ENERGY MANAGEMENT FOR MISSION-CRITICAL APPLICATIONS: OPTIMIZING SMALL TO MID-SIZED DATA CENTERS

Jiaqi Liang
Shrenik Ajmera
Tejas Desai
Willdan Energy Solutions, 445 N. Wells Street, #203, Chicago, IL, 60654

ABSTRACT

Optimizing data center energy efficiency is often overlooked by small to mid-sized data center (typically less than 1 MW) operators, which often leads to higher than normal system operational costs. Even though the majority of data centers range from small server rooms to mid-sized data centers, the aging equipment, oversized cooling system, underutilized space, and a lack of sub-metering systems create bottlenecks to improve operations. In addition, the growing demands for big data deployments are constantly being challenged due to existing data centers' limitations on redundancy, reliability, and flexibility for future expansions.

Utility companies and policy makers have designed, developed and implemented data center energy efficiency incentive programs to resolve this issue over the past several years. However, it is observed that small to mid-sized data centers have a relatively low participation rate in the utility programs when compared to other market segments.

This paper studies healthcare-sector data centers as examples, evaluates the causes and consequences of lower participation to help optimize the data center design and operations. By leveraging successful past experiences in running multiple energy efficiency programs across the country, this paper will analyze unique features of small to mid-sized data centers, but not limited to, system size, typical energy-conservation measures, energy performance benchmarking and discuss guidelines to aid in the decision-making process. This paper presents a sample case for a small to mid-sized data center for a hospital system.

INTRODUCTION

Data centers are tasked with meeting ever-changing demands for data and the sheer volume of data being stored and accessed on-demand is exploding. Many small to mid-sized data centers struggle to meet balancing the requirements of redundancy, power resiliency, flexibility for future expansions, and managing operational efficiency to maintain uptime in their facilities.

Data center operators typically focus on two key factors: business challenges and technology challenges. Business challenges focus on reducing operational expenses, increasing security and compliance, and maintaining a strong 24/7 data center operation. The technology challenges include managing capacity, reliability, and keeping in sync with the ever-changing data center market place.

In addition to navigating business and technological challenges, small to mid-sized data centers often do not have capabilities to optimize their data center operations like large data centers can and are limited when it comes to implementing common data center energy efficiency such as infrastructure consolidation, server virtualization, etc. This paper focuses on addressing the challenges faced by small to mid-sized data centers and presents an approach to optimize energy efficiency in data centers to allow organizations to better manage their data center needs with the lowest total cost of ownership.

SMALL TO MID-SIZED DATA CENTER CASE STUDY - HOSPITAL VERTICAL SECTOR

Hospital data centers are good representatives of small to mid-sized data centers. By leveraging successful experience in multiple states, this article discussed the following four topics, including the hospital data center benchmark, current issues of hospital data centers, two distinct solutions for hospital data centers, and a total cost of ownership model for hospital data centers. The methodologies and findings provided in this article can be applied to other small to mid-sized data centers in different vertical markets.

HOSPITAL DATA CENTER BENCHMARK

There are 5,686 hospitals in the U.S., according to the American Hospital Association (AHA) [1]. Approximately 4,974 of these hospitals can be classified as community hospitals. Almost all these hospitals have data centers due to the increasing demand for patient record storage, CRM, medical applications such as surgeries, research, etc. and to run IT processes. However, limited literature exists to guide small to mid-sized data centers to improve energy efficiency levels. The data center energy consumption for a hospital has often been overlooked. Hospitals generally focus on the systems that directly interact with patients and ignore back-of-house operations and their needs. Due to rising energy costs and sustainability issues with carbon emissions, healthcare system owners across the country are becoming more interested in improving energy efficiency of their existing data center operations.

Methodology

Hospitals vary greatly in size, from small rural facilities to large, tertiary care facilities and academic medical facilities.

The number of beds, among all other variables, is the most critical parameter to evaluate the size of the hospital. The information about the break-out of U.S. hospitals by bed count in 2013, the latest year for which data was publicly available, can be found in the AHA database[2]. Data centers, located in hospitals, also have different sizes varying from small server rooms to mid-sized data centers.

TABLE 1: MIDWEST PROJECTS DATABASE

No. of Beds	Midwest Hospital DC Projects	IT Load	Square Footage
40	A hospital	19	1,630
49	B hospital	11	150
273	C hospital	50	970
302	D hospital	94	2,100
346	E hospital	27	600
346	F hospital	50	2,000
398	G hospital	115	3,000
468	H hospital	150	3,500
638	I hospital	215	7,200
749	G hospital	50	1,520
817	K hospital	215	6,500

The model used in this paper to evaluate energy efficiency is based on the implementation of an energy efficiency program in eleven (11) hospital data centers in the mid-west region. The energy savings potential for hospitals can be estimated as per the following equation:

$$\boldsymbol{S} = \sum_{\boldsymbol{T}} (\boldsymbol{A} \times \boldsymbol{B}) \times (\boldsymbol{PUE_{Baseline}} - \boldsymbol{PUE_{proposed}}) \times \boldsymbol{C}$$

S: Energy savings in kWh
T: Type and size of the hospital based on # of beds
A: Number of hospitals
B: IT load in kW
C: Annual operating hours

IT load and data center square footage can be used to represent data center size and associated power density in terms of W/ft^2. By looking up each hospital's bed information (Table 1) and matching the data with national statistical data, the IT load of the U.S national hospital data center can be estimated (Table 2). Then, by incorporating power usage effectiveness (PUE) and operating hours into the equation, overall saving potential can be approximated.

Baseline Efficiency

Based on Lawrence Berkeley National Laboratory's (LBNL's) 2016 data center report[3], the U.S. national average PUE is 1.8-1.9. Based on the hospital data center size data, the average PUE of U.S. hospital data centers is estimated to be 2.25, which is slightly higher than the national average. This observation can be attributed to various factors outlined in the subsequent sections of this paper.

Proposed Efficiency

Two strategies are provided in this paper in regards to improving current data center operations for small to mid-sized data centers. One involves moving to colocation or cloud providers, as most large colocation or cloud providers are high-end or hyper-scale data centers with an average PUE of 1.2 to 1.7. The other strategy involves implementing energy efficiency projects and keeping the data center facility on-site. On-site data centers have the potential to achieve a PUE level similar to that of high-end or hyper-scale data centers by implementing energy efficiency projects, such as high-efficiency uninterruptible power supply (UPS) upgrade, variable-frequency drive (VFD) upgrade, free cooling upgrades, computer room air conditioning (CRAC) unit upgrades, and air-flow management and containment. It is estimated that the implementation of these measures can reduce the PUE to approximately between 1.4 and 1.5.

Results

Based on the quantitative model, facilitating energy efficiency upgrade projects in U.S national hospital data centers can have an energy savings potential of **1.207 billion kWh per year**.

Illinois Hospital Market Potential as an Example

The top five states with the most hospitals, according to Kaiser Health Facts[4], are: Texas - 426; California - 343; Florida - 210; Pennsylvania - 196; and Illinois - 189. Using the State of Illinois as an example, the annual savings potential calculated by the model for all hospital data centers is 40.13 million kWh. If all 189 hospital data centers improve their energy efficiency within the next four years, there will be 8 million kWh in annual savings (~20%) contributed to the local utility program solely from the hospital sector.

TABLE 2: U.S. HOSPITAL DATA CENTER ENERGY SAVINGS BENCHMARK

	Hospital Size (# of beds)	IT kW Per Room	No. of Community Hospitals	Operat-ing Time %	# of All Hospitals	Total IT kW	Baseline PUE	Proposed PUE	kWh Savings Potential
Closet	6-24	15	469	100%	536	8122	2.5	1.45	74,710,210
	25-49	15	1186	100%	1356	20540	2.5	1.45	188,926,031
	50-99	15	959	100%	1096	16609	2.5	1.45	152,765,653
Localized	100-199	33	995	100%	1137	37052	2	1.45	178,515,272
	200-299	50	571	100%	653	32637	2	1.45	157,243,964
	300-399	72	334	100%	382	27299	2	1.45	131,528,655
Mid-tier	400-499	150	183	100%	209	31379	1.9	1.45	123,697,250
	500+	160	277	100%	317	50696	1.9	1.45	199,842,933
Total			**4974**		**5686**				**1,207,229,966**

CURRENT ISSUES OF HOSPITAL DATA CENTERS

In 2015, New York State Energy Research and Development Authority (NYSERDA) collaborated with the Cadmus Team to examine the data center market in New York State. The healthcare sector was investigated using in-depth surveys. Out of 10 participating hospitals, none managed an enterprise data center, four managed mid-tier data centers, and six managed server room or localized data centers.

Some key findings for the hospital sector from the Cadmus report are[5]:

- Energy efficiency and energy costs are "always" or "often" considered at least 40% of the time.
- Reducing risk, increasing uptime, decreasing operating costs, and increasing security were the "very important" factors in obtaining energy efficiency project approval.
- Energy-efficient UPSs were implemented most frequently (with especially high implementation levels in hospitals) - 80%
- Variable-speed drive upgrades are the most popular cooling measure - 40%
- No computational fluid dynamics or containment was adopted - 0%
- In deciding to implement energy efficiency projects, hospitals tend to use return on investment (ROI) calculations or regulatory standards required for budgetary funding.
- As high as 60%-70% of data center managers did not know their server load (the main component of IT load) in their data centers
- None of the hospital and college/university data center managers and only two financial services data center managers knew their PUE, a most recognized and widely used measurement of how efficiently a data center is designed and operated
- Technical assistance to identify energy efficiency upgrades, utility incentives, tax credits for upgrades, and energy rate discounts for new data centers were selected as the most favorable ways to help data centers to grow in New York State.

The findings in the NYSERDA study align with what we have found in other hospital data center projects across the country. From the 11 hospital data center customers in Midwest, we have observed the following:

Overview

- An average data center has an IT load of 91 kW and a size of 2,652 sq. ft.
- IT load density is low, at only 34 watt/ sq. ft.
- Most facilities have oversize issues due to high-density servers and virtualization deployment.
- Most facilities have aging equipment.
- The IT department handles data center operation by focusing more on IT equipment refresh and reliability than energy efficiency.
- The HIPAA requirement for data security is sometimes overlooked due to the lack of staffing or adequate resources.
- Approximately one-half of hospital data centers have little to very limited redundancy. They often rank at Tier I or Tier II, as defined by Uptime Institute.
- A corporate energy/sustainability manager and a knowledgeable IT operation manager are keys to a successful energy efficiency project implementation.

System Configuration

- Lightly loaded legacy UPS is widely adopted. The efficiency often varies from 62% to 87% at an average load of approximately 30%.
- Direct expansion CRAC units with open return and constant-speed fans are most commonly used for cooling.
- Return temperature set-point is often set between 67ºF to 72ºF
- Few data centers are equipped with constant-speed fans on CRAH units that use chilled water provided by the hospital's central chilled water plant.
- Small server room/closet often have a standalone split AC unit or rooftop DX unit
- Data centers in this size range typically do not have any form of containment. Absence of blanking panels, floor air leakage, and excessive air stream mixing are very common.

Type of Energy Efficiency Projects

- The VFD project ranks as the most popular among all measures; due to the relatively quick return on investment from this type of project.
- UPS upgrade is the second most popular project.
- Installing new CRAC units or AC units with economization is the most efficient way to significantly improve system PUE from ~2.2 to ~1.6 in favorable weather zones.
- Low-hanging fruit measures - such as adjusting temperature set-points, expanding the humidification band, and enabling

the UPS bypass kit when incoming power is in good condition, etc.—can be bundled with capital measures to lower the overall project payback from multiple-measure implementation.

- Disconnect the data center chilled water loop from hospital main chilled water loop. Elevate data center chilled water supply temperature and take advantage of free cooling.

SOLUTIONS FOR HOSPITAL DATA CENTERS

This article provides two distinct solutions for improving data center efficiency: 1) staying on site; and 2) moving to colocation or cloud. In-house data centers are attractive to hospital operators for their easy accessibility and full controllability. Hospital operators can modify their systems on their own terms, to accommodate any shifting needs, including expansion as business scales up. With the right measures, in-house data centers can be operated at a lower cost and at a higher level of redundancy. On the other hand, colocation or cloud is generally ideal for ensuring cybersecurity and scalability. From an energy efficiency standpoint, the colocation or hyper-scale data centers are usually three or four times more efficient than server closets. Also, by handing off the maintenance responsibilities, hospital operators are less likely to experience network outages, since large colocations necessarily have redundant backup systems for network access, electricity and climate control. Each option has its own pros and cons. We highly recommend that hospital operators perform a full evaluation on their system and then decide. A total cost of ownership model is also provided at the end of this paper to guide the decision-making process.

Option 1- Staying On-Site

Keeping the data center easily accessible and having full control over its operations are attractive options to some hospital data center operators. They would prefer keeping the data center on-site. This is true especially when the data center has been built or renovated in the past several years. With knowledgeable operational staffing, newer equipment, a properly sized system and adequate support from the corporate financial department, it is observed that these customers can operate their data centers at lower cost, with better security and with higher levels of redundancy.

It is recommended that the IT department, facility department and financial department work closely with each other to determine the best energy efficiency project that will not only reduce operational costs but also improve critical system reliability. With assistance from the internal corporate energy manager, external consulting firms and utility incentives, customers will be able to successfully implement various energy efficiency projects.

Given below are 10 recommendations for data center operators intending to keep their data centers onsite:

1. Get familiar with potential available utility energy efficiency programs for your site. Utility programs often offer incentives and engineering services for implementing data center projects.
2. Get the corporate energy manager on board if there is one. An energy manager may be able to provide insight and add data center projects into the hospital capital improvement plans.
3. Benchmark the data center. Read the IT load from UPS output and understand the size of the data center. Make an equipment inventory form including make/model number, age, maintenance log, etc. Try to estimate the PUE based on the IT load and the metered data center total energy usage. This will help you understand the savings potential and determine if it is wise to keep the data center onsite.
4. Optimize the air flow. Adding blanking panels and sealing the floor air leakages are relatively easy to implement by trained in-house staff. These will increase cooling system efficiency by reducing excessive air mixing.
5. Watch your set-points. If your data center is still set at 67F return on CRAC units, consider progressively increasing the temperature set-points to the ASHRAE TC 9.9 recommendation[6].Make sure you increase the set-point one degree per week and watch the server inlet T using thermostats to make sure it is below 80F.
6. Evaluate your UPS system. Replacing the aging and lightly loaded UPS with smaller, modern UPS often yields a significant amount of energy savings. It is often observed that the UPS efficiency can increase from 65% to 92% by replacing old, inefficient UPS modules.
7. Retrofit constant-speed fans inside the CRAC or CRAH units with VFDs. Reducing fan speed by 20% will generate approximately 50% fan kW savings based on affinity laws. Most manufacturers have standard upgrade kits for VFDs; it is an easy upgrade that can be completed within 3 weeks and often has an average payback of less than 3 years.
8. Consider free-cooling CRAC units when purchasing new cooling units. Free-cooling units in the market use airside, glycol or pumped refrigerant cooling. With free cooling, the compressor usage is lowered. The payback for the incremental cost is often less than one or two years if the data center is in favorable climate zones, such as Seattle, Chicago, New York, San Francisco etc.
9. Watch the humidification set-points. A lot of customers are not aware that, when they are setting the humidification bands between 50% RH to 55% RH, they contribute to excessive mechanical system energy usage. Without proper sensors and set-points, cooling units fight with each other to maintain the set-point. Consider progressively widening the allowable humidity range as per the ASHRAE TC 9.9 recommendations[7]. Enable dew point control if the system is capable of it.
10. Leverage other resources. If the data center uses chilled water from the hospital central plant, please consult a professional energy engineer or consulting firm to develop the most cost-effective solution that meets the data center needs.

A Successful Case Study

A hospital in the Midwest successfully implemented four energy efficiency projects in their data center over the past three years. The mid-sized data center is approximately 6,500 sq.ft., with an IT load of approximately 215kW.

The data center has a total of ten (10) DX system based CRAC units with eight units in the data room with 22 tons of total cooling capacity from each unit. Two of the remaining CRAC units in the UPS room have a total cooling capacity of approximately 15 tons each. Two 500 kVA UPS modules support the server room and one 60 kVA UPS supports the communication room. Four energy-conservation measures have been implemented step by step in the past three years, which yielded higher system efficiency and greater system resilience.

Step 1: Added redundancy to the data center by installing one high-efficiency, 500 kVA UPS module, in addition to the existing standard-efficiency 500 kVA UPS. The IT load has been split between the two units. This project helps increase system redundancy and reliability; in the meantime, modern UPS is able to run at higher efficiency, even with a 50% load. The new UPS ran at 90.7% efficiency compared to 85% efficiency as the baseline for the standard efficiency UPS module. Compared with installing a standard-efficiency UPS, this project provided 59,486 kWh in annual energy savings, with a simple incremental payback of approximately six years.

Step 2: Replaced a small 60 kVA, end-of-life UPS in a communications room with a new, high-efficiency UPS. New units ran at 96% efficiency at 56% load compared to old UPS running at 91% efficiency. Compared with installing a standard-efficiency UPS, the project gave the customer 23,871kWh annual savings, with a simple incremental payback of 3.9 years.

Step 3: Implemented VFD retrofits on existing CRAC units to lower the fan speed from an average of 100% to 79.4%. Customer also added rack sensors and changed their set-point in the data room from 72-degree Fahrenheit (ºF) dry-bulb return temperature to 71ºF supply temperature. Compressors ran less hard after this adjustment. The project yielded 320,606 kWh annual energy savings, with a simple payback of approximately 2.7 years.

Step 4: Installed ducted return air plenum for CRAC units. This prevents mixing of cold supply air with the warm return air, which gives customer ability to further increase supply temperature set-point. In addition, CRAC unit can operate more efficiently and have an increased capacity by receiving the warmer temperature air. Upon completion, customer further increased their supply air temperature set-point from 71ºF to 72ºF ~ 75ºF. The new temperature set-point compiles with the ASHRAE T.C. 9.9 guideline. Final measurement and verification shows that CRAC units are running more efficiently after the project. The project yielded 77,413 kWh annual energy savings, with a simple payback of approximately 5.5 years.

These four projects combined yielded approximately half a million kWh savings, with an overall simple payback of 3.5 years. Utility incentives played a significant role in gaining approval for these projects. Through all these efforts, the hospital increased its asset value, improved energy efficiency, lowered its operational costs, and improved resiliency/redundancy of its critical infrastructure.

Option 2- Moving to Colocation or Cloud

Operating a data center efficiently and reliably is not always a major focus for small to mid-sized data centers. For this and various other reasons, many hospital data center operators are considering moving their data center operations into a colocation facility.

Moving to colocation and paying monthly fees is often more cost effective than making significant capital investments to build an on-site data center and subsequently paying high electricity bills. This typically happens when a new data center is to be built or an existing one is at the end of its useful life, requiring a major capital-intensive system upgrade to continue data center operations. High electricity bills can also be due to aging and inefficient equipment, requiring excessive maintenance to keep it operational.

When moving into a colocation facility, the existing data center space can be converted to some other use such as adding more patient beds, diagnostic centers, etc. An oversized data center can have more than 5,000 sq.ft. of white space with additional spaces for a UPS room, a battery room, an IT operation room and a loading/receiving dock. If the hospital does not have more land to expand and wants to add more beds, the data center can be moved into a colocation facility, and the space can be used for other revenue-generating purposes.

Colocations generally provide better cybersecurity. The more recent HIPAA Security Rules add additional cybersecurity compliance requirements for PHI through administrative, technical, and physical safeguards[8]. Operating the data center at a colocation will reduce risk of potential attacks and fines.

Colocation also provides better scalability, which is hard to achieve through a self-built data center. With the dynamic environment of new server and virtualization technology, it is more and more complicated to properly size a data center. For hospitals unsure of how their business will expand or contract in the next 10 years, it is more reasonable to operate the data center from a colocation facility instead of building the infrastructure and recruiting a team to operate the data center on-site.

Some utilities are providing incentives to help customers move from on-site data centers to colocations. It is very beneficial from a societal benefits perspective because colocation facilities typically have a PUE of approximately 1.45, while the on-site server rooms or server closets usually have a PUE of approximately 2.5. Moving to the cloud will have an even potential for higher savings due to the ultra-low PUE for a hyper-scale cloud data center. Based on a study by LBNL and Northwestern University, the savings potential of running cloud-based software is approximately 87% of operating data centers locally. That is mainly because a cloud-computing data center is much more efficient than localized data centers [9].

A GLANCE AT THE TOTAL COST OF OWNERSHIP MODEL

We built a comprehensive total cost of ownership model to aid hospital customers in the decision-making process as it relates to keeping the data center on-site or moving it to a colocation facility.

$$\boldsymbol{TCO = f(A, B, C, D, E, F)}$$

A: Annual IT Hardware Cost
B: Annual Hardware Maintenance Cost
C: Annual Colo Expense with Incentive
D: Annual Administration Cost
E: Annual Utility Cost
F: Annual Data Center Construction Cost

Equations for each component are shown below:

$$Annual\ IT\ Hardware\ Cost = \left(A \times \frac{B}{EUL}\right) \times (1 + C)$$

A: Total Number of Standard Small Servers
B: Cost Per Server
EUL: Server and Network Device Useful Life
C: Network Hardware Cost Factor

$$Annual\ Hardware\ Maintenance\ Cost = A \times B$$

A: Annual IT Hardware Cost
B: Network Maintenance Cost Factor

$$\begin{aligned} Annual\ Colo\ Expense\ with\ Incentive & \\ &= NRC + MRC + MRS \\ &- Annual\ Utility\ Incenitves \end{aligned}$$

NRC: Colo Non-Recurring Cost
MRC: Colo Monthly Recurring Cost
MRS: Colo Monthly Recurring Cost Service

$$NRC = B \times \frac{C}{EUL}$$
$$MRC = A \times D \times 12$$
$$MRS = B \times E \times 12$$

A: Total IT Load kW
B: Total Number of Racks
C: Initial Colo Setup Fee Per Rack
D: Monthly Co-Lo Fee (Per Kw)
E: Monthly Co-Lo Service Fee (Per Rack)
EUL: Useful Life

$$Annual\ Utility\ Incenitves = A \times (B - C) \times 8760 \times \frac{D}{EUL}$$

A: Total IT Load kW
B: Baseline PUE
C: Proposed PUE
D: Utility Incentive Rate $/kWh
EUL: Useful Life

$$Annual\ Administration\ Cost = \frac{A}{B} \times C \times D$$

A: Total Number of Standard Small Servers
B: Servers per FTE
C: Annual Salary per FTE
D: Overhead Multiplier

$$Annual\ Utility\ Cost = A \times B \times 8760 \times C$$

A: Total IT Load kW
B: Bassline PUE
C: Electricity Price $/kWh

$$Annual\ \ Construction\ Cost = A \times \frac{B}{EUL}$$

A: Total IT Load kW
B: Data Center Non-IT Cost $/kW
EUL: Construction Useful Life

An example of applying the model: 100 kW IT load in a hospital data center, with approximately 5 kW per rack. We ran the model and analyzed the results. Key assumptions are included in the Appendix.

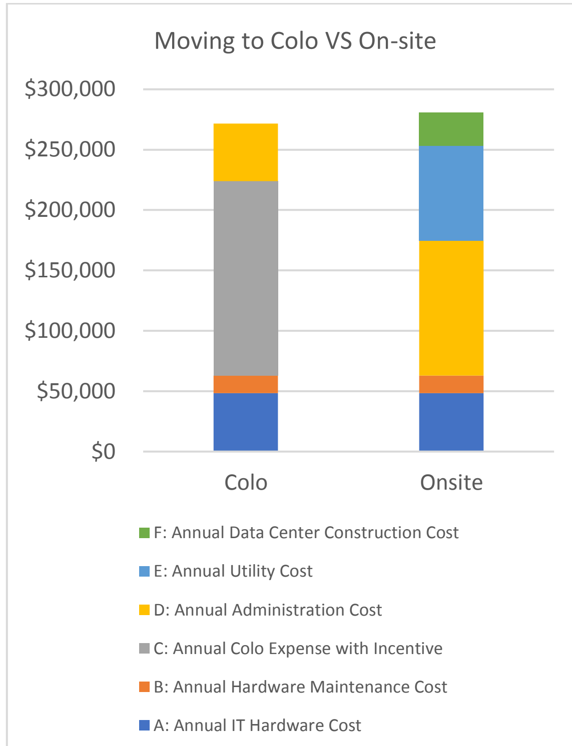

FIGURE 1: TCO MODEL FOR A 100KW HOSPITAL DATA CENTER

In this model, it is observed that moving the data center into a colocation facility is more cost effective than operating the data center on-site. Moving the data center into a colocation facility results in $83,669 in annual cost reductions, compared to keeping the data center on-site.

Limitation of the model

The model does not account for the location of the data center, constraints of the existing data center system and the corporate business plan. The electricity cost, incentive rate, construction cost and administration cost may also vary, depending on different hospital data centers. This model is intended to provide guidance on factors that decision-makers can consider when comparing two options. It is recommended that hospital operators use this model and enter their own assumptions, based on actual data.

SUMMARY AND CONCLUSIONS

Optimizing data center energy efficiency is often overlooked by small to mid-sized data centers; however, the national energy saving potential for small to mid-sized data centers is significant. Using hospital data centers as an example, it is estimated that facilitating energy efficiency upgrade projects in U.S national hospital data centers can have an energy savings potential of 1.207 billion kWh per year.

By comparing the market research performed in the New York State Energy Research and Development Authority (NYSERDA) territory with eleven (11) real projects implemented in the Midwest, we found several common issues such as aging equipment, constrained staffing, low participation and lack of energy management knowledge, etc. to be contributing factors. We also summarized the common system configurations and types of energy efficiency projects for decision makers to use as a reference.

With most of the issues identified, this article provided two distinct solutions to help hospital data center operators, who are considering keeping their data center on site or moving their data center to a colocation facility or cloud-based platform. Pros and cons were analyzed for both options. At the end of the article, we built a quantitative total cost of ownership model to help hospital operators make better decisions whether they should move to colocations or not.

We hope that this article can serve as the foundation for the development of best practices when analyzing the small to mid-sized data center market and can be used as a tool in the adoption of cases in various market sectors; and to generate ideas.

APPENDIX

TCO Model Key Assumptions:

- Average IT Density - 5kW per Rack
- Cost Per Volume Small Server - $333
- Server and Network Device Useful Life - 3 years
- Network Hardware Cost - 20% of Initial Server Hardware Cost
- Annual Maintenance Cost - 10% of Initial Server and Hardware Cost
- Initial Colo Setup Fee Per Rack - $1,200
- Monthly Co-Lo Fee (Per Kw) - $228
- Monthly Co-Lo Service Fee (Per Rack) - $200
- Data Center Useful Life - 20
- Baseline PUE - Varies from 1.9 to 2.5
- Proposed PUE - Varies from 1.3 to 1.7
- Utility Incentive Rate $/kWh - $0.05/Annual kWh Savings
- Servers Labor per FTE - 1,200 for Colo and 300 for On-site
- Annual Salary per FTE - $66,985
- Salary Overhead Multiplier - 1.5
- Electricity Price $/kWh - $0.09/kWh including transmission
- Data Center Non-IT Cost $/kW - $11,000/kW

Please note that the above assumptions were identified based on vendor information, literature, RS Means 2016 and Willdan's project database. Different data centers may vary.

AUTHORS' BIOS

Jiaqi Liang, P.E., CEM, CMVP

Jiaqi Liang is a Senior Engineer at Willdan Energy Solutions. Mr. Liang is currently leading the Midwest engineering team in running three data center energy efficiency programs in multiple states, delivering 60 plus million kWh savings annually. Mr. Liang has overseen more than 200 data center energy efficiency projects and audits, as well as managed program evaluation and tool development. Mr. Liang has also developed models and published papers for Google Inc. and the Environmental Protection Agency (EPA), addressing cloud computing energy efficiency.

Mr. Liang holds a Master of Science (M.S.) degree in mechanical engineering from the Northwestern University, and a Bachelor of Science (B.S.) degree in mechanical engineering from Zhejiang University.

Shrenik Ajmera, PE, PMP, CEM, LEED AP, EBCP

Shrenik Ajmera is an Engineering Manager at Willdan Energy Solutions. Mr. Ajmera has led the development of design solutions for various multi-million-dollar data center expansion, retrofit, and expansion projects across the nation. Mr. Ajmera has also completed several surveys, feasibility studies, and energy assessments to help customers mitigate risks, improve infrastructure reliability, and increase operational efficiency.

Mr. Ajmera holds a Master of Science (M.S.) degree in mechanical engineering from the University of Illinois at Urbana-Champaign, and a Bachelor of Science (B.S.) degree in mechanical engineering from Virginia Tech.

Tejas Desai, PE, CEM, LEED AP, CDSM, CEA, EBCP

Tejas Desai is an Engineering Program Director at Willdan Energy Solutions. As a key member of Willdan's data center team, Mr. Desai has successfully completed numerous data center energy efficiency projects related to IT energy efficiency, server/desktop virtualization, variable-speed drives for fans/pumps, air-flow management, set-point adjustments, economizers and many others.

Mr. Desai holds a Master of Science (M.S.) degree in mechanical engineering from the Illinois Institute of Technology (IIT), and a Bachelor of Engineering (B.E.) degree in mechanical engineering from Maharaja Sayajirao University, India. Mr. Desai is also an active member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), as well as the Association of Energy Engineers (AEE).

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