by 5-15%. In such a situation, the facilities department may notice that one of the HVAC units is using substantially more energy than the other units. This might indicate that the unit in question has an unclean filter or some other component is malfunctioning. This in turn causes it to use more energy. More sophisticated metering allows for a further breakdown of consumption by equipment use and will help management continue to address issues in the electrical system as they arise. The ability to act so proactively makes an enormous difference in building energy management. The moment a piece of equipment stops operating at full efficiency is the moment it begins to use more energy than it needs to. Problems left unidentified are not a onetime loss, they act as a continual drain on resources month after month and year after year.

The same report also introduces a formula designed to aid in making sub-meter arguments. The equation is presented as follows:

FIGURE 1: FORMULA FOR CALCULATING MINIMAL ANNUAL BILL FOR PAYBACK

Formula and sample calculation:

$$\left[\frac{\left(\frac{\text{Installed Cost}}{\text{Desired Simple Payback}} \right) + \text{Annual Cost}}{\% \text{ Annual Savings}} \right] = \text{Minimum Annual Electric Bill}$$

= [(\$5,000) ÷ (10 years) + (\$25per month) x (12 months per year) ÷ (0.02)] = \$40,000 (U.S. Department of Energy, 2006)

The equation takes the installment cost of meters, desired payback time years, annual cost of upkeep, and expected annual savings to calculate what the organization’s minimum electrical bill would need to be in order to pay off the meters in the specified desired

number of years. The example shows that if the decision maker wants meters to payback in 10 years, and the meters cost \$5,000 to install, \$300 (12 x \$25) a year to maintain, and saves approximately 2% in annual energy use, their annual energy bill would need to be \$40,000 to achieve that 10 year payback.

Most other papers focusing on the economic justification for sub-meters refer to the work done by the DOE and use the table and formula above to show how the business case for sub-metering might be made (Plourde, 2011). Other common return on investment equations, such as simple payback, net present value, and internal rate of return are also identified as standard methods for calculating metering paybacks (U.S. General Services Administration (GSA), 2012).

Use Justification Factors

The economic justifications are ultimately based on the use of the meter. Examples of meter uses were outlined in tables 1 and 3 above, but certain uses require different levels of metering. For example, multiple tenant billing cannot be achieved by using a meter that only measures electrical use at the whole building level². In this case the whole building meter must still be installed to further sub-meter tenants. The following table shows the level of metering required for various meter uses.

² The “whole building level” means installing one main meter to track the energy use of the entire building.

TABLE 2: LEVEL OF METERING REQUIRED FOR VARIOUS END USE

Use of meter	Level of metering
Energy bill verification	Whole building
Tenant billing / improved awareness	Tenant
Rate monitoring	Whole building
Demand response	System / Device /Circuit
Identifying equipment issues	System / Device / Circuit
Baselining energy use	Building / System / Device / Circuit
Efficiency project verification	Building / System / Device / circuit

(Tutterow, Schultz, & Yigdall, 2011; Corporate Energy Managers' Consortium, 2004; Plourde, 2011).

As the table demonstrates, the installation of sub-meters allows simple energy bill verification and monitoring of different sections across the whole building. Baselining energy use at the building level is also possible, but identifying equipment issues, verifying project results, or tenant billing, would require a more sophisticated sub-meter system. By measuring at the device level, for example, one would be able to pick out specific abnormalities in energy use on chillers, air handlers, or any other equipment that is metered. By combining table 1 and 2 readers can better understand the relationship between the level of metering required for various end uses and the potential savings by end use.

TABLE 3: LEVEL OF METERING REQUIRED TO OBTAIN OBSERVED SAVINGS SPECIFIED BY METER END USE

Use of Meter	Minimum Level Of Metering Required	Potential savings
Installation / basic billing	Whole building	0 - 2%
Tenant Metering	Tenant / Circuit	2.5 - 5%
Building tune up*	System	5 - 15%
Constant Commissioning*	System / Device	15 - 45%

*Indicates a use that UCSD could take advantage of after implementation of metering plan

The combination of these resources demonstrates how the puzzle begins to fit together. Once a desired sub-meter use has been specified in the project scope we can see the required level of metering and the potential savings that it might generate. Still, at the end of all this, meters do not directly save money. One still needs to turn to the literature to see how to lend credibility to the potential savings listed above. There does not appear to be much in the way of further literature that focuses on financial justification specifically. The next section will therefore draw from literature on other energy efficiency projects to help support the information provided above.

Measurement and Verification / Baseline

Prior to undergoing any energy efficiency retrofit, the project team needs to understand the scope and requirements of the project, and how they intend to measure the outcomes of the project in a tangible way (U.S. Department of Energy, 2015). For obvious reasons, an important step in the process is defining a project baseline for post implementation comparisons. For energy efficiency related projects, the baseline would be a measure of current performance, such as energy currently consumed. Simply put, for energy efficiency projects, project managers want to see energy consumption drop from the baseline value. This can either be achieved through replacing inefficient technology or scheduling its use more efficiently so that it is used less often (ADM Associates, Inc., 2013). An example of an energy baseline could be average annual consumption, or energy consumed per square foot of a building.

While sub-metering buildings will cause no reduction in baseline energy use, the baseline can be compared across a building's peer group. This provides additional credibility to savings estimates included in tables 1 and 3 in the sub-meter financial literature section. If a building drastically underperforms its peers, this might justify a high savings potential from the table. Furthermore, creating a building level baseline with peer group comparison actually requires very little data. All that is needed is energy bill data, information about the property, such as square footage, and a web based energy management software, like EPA's Energy Star Portfolio Manager, which is free to the user. Portfolio Manager compares

a building to a national group of its peers and can be established for nearly any commercial building (Energy Star, 2016).

Even without Portfolio Manager, a simple scatter plot of a building's energy consumption data can make for a very telling baseline. Combining the existing sub-meter literature, as well as some literature on establishing baselines for other energy efficiency projects, leaves us with several powerful tools for building a more complete financial model for sub-meter justification. The second half of this paper will focus on the results of this approach at UCSD, and the barriers that were encountered at the Medical Center.

3. Methods

3.1 Data Collection and Financial Estimates

The primary data for this case was collected during the months of June, July, and August of 2015. The data consists mainly of utility consumption information of three buildings on the UCSD Medical Center campus. The data includes the monthly cost and consumption of water, gas, and electricity at the buildings, and was collected by UCSD employees from the main campus facilities department. Additional information on equipment costs, or installation costs were estimated based on conversations with account representatives from a variety of companies, as well as catalog prices for various equipment. Savings estimates were based on a combination of suggestions from existing literature and baseline comparisons to energy use at similar buildings.

3.2 Case Overview on USCD

All University of California main campuses and Medical Centers are subject to policies set forth by the Office of the President (UCOP). The UCOP has established very ambitious policies for sustainable practices within the UC system, some of the most relevant for this project included:

- Reducing emissions to 1990 levels by 2020
- Net zero emissions by 2025
- Engaging in Energy Star Programs to encourage energy efficient practices and purchases within the university system (UC San Diego, 2008)

Much of the effort in achieving policy goals has fallen on the University main campuses while less attention has been focused on the Medical Centers. The UCSD Main Campus has set a high bar for sustainability. They have earned over \$7 million dollars in incentives from the local utility company, and their cogeneration plant saves them nearly \$8 million dollars a year. The plant also lowers emissions from what they would be if they were supplied directly through the utility by approximately 75%. They have also saved hundreds of thousands annually thanks to reinvestment in energy efficiency throughout their buildings. These projects have primarily been pursued by the UCSD Campus facilities department, specifically their Energy Manager and Assistant Energy Manager, and made possible by sub-

metering buildings on campus to identify energy use trends and track the performance of efficiency upgrades.

Currently there is no formal system or group in place within the UCSD Medical Center to monitor energy consumption and analyze potential energy efficiency projects. Any investment in energy efficiency is typically need based. When equipment needs to be replaced it becomes an opportunity for efficiency. Large scale equipment overhauls typically only happen from planned expansions. One such example would be the creation of the new central utilities plant, a necessity resulting from the construction of the new Jacobs Hospital at the La Jolla Medical Center.

In light of the efforts put forth by the main campus and the policies established by the UCOP, the Medical Center has begun making an effort to better track and manage their utility consumption. As a result, the focus of this project was to demonstrate the need for a metering expansion, and an additional staff member to act as an Energy Manager for the Medical Center. The primary results indicate that the Medical Center is consuming far more energy compared to similar hospitals, and that the Medical Center would see significant financial savings by pursuing energy efficiency projects.

Metering Background

In the Case of UCSD, the Medical Center is comprised of multiple buildings, some are hospitals, and others are medical administration buildings. The sub-metering assessment took place at three of UCSD's hospitals in La Jolla, CA. The buildings are physically connected and share the same HVAC system. Thornton Hospital was the first to be built in 1991, followed by the Perlman Clinic in 1998, and the Sulpizio Cardio Vascular Center (SCVC), finished in December 2010.

The three buildings have separate meters, the meters at Thornton and Perlman are not sophisticated enough to be read remotely. Perlman's electricity is fed through Thornton's electrical system, so campus facilities only reads Thornton's meter and the two are then billed together. Thornton has two main electrical meters each tracks about half of the building's consumption. SCVC has three advanced meters, the same kind used to track energy on the main campus, but the meters have never been configured to be read remotely. Two of SCVC's meters track most of the building's energy use, whilst one tracks the radiology department specifically.

4. Findings

4.1 Barriers to Advancing Energy Efficiency at UCSD Medical Center

Based on the work at UCSD Medical center, five primary factors were identified which limit the pursuit of energy efficient projects at the Medical Center. This five factors include regulation, building type, Lack of top down pressure, insufficient staff capacity, and inappropriate economic incentive. The following table presents these five factors along with a brief summary of points regarding their impact. Each factor is then expanded upon in more depth below.

TABLE 4: BARRIERS TO ENERGY EFFICIENCY AT UCSD

	Low Economic Incentives	Structural / Operational	Regulation	Lack of Top Down Pressure	Insufficient Staff Capacity
Summary of Barriers	Low energy prices from the campus do not create enough incentive for serious efficiency measures	Hospitals have some sections running 24 hours a day this make regular maintenance difficult	Hospitals in California face strict seismic regulation, making some efficiency projects economically unviable	Lack of serious pressure on the Medical Centers from the Top of the organizational pyramid has failed to create a sense of urgency	The existing staff within facilities lack the time and resources to focus on energy efficient measures

Low Economic Incentives

The UCSD Medical Center is powered by the UCSD Main Campus, which operates its own cogeneration plant. The Energy Manager at the UCSD Campus purchases the majority of their energy from the wholesale market, rather than through the local utility. This substantially lowers the cost of energy for the main campus as well as the Medical Center and lowers the emissions from energy consumption. While the cogeneration plant is clearly beneficial to the university, it reduces the economic incentive for the medical center to be more efficient. This is because the campus charges them at a rate lower than the rates of the local utility company. Higher energy bills for the medical center are therefore the result of inefficiency, rather than high energy prices.

Structural Operation

As it has already been mentioned, healthcare faces its own unique issues as an industry with 24/7 operations and patient concerns, UCSD is no different. The patient wings at Thornton, the largest and oldest hospital at the La Jolla campus, are nearly always fully occupied. Facilities staff are understandably discouraged from disturbing patients unless absolutely necessary to do basic maintenance. This presents a frustrating problem as the patient wings are also the largest areas that operate 24/7, and therefore offer the largest potential savings for energy projects. Other areas can also prove difficult due to the patient safety concerns, especially in areas with very vulnerable patients, like the ICU.

Regulation

As a state prone to Earthquakes, California has a number of unique laws regarding the seismic fortitude of existing buildings, and new construction. UCSD's Medical Center falls under Senate Bill 1953. This bill requires that hospitals meet specific seismic compliance regulations. These regulations are more stringent than the requirements of hospitals in other states. Adherence to this bill can make various types of energy efficiency projects much more expensive to implement. Replacing an HVAC unit on the roof, for example, would have to go through a variety of permitting processes in order to ensure that the additional weight would not significantly jeopardize the structural resilience of the building. This process would involve a host of consultants, architects, and engineers to ensure viability. As a result, some energy efficiency projects have processes that tend to be longer and more expensive in California than in other states. There is also additional fear that extensive retrofitting might trigger unforeseen building codes as projects progress. Such an event is not only expensive, but has the potential to make the entire project cost prohibitive.

Lack of Top Down Pressure

The UC medical centers do not face substantial organizational pressure for change from the top. Given that hospital regulation and operations are so complex, it seems as though the universities have resigned to allow the medical centers to have more leeway with their

operations. As of 2013, the University of California Office of the President (UCOP) announced that they would be pursuing carbon neutrality for their buildings and vehicles. This mandate applies to all UC campuses, and will be achieved through a mixture of renewables, offsets, and efficiency measures. Prior to this commitment, the UC medical centers faced little organizational pressure to reduce their energy consumption. The repercussions of this development will be highlighted later in the findings.

Insufficient Staff Capacity

Facilities departments in any organization tend to have a reputation for being understaffed and overworked. The facilities staff at UCSD acknowledge the importance of energy efficiency and other sustainability initiatives, but none of the staff have the time to actively pursue large scale efficiency projects. Typically, equipment is replaced on an as needed basis. If for example, a staff member is able to find a LED bulb that can sufficiently replace a number of compact florescent bulbs (CFLs) within one of the buildings, they will do so as the CFLs burn out. The lack of staff capacity also makes it difficult to assess current performance levels, collect relevant data, and build strong cases for enhanced energy management.

4.2 Making the Case for Sub-Metering

In the case of UCSD, a decision making process was created to arrive at the financial justification for installing sub-meters, and to help decide on an appropriate savings estimate to use in calculating the expected savings from future energy projects identified by the meters. This process was designed based on existing sub-metering and baselining literature as well as inside knowledge from working on the case at UCSD. The process is presented as follows:

1. Review of building characteristics
2. Definition of project scope
3. Establishment a building baseline
4. Comparison this baseline to the building / property peer group
5. Use of the baseline and literature to justify a potential savings estimate

We will briefly offer an overview of each step in this process as it applied to UCSD, starting with a background of the buildings specifically worked on.

Review of the Building Characteristics

Buildings have a variety of characteristics that will significantly affect the amount of energy they consume. The size of the building, age, type of lighting fixtures, HVAC design, and building use are all significant factors that influence consumption. In general, a larger building will require more energy to heat and cool, and if it is fully occupied, it will use more

energy in day-to-day operations. The complexity of operations also significantly influences energy use. More complex and technical operations can be more energy intensive. A basic review of the buildings under consideration for sub-metering will quickly tell whether or not such a project will be financially feasible.

The three hospitals assessed for metering at UCSD are large buildings, approximately 850,000 square feet. This is roughly close to the size of 15 football fields. Many areas are occupied and using energy 24 hours a day. The buildings have two MRI machines, a variety of equipment for monitoring patient vitals, and other sophisticated equipment constantly drawing electricity. Essentially, the three buildings make up a large, complex, and energy intensive medical campus. Given these types of physical building characteristics and use patterns one can reasonably assume that these buildings are highly energy intensive, and that sub-metering some aspects of the building might lead to fruitful data collection.

Define the Scope of the Project

After reviewing the building use characteristics one can begin defining the scope of the metering project. Based on the review of the literature, it is known that sub-meters pay off depending on how they are used. Referring back to Table 3, it is clear that in order to receive a substantial payback a sub-meter plan should strive to cover at least the main electrical systems. The plan should therefore at least separate the lighting and HVAC. It should be extended to the device level if possible. Such a system would allow users to attain

5-45% savings by helping to identify projects, verify project outcomes, and perform regular equipment maintenance. Because additional meters add additional costs, it is recommended that a variety of metering options are presented. The first option might suggest adding sub-meters onto the most complicated and energy intense equipment, like chillers. Further options might provide for additional meters to be added to the air handlers, the lighting system, and other equipment. Once the project scope is established data on existing energy use should be collected to help justify the projected savings range down the line.

Establishing a Building Baseline³

After identifying the desired scope and savings, a baseline was created to analyze historical energy bills to quantify how much was being consumed. The following graphs show the rough baseline of hospital energy use over the last 10 years. The first shows electricity consumption from the combined Thornton and Perlman buildings, which as explained earlier, are billed together. The second graph shows electricity consumption from all three buildings assessed. Again, the buildings had to be taken together because they are connected, and share the same HVAC system.

³ More data and tables for the baseline are presented in appendix A.

FIGURE 2: THORNTON AND PERLMAN kWh CONSUMPTION

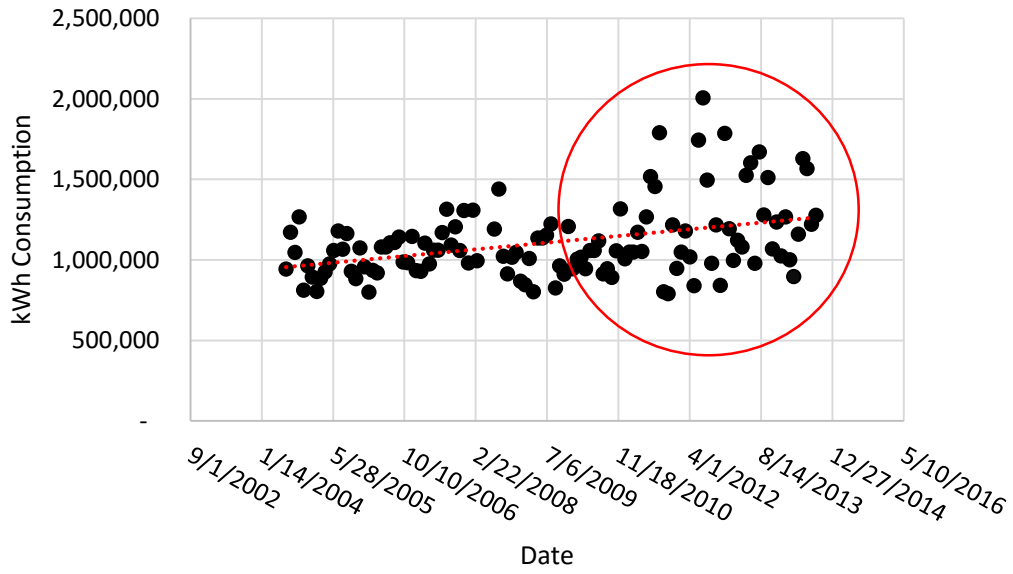
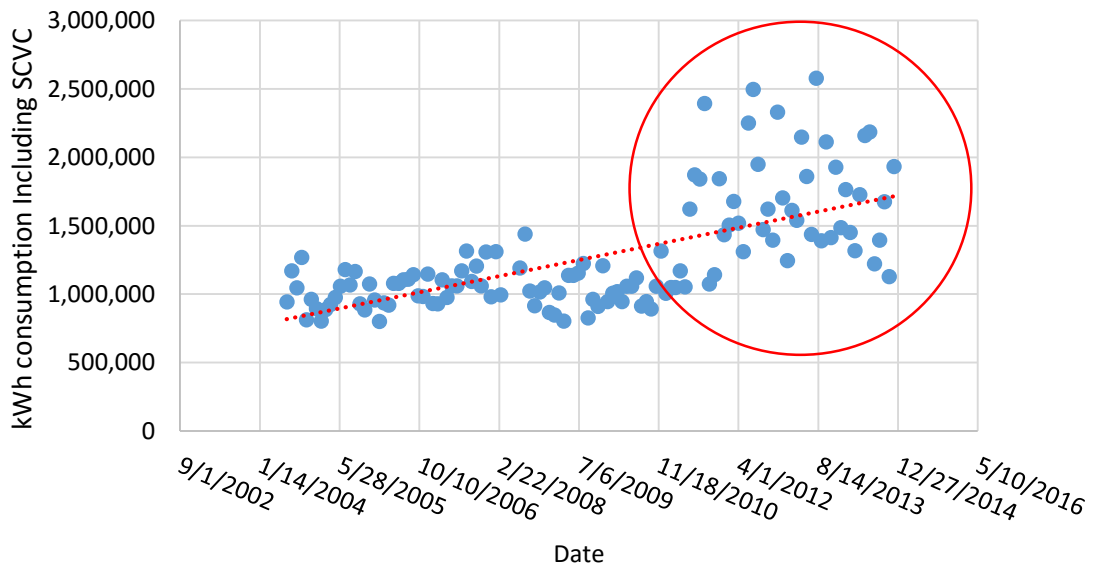


FIGURE 3: kWh CONSUMPTION INCLUDING SCVC



These graphs present incredibly valuable information to help justify the potential savings outlined in the project scope. The third building, SCVC, opened in December, 2010. Prior to that date, there was relatively little variation in energy consumption between the buildings. After that date, the energy consumption becomes incredibly varied on a month to month basis. In an ideal building, one would want to see consistent energy use from month to month as seen the first 6 years of data, not like the last 4 years. According to the graph, energy use can practically double between some months, then drop by half at the three buildings. While it is possible that weather plays some role in this, UCSD is located in La Jolla, CA, a notoriously temperate region of the United States.

These graphs also indicate that because the variation shows up in the Thornton and Perlman energy bills, without including SCVC, the HVAC system is most likely the root of the inefficiency. This is because it is shared between the three buildings, and most of that equipment is housed in Thornton. From looking at the energy consumption on a monthly basis, it is obvious that there is unhealthy variation. It is likely caused by something in the HVAC system, and reducing this variation would lead to energy and cost savings. Sub-meters would allow workers to further analysis specific HVAC components to better track the issue.

Comparing the Baseline to the Building Peer Group

Knowing a building energy consumption position against similar buildings in its peer group is instrumental in estimating the potential for reducing energy use. For example, if the median hospital in a data set of peers uses 20 million kWh annually, but the assessed building uses approximately 16 million kWh annually, it is already performing significantly better than the median. This might make additional efficiency project opportunities hard to identify even with additional meters. Comparisons can be made in a number of ways, but the project at UCSD primarily used large hospital data from the Energy Information Administration, and Energy Star's Portfolio Manager Tool from the Department of Energy. The following table shows the results of the comparison between UCSD's baseline to its peer group, according to Energy Star.

TABLE 5: BASELINE COMPARISON OF UCSD MEDICAL CENTER TO HOSPITAL PEER GROUP

Metric	2011-Dec	2014-Dec	2011-2013 Change	Median
Energy star score	23	17	-26%	50
Site EUI	319	331.5	3.79%	273
Site energy use (kBtu)⁴	143,966,419	149,404,658	3.77%	123,121,188
Energy cost (all three buildings)	\$1,865,262	\$2,305,654	23.61%	\$1,900,040
GHG emissions (Tons of CO2 equivalent)	10,817	11,448	5.52%	8,092

As we can see from the table, UCSD’s Medical Center is underperforming healthcare properties of similar size and use. Its Energy Use Intensity (EUI), which is energy use per square foot, is much higher than the median, showing that it consumes 331.5 kBtu per square foot compared to 273 at the median hospital. Because EUI is standardized by account for square footage, it better accounts for the size of the building. A large hospital using a lot of energy will not necessarily have a worse EUI than a small hospital using a lot of energy. In addition to having a EUI well above the median, UCSD’s EUI has grown by 3.79% from 2011 to 2014. While this information is bad news from an energy management perspective, it further solidifies our financial argument for the implementation of sub-metering systems.

⁴ Data on energy consumption has been weather normalized

Using the Baseline and Literature to Justify a Financial Savings Estimate

Currently, UCSD’s energy consumption is 21% higher than the median hospital, and their bills are approximately \$400,000 dollars higher annually. Looking at their baseline, their energy consumption has become increasingly variable month to month, and without sub-meters, it is impossible to being seriously identify the root of this problem.

Taking both of these assessments into consideration, it is now possible to return to the savings estimate table and answer a key question, what is an appropriate estimate for savings potential from metering projects? The literature suggests we use something between 5-45%. In the interest of being conservative, a 5% savings from future metering projects was selected though in all likelihood this estimate may be too conservative. Based on UCSD’s energy bills and the 5% savings estimate, the results of the project are in the following table.

TABLE 6: METERING PROJECT RESULTS

Project	10-yr NPV of cost savings	Up Front Investment (net of rebates)	Annual Cost Savings	Annual kWh savings	Savings potential estimate	CO2 reduction (metric tons/yr)	Payback (yrs)
UCSD Metering upgrade	\$490,832	\$74,789	\$72,862	971,494	5%	353.51	1.03

Metering Conclusions

Prior to pursuing any investments in efficiency, the Medical Center should invest in existing metering infrastructure, to help identify projects and measure outcomes. As Table 6 shows, even a conservative 5% savings estimate shows that the use of sub-meters has the potential to identify highly lucrative projects. This is largely due to its already energy intensive consumption driving high energy bills at UCSD, which total roughly \$1,200,000 dollars annually. Overall, the net present value of the project totals approximately \$490,832 dollars over 10 years, the result of \$72,862 dollars in annual savings. If we want to create a range of savings, we could simply assume that the medical center is able to save 10% on energy consumption each year. While this estimate may seem too high, it is still within the boundaries identified in the literature, and would double annual savings to \$145,742 dollars. We might then use both estimates together and suggest that it is possible to save something in the range of \$72,000-\$145,000 dollars annually. ⁵

⁵ A full breakdown of meter costs and example diagrams are presented in Appendix B.

6. Discussion

6.1 Barriers to Energy Efficiency Revisited

The largest barriers to pursuing energy efficiency at UCSD seem to be almost opposite of the average hospital. The largest barriers for most hospitals are lack of capital funding and uncertainty of payback. While this is a concern at UCSD, the fact that they source their energy from the university means they pay a more favorable price per kilowatt hour. This in turn means that their facilities department pays significantly less than it would under normal circumstances. While this does mean they have a higher budget for improvements, it also means they have been less concerned by their excessive energy consumption.

The case study at UCSD seems to agree with the existing literature about operational barriers and regulatory barriers. Like other Hospitals, UCSD is constrained by the nature of hospital operations; scheduling access to patient rooms and patient safety concerns require significant planning and create serious constraints on what can be done and when. While there is literature that suggests market regulation creates a barrier for certain energy efficiency projects like demand response, this is not the case at UCSD (Marquez, McGregor, & Syme, 2012). UCSD could participate in demand response through their local utility, SDGE, but patient safety concerns prevent them from participating in such programs at a large scale. One study mentioned seismic codes, specific to California, as a significant

barrier to advancing some energy efficient measures at hospitals (Cleveland & Irwin, 2013). This barrier also presented itself at UCSD, and it is understandable that existing hospitals in such areas may never be able to circumvent these regulations. Moving forward, newly constructed hospitals should be designed to account for these issues.

There has been a lack of top down pressure at UCSD to engender a more strategic approach to energy management. As the literature suggests, this is likely because the primary focus off hospitals is patient care, which is understandable (Health Research & Educational Trust, 2014). While some managers and directors recognize the benefits of energy management, they do not have the capacity to devote all of their attention to it. As University wide policy towards environmental impact, specifically a focus on carbon emissions, becomes more developed, it seems that upper management is beginning to view energy management issues as part of their career expectations. As this focus develops, it will likely become easier for managers to justify additional staff positions for energy management, and additional funding for energy management activities. This will hopefully aid in addressing existing staff capacity issues for energy management projects faced not only by UCSD, but many other organizations as well.

6.2 Metering Methodology at UCSD

As previously explained, there is no one source, academic or otherwise, that perfectly outlines a methodology for building a business case for building sub-meters. The case work at UCSD involved comparing a number of different resources which outline the quantitative and qualitative benefits of sub-metering to help construct their financial justification. The results show that while energy savings from projects implemented after meter installation are unpredictable, it is still possible to create a strong financial justification for sub-meter projects using baseline comparison and reference to existing literature.

At UCSD, like many other organizations, the primary barrier was the economic justification. Beyond this point, approval from management and existing building infrastructure proved to present additional challenges. Management approval at UCSD was easily secured at the departmental level, but the expense of the project required additional approval from senior management. Getting both a staff member to manage the meters as well as expensive new metering equipment would require additional approval from the Vice President of Facilities for all of the UCSD Medical Center properties. Given the strength of the business case for additional staff and metering, it is likely that both will be approved. This final step does still present another barrier to the overall project implementation.

Finally, infrastructural barriers at UCSD came in the form of continued operation. In many buildings, replacing a meter would require the electricity to be temporarily shut down. Such

a requirement would be nearly impossible for a hospital because of the considerations necessary for the patients. This issue was ultimately circumnavigated by working with facilities electricians and representatives from Schneider Electric, the company that would provide the meters.

7. Conclusion

Healthcare will continue to present unique challenges to the field of energy management well into the foreseeable future. While sub-metering is not an all-encompassing solution for the industry, it provides facilities departments with a powerful tool for energy management. Though sub-meters do not directly reduce energy consumption, their financial justification stems from their ability to proactively identify issues with operational systems in buildings. Though meters may seem expensive, hospitals and other healthcare buildings are naturally energy intensive. This makes them a particularly rewarding challenge when solutions to energy management are uncovered. Finally, building managers should stress the importance of energy efficiency for improving the quality of patient care. More finely tuned building operations can be seen as directly improving patient comfort. Furthermore, tracking building systems more aggressively will reduce the likelihood of failures which could jeopardize patient safety.

To the best of the author's knowledge this is the first academic study that builds the justification of sub-metering through a combination of literature and real world baseline

comparison. Indeed, there exist very few papers which explicitly outline a step by step process for building a business case for sub-metering of any kind. This fusion of literature and real world application will hopefully provide substantial assistance to other researchers and practitioners in the broader field of building energy efficiency, and more specifically, sub-meter implementation. While there may be other similar papers which are unpublished or not publically available as of yet, the field of sub-meter research at the building level continues to offer opportunities for future research. Aside from the work done by the Department of Energy, it seems no other organization has tried concertedly to attribute the potential savings from other energy efficiency projects to the use of sub-meters. Though this paper has provided an example of how one might use and justify the estimates of the DOE, this is still extensive room for refinement of this method.

While some of the barriers outlined in this paper are unique to UCSD, others are clearly shared with the industry as a whole, and seem to present no immediate solution. While financial barriers may continue to drop as innovation spreads and technology becomes less expensive, other barriers like building code regulations, patient health and safety concerns, and 24 hour operation, are likely to remain firmly in place. While many of these concerns have been raised, there does not seem to be a body of literature that focuses on building strategies to address them. Perhaps finding a way to better coordinate hospital operations would reduce some of the systems' need for 24 hour operation. Better foresight might also see the construction of a building designed with flexibility in meeting building code. Though

this case study has yielded a fruitful exploration of the problematic nature of energy efficiency in the healthcare industry it remains one of only a few studies on the subject. Additional contributions to the field will continue to aid in informing the decisions behind proactive hospital energy management.

Appendix A.

FIGURE 4: THORNTON, PERLMAN & SCVC CONSUMPTION AND EMISSIONS

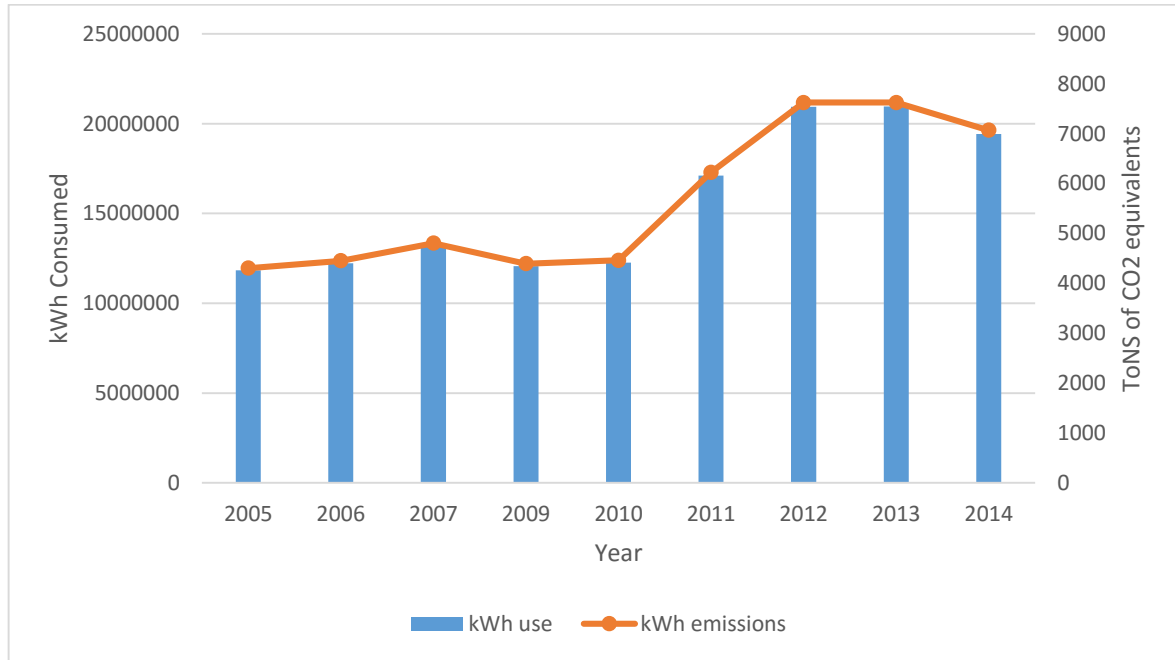


TABLE 7: CHANGE IN ELECTRIC UTILITY OVER TIME

	2005 use (kWh)	2014 use (kWh)	Percent change	2005 Cost	2014 Cost	Percent Change
Electrical Utility	11,832,800	19,429,881	64.2%	\$896,737	\$1,671,289	85.95%

TABLE 8: CHANGE IN WATER AND GAS UTILITY OVER TIME

	2005 use	2014 use	Percent change	2005 Cost	2014 Cost	Percent Change
Gas (Therms)	876,982	826,166	-5.79%	\$775,565	\$634,365	-18.2%
Water (hcf)	22,274	37,628	68.93%	\$105,840	\$279,541	164.11%

TABLE 9: CHANGE IN UNIT COST OF WATER IN CAS OVER TIME

	Average per unit cost 2005	Average per unit cost 2014	Percent change
Gas (Therms)	0.76	0.77	1.31%
Water (hcf)	4.62	7.33	58.65%

FIGURE 5: ENERGY CONSUMPTION BETWEEN ELECTRICITY AND GAS

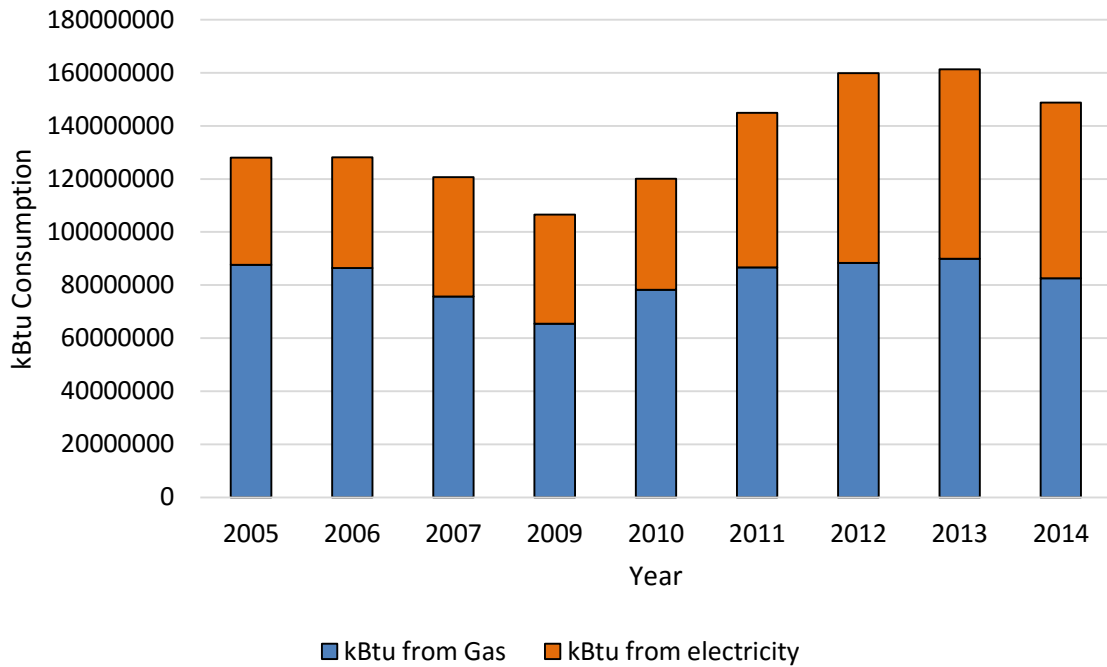


FIGURE 6: WATER CONSUMPTION AND COSTS AT THORNTON, PERLMAN, AND SCVC

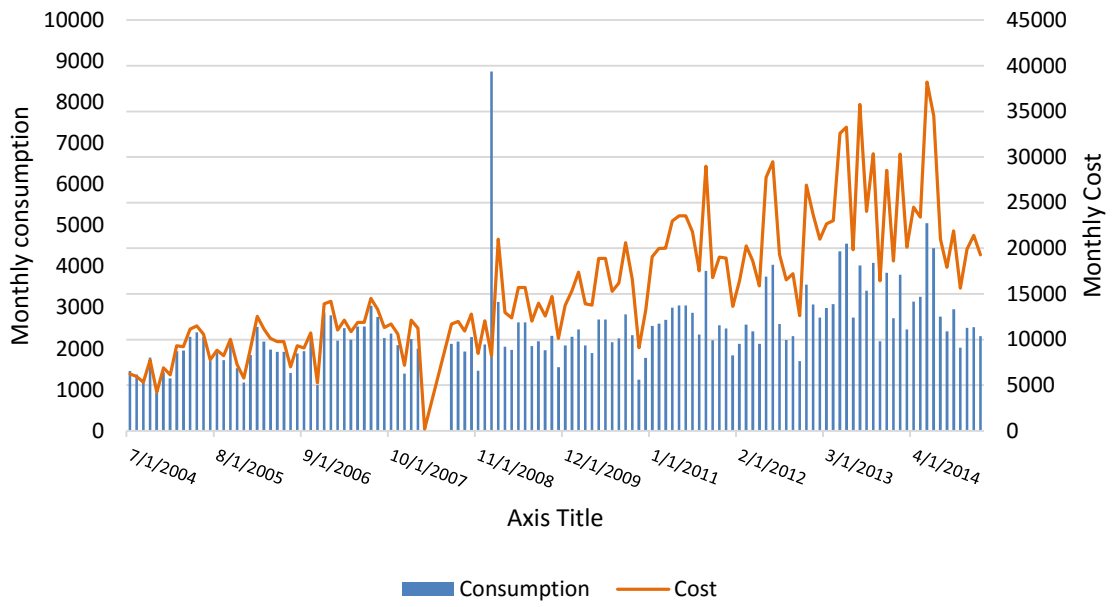


FIGURE 7: EMISSIONS FROM THORNTON, PERLMAN, AND SCVC

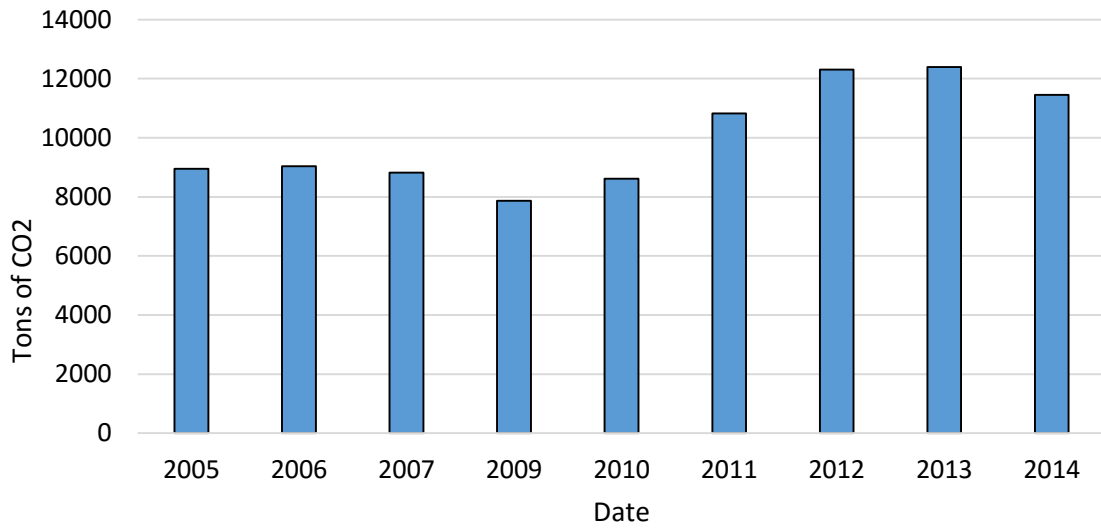


FIGURE 8: 2014 EMISSIONS BY UTILITY SOURCE FROM THORNTON, PERLMAN, AND SCVC

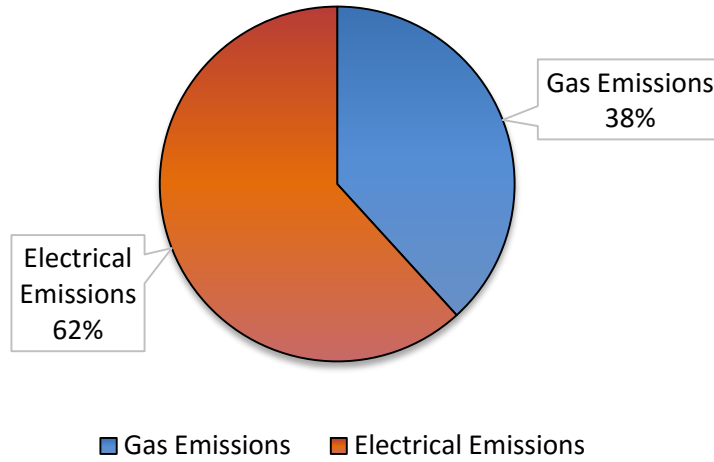


TABLE 10: SITE EMISSIONS OVER TIME

	2009	2010	2011	2012	2013	2014	% change
CO2 Emissions (tons)	7,864	8,610	10,817	12,310	12,392	11,448	45.57

TABLE 11: FULL ENERGY STAR PERFORMANCE TABLE

	2010	2011	2012	2013	2014	Target	Median
Energy star Score (0-100)	n/a	23	8	7	17	30	50
Site EUI (kbtu/sqft)	399	319	354	360	332	305	197
site energy use (kBtu)	119,532,085	143,966,419	159,529,711	162,121,235	149,404,659	137,285,457	58,792,413
Energy Cost (\$)	1,729,845	1,865,262	2,135,068	2,405,189	2,305,654	2,118,559	1,144,368
GHG emissions (metric tons CO ₂ e)	8,610	10,817	12,310	12,392	11,448	9,022	8,092

Appendix B: Sub-metering cost and installation location

TABLE 12: COST ASSESSMENT FOR EACH METER

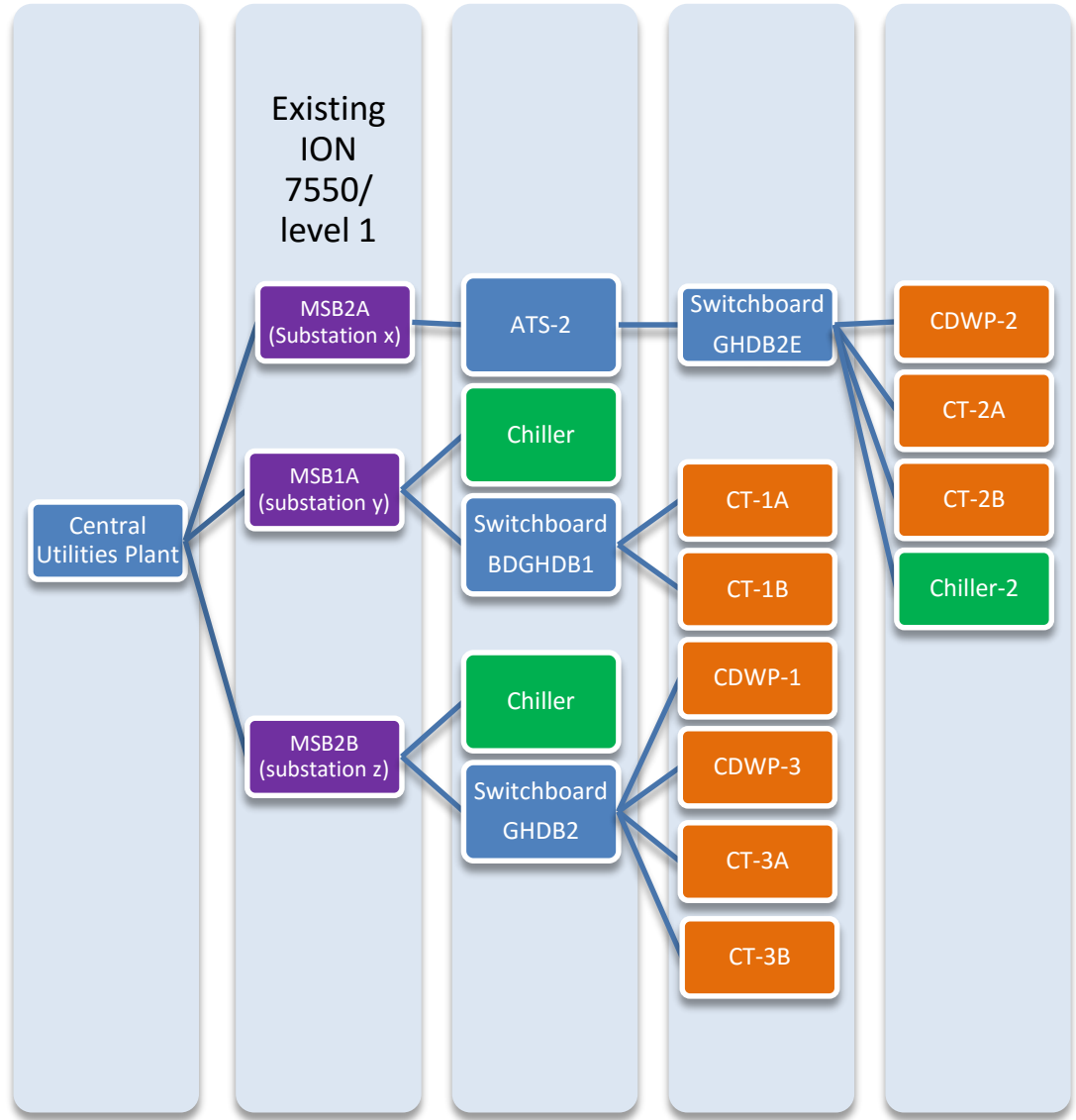
Thornton			
Location/circuit	Number of meters	Type of meter	Total cost of meters
Main Subs	3	ION 7550	\$37,830.00
Lighting	4	Enercept 300 amp	\$3,200.00
MCC	3	2xEnercept 400 amp, 1xEnercept 100 Amp	\$2,376.00
Radiology	1	Enercept 400 amp	\$823.00
			\$44,229.00

Perlman			
Location	Number of meters	Type of meter	Total cost of meters
Main Sub	1	ION 7550	\$12,610.00
			\$12,610.00

SCVC			
Equipment circuits	Number of meters	Type of meter	Total cost of meters
Lighting	3	Enercept 100 amp	\$2,328.00
Elevator MCC	1	Enercept 800 amp	\$847.00
			\$3,175.00

Central Utilities Plant			
Equipment circuits	Number of meters	Type of meter	Total cost of meters
Cooling Towers*	6	Enercept 100 amp	\$4,656.00
Chillers*	3	PM5000	\$5,450.00
Chilled Water Pumps*	3	Enercept 400 amp	\$1,669.00
			\$11,775.00

FIGURE 9: SAMPLE METERING LAYOUT FOR CENTRAL UTILITIES PLANT



Optional PM 5000 meter

Existing / Proposed 7750 Meter

Optional Enercept meter

FIGURE 10: SAMPLE METERING LAYOUT FOR THORNTON

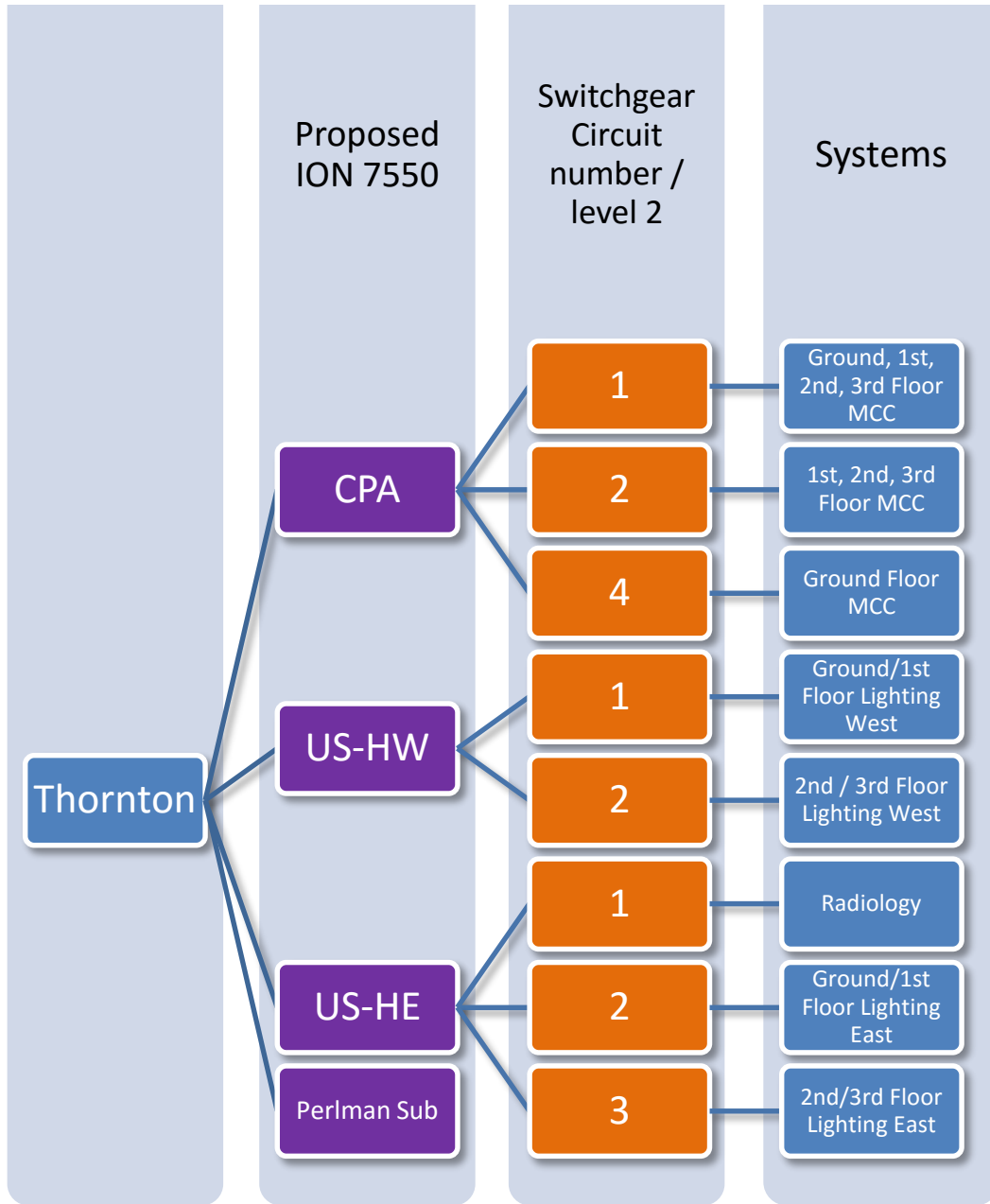
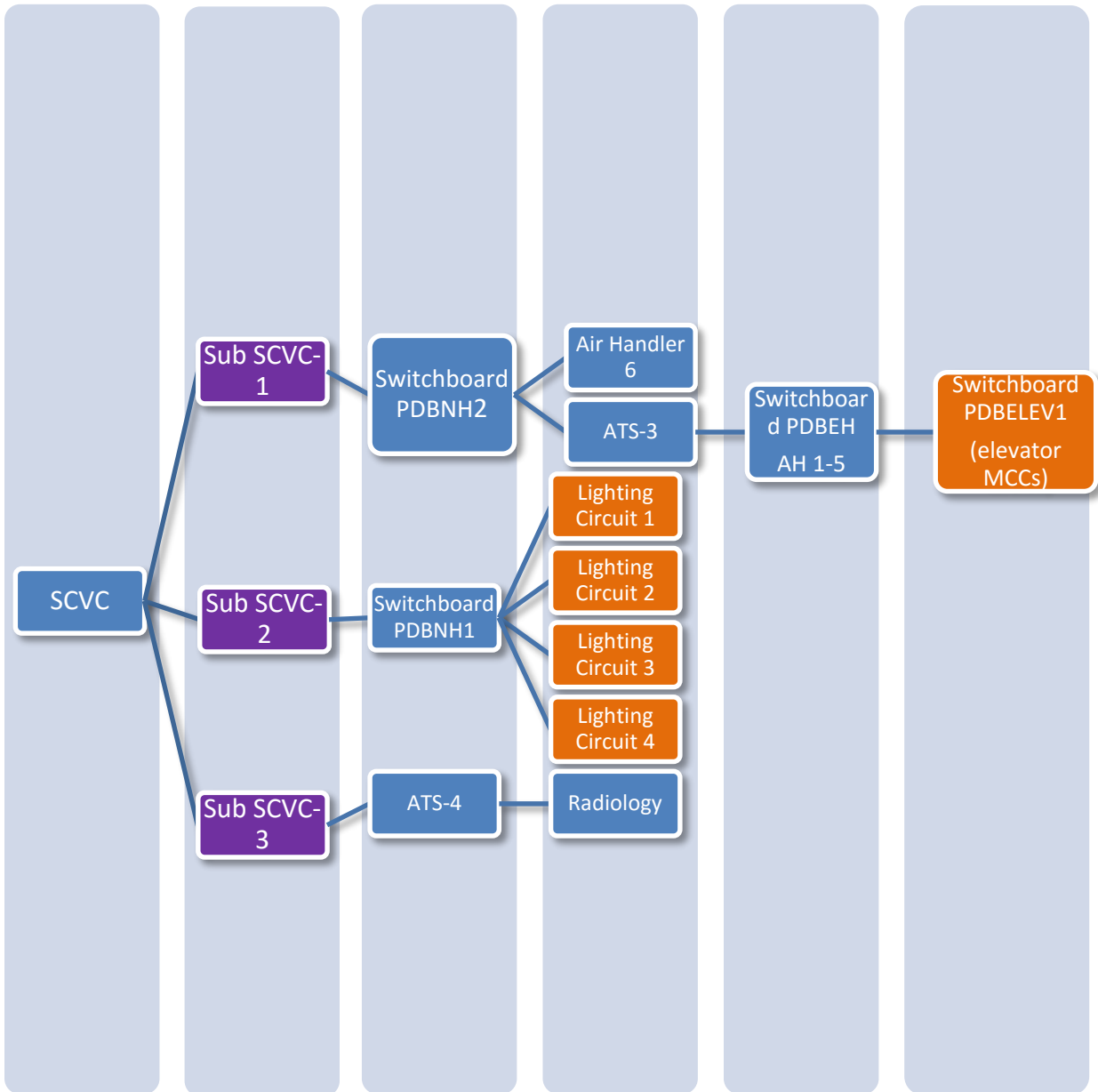


FIGURE 11: SAMPLE METERING LAYOUT FOR SCVC



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