Federal Energy Management Program

Carl T. Hayden Veterans Affairs Medical Center: Smart Buildings Case Study

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Disclaimer

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List of Acronyms

AHU	air handler unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	building automation system
ECM	energy conservation measure
GEB	grid-interactive efficient building
HVAC	heating, ventilation, and air conditioning
PV	photovoltaic
VA	U.S. Department of Veterans Affairs
VAV	variable air volume

Executive Summary

Demand flexibility can play an important role in helping maintain grid reliability, improving energy affordability, and integrating a variety of generation sources. New and existing grid-interactive efficient building (GEB) technologies and strategies can be implemented to create smart buildings—buildings that use sensors and controls to manage peak demand and electricity loads. These smart buildings provide an opportunity to reduce electricity consumption in the building sector during peak periods and lead to substantial utility bill savings for building owners.

The purpose of this smart buildings case study is to showcase a leading example of a GEB renovation project in the federal buildings space and provide key information on the technology and control upgrades, costs, and energy and utility bill savings. This case study also provides information and recommendations for selecting energy conservation measures (ECMs) and choosing energy and cost reduction strategies from the energy management team at the site. The findings from this successful GEB project can be used to help pave the way for additional GEB retrofits in the future.

The Carl T. Hayden Veterans Affairs (VA) Medical Center in Phoenix, Arizona, demonstrates that GEB strategies and technologies can be realistically deployed today across buildings with substantial energy and cost savings. The project implemented both ECMs and grid-interactive technologies and controls strategies, making it a leading example of a smart, sustainable, and efficient commercial building. Ultimately, these ECM retrofits helped the medical center achieve over 25% energy savings and an ENERGY STAR® rating of 99, making it one of the most energy-efficient medical centers in the United States. This case study highlights the challenges and the lessons learned throughout the project development and implementation, in addition to some of the best practices for project management, operations, load shifting and peak management, and heating, ventilation, and air-conditioning (HVAC) system management.

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1 Introduction

Growing peak electricity demand, transmission and distribution infrastructure constraints, and an increasing share of variable renewable electricity generation are challenging the electrical grid. As the grid becomes increasingly complex, demand flexibility can play an important role in helping maintain grid reliability, improving energy affordability, and integrating a variety of generation sources. Smart buildings or grid-interactive efficient buildings (GEBs)—buildings that use sensors and controls to manage peak demand and shift electricity loads—can provide flexibility to the grid by reducing energy waste, helping balance energy use during times of peak demand and/or plentiful renewable generation, and reducing the risk of utility disruptions, as shown in Figure 1 (Neukomm, Nubbe, and Fares 2019).

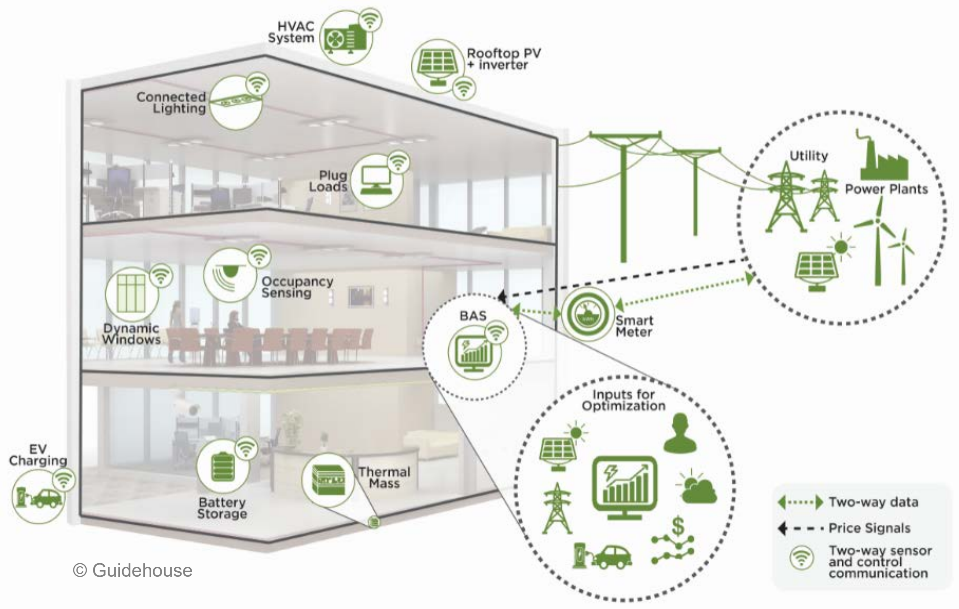


Figure 1. Commercial GEB or smart building

Source: Guidehouse Consulting

Buildings, especially large commercial facilities, offer a unique opportunity for cost-effective demand-side management because buildings are the nation's primary users of electricity: 75% of all U.S. electricity is consumed within buildings, and, perhaps more importantly, building energy use drives a comparable share of peak power demand. The electricity demand from buildings results from a variety of electrical loads that are operated to serve the needs of occupants. However, many of these loads are flexible to some degree; with proper communications and controls, loads can be managed to draw electricity at specific times and at different levels, while still meeting occupant productivity and comfort requirements (Building Technologies Office 2020). New and existing GEB technologies can be implemented to create smart buildings that provide an opportunity to reduce electricity consumption in the building sector.

The purpose of this case study is to showcase a leading example of a GEB or smart building renovation project in the federal buildings space and provide key information on the energy savings and demand response strategies and benefits. The findings from this successful GEB project can be used to help pave the way for additional GEB retrofits in the future. The Carl T. Hayden Veterans Affairs (VA) Medical Center in Phoenix, Arizona, demonstrates that GEB-ready strategies and technologies can be realistically deployed today and lead to substantial energy and utility bill savings. The project involved multiple retrofits and operational changes, which led to a reduction in energy consumption of 25%. The VA Medical Center was able to achieve significant utility bill savings from shifting energy loads to reduce peak demand for the site and avoiding demand charges. This case study highlights the key successes of the project as well as the challenges and the lessons learned throughout the project development and operations. All information in this report was gathered directly from conversations and materials with the key project leaders involved in this building renovation project.

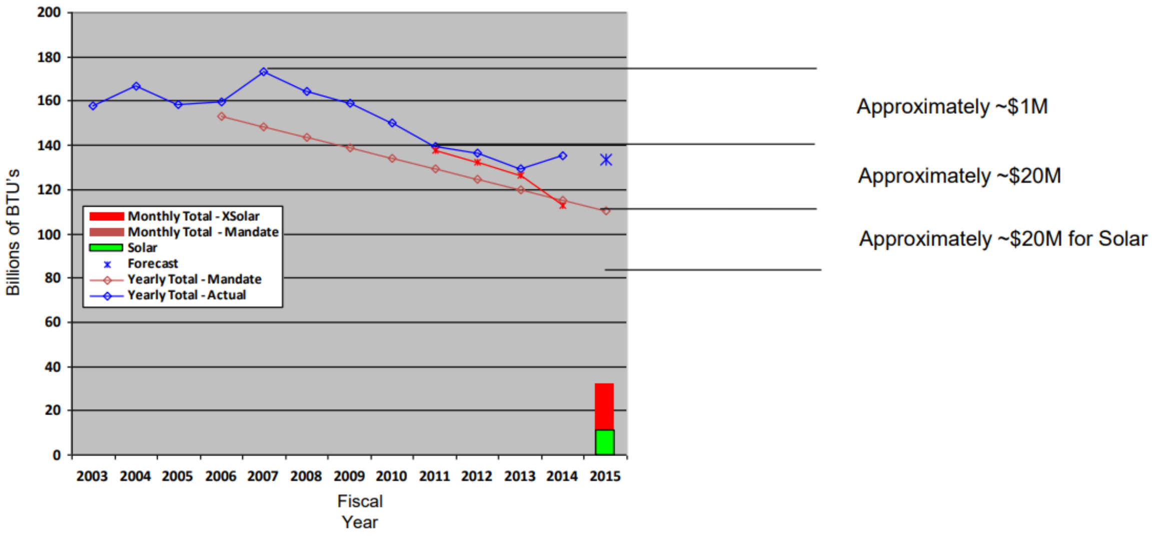
2 Project Overview

The Carl T. Hayden VA Medical Center (Figure 2) in Phoenix, Arizona, is a 279-bed medical facility in a campus of 25 buildings and has a total floor area of approximately 850,000 square feet. It was originally built in 1975, and the recent renovations occurred between 2007 and 2015. There are a total of 2,500 employees serving 80,000 veterans. The goal of this retrofit project was to reduce energy consumption and improve operations to meet federal energy mandates. The federal energy reduction mandates from the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, and Executive Order 13423 require a 30% reduction in energy use and a 16% reduction in water usage. In response, the medical center energy management team deployed various energy conservation measures (ECMs) and strategies over the course of 8 years to drastically reduce energy consumption and shift energy loads to reduce peak demand periods.

Figure 2. Carl T. Hayden VA Medical Center in Phoenix, Arizona

Source: U.S. Department of Veterans Affairs

As shown in Figure 3, the medical center decreased its energy usage by approximately 25% using trivial expenditures, including controls and operational strategies, load shifting, and solar energy. In 2007, the medical center consumed 204 kilo British Thermal Units (kBtu) per square feet of floorspace (kBtu/sq. ft.) of energy, reducing to 157 kBtu/sq. ft. in 2014. Over the 8-year period, upgrades totaling approximately $41 million provided annual utility bill savings of over $260,000 in 2014 compared to 2007, despite a 40% increase in electrical rates during this period. Electricity consumption decreased by 12.5% from 2007 to 2010 but spending on electricity increased 10% during this time because of substantial rate increases. In 2018, the medical center achieved an ENERGY STAR rating of 99, making it one of the most energy-efficient medical centers in the United States.



Approximately ~$1M

Approximately ~$20M

Approximately ~$20M for Solar

Figure 3. Carl T. Hayden VA Medical Center Btu usage (2003–2015) and spending

Source: James Larson; Energy Symposium Presentation (May 2015), Monterey, California.

3 ECMs Selection Process

3.1 Understanding Energy Usage and Utility Charges

The project began with the goal of 30% reduction in total energy use to achieve federal mandates, without knowing how this would be achieved. The first step was understanding current energy usage and utility charges at the site. Initially, the project did not consider any grid-interactive strategies but instead looked for ways to optimize energy savings and utility bills savings.

Before selecting technologies for retrofits, the medical center energy management team collected data to understand the hourly, monthly, and daily load profiles of the facilities. This analysis looked further at the split between electricity and gas, as well as the variation by season over the 12-year period of 2003–2014 (Figure 4). This showed that in 2008, the facility used about 45% gas and 55% electricity, which was a nearly even split. The analysis also showed that energy use varied greatly by season, with the greatest peak for electricity in the summer months and a smaller peak for gas in the winter months.

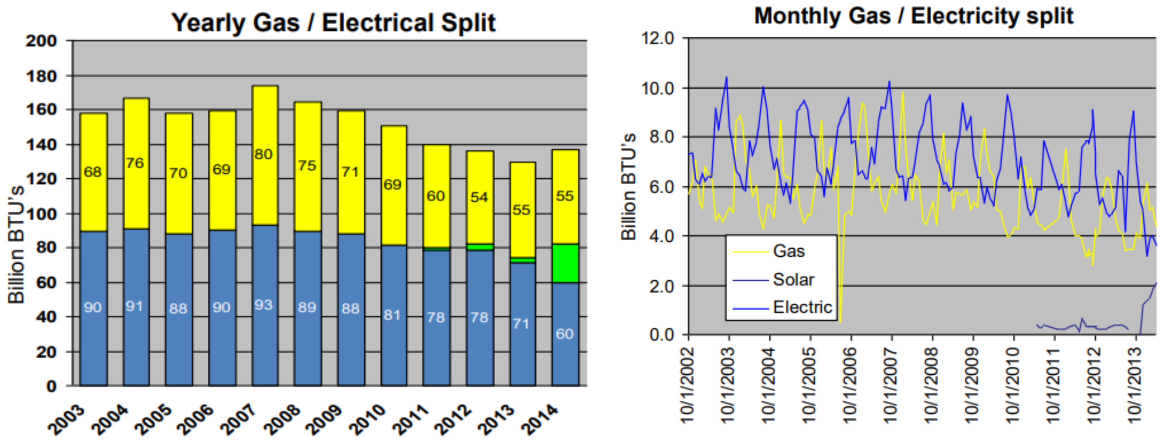


Figure 4. Electricity and gas energy consumption from 2003–2014

Source: James Larson; Energy Symposium Presentation (May 2015), Monterey, CA.

In addition, the team analyzed utility bills to better understand rate differences from peak to off-peak periods and the demand charges for their site. A key finding in this analysis was that the cost of energy and energy usage is not directly linked because of the utility's substantial demand and demand ratchet charges. A demand ratchet charge is imposed on large commercial facilities who get billed based on the highest kilowatt (kW) of demand that the site had for a set time period for the entire year, or a portion of the highest demand. As an example from Pacific Northwest National Laboratory, "If your facility experiences a peak demand of 1,000 kW for one hour (or 15-minute interval) you will be billed for a minimum of 800 kW during the next 11 months, even if your actual demand is much lower" (Pacific Northwest National Laboratory n.d.). For reference, a similar VA medical facility in Arizona consumed an additional $350 worth of electricity during their annual peak demand period in 2008, which added $2,500 to the utility bill due to a demand charge from the facility. However, if the facility had ratchet charges, they would have paid 80% of that peak demand over the entire year, which would have added $24,500 to the bill over the year.

3.2 Selecting ECMs

The next step was to understand energy usage by equipment in the facilities. Figure 5 shows the breakdown of energy usage as a percentage of the total for the major equipment at the medical center in 2008. This analysis showed that the boilers, chillers, and laundry equipment for the site accounted for 64% of all campus Btu energy consumption in 2008, with 43% from boiler, 18% from chillers, and 5% from laundry equipment. This also showed that heating equipment accounted for about 2.5 times as many Btus vs. cooling equipment. The “all else” category includes lighting, computer, office equipment, medical equipment, and refrigerators, among others.

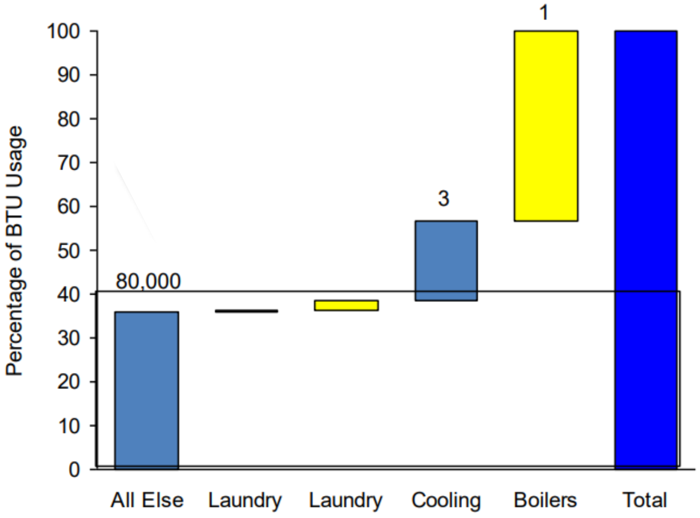


Figure 5. Energy reduction by equipment in 2008 and 2013 as percentage of Btu usage

Source: James Larson; Energy Symposium Presentation (May 2015), Monterey, California

A key strategy of this project was to focus reducing the energy usage on these three “critical few” energy loads, as opposed to the “non-trivial many.” In other words, it is a more effective use of time and resources to maximize the efficiency of the constraint, or in this case the largest loads, rather than the many smaller loads. Focusing energy reduction measures and strategies on these three critical energy loads (boilers, chillers, and laundry) allowed them to achieve a 29% reduction from 2008 to 2013.

3.3 Choosing Energy and Cost Reduction Strategies

The energy management team analyzed and applied four energy and cost reduction strategies to achieve the overall energy and utility bill savings during the project period of 2008–2015. They looked at both how to lower and manipulate the energy demand at the site and how to increase their energy supply and change utility rate structures.

1. **Demand reduction**: The first step was to focus on how to use less energy and how to operate equipment more efficiently to ensure energy is not wasted. As mentioned previously, the focus was on demand reduction for boilers, chillers, and laundry equipment.
2. **Production cost alternatives**: The second step was to look further into the utility rate structures and the energy use to understand how money could be saved with alternative utility rate structures. The site was able to save on utility bills by using and optimizing energy use with time-of-use utility rate structures and avoiding high-demand ratchet charges.
3. **Demand manipulation**: Then, the site used load shifting and peak management strategies with a building automation system (BAS) to align to off-peak pricing periods and reduce their highest-demand periods to avoid ratchet charges.
4. **Energy production alternatives:** Finally, the owners looked at energy generation opportunities on-site to lower utility energy use. The owners invested $20 million in a 4.4-megawatt (MW) solar photovoltaic (PV) array above their parking lot, which generated 6.6 million kilowatt-hours (kWh) of energy in 2014.

4 Technology and Strategy Upgrades

4.1 ECMs and GEB Strategies

The energy management team selected the ECMs and GEB strategies over the 8-year period, as shown in Table 1. In total, these upgrades cost $41 million. A battery energy storage system was also considered but was not found to be cost-effective. The owners did not use any utility incentives, government grants, or tax credits to fund these upgrades and ECMs.

These ECM and GEB technologies and strategies contribute in one or more of the following ways to increasing grid interactivity:

- **Energy efficiency**: The ongoing reduction in energy use while providing the same or improved level of building function.
- **Load shed**: The ability to reduce electricity use for a short period of time and typically on short notice. Shedding is typically dispatched during peak demand periods and during emergencies.
- **Load shift**: The ability to change the timing of electricity use. In some situations, a shift may lead to changing the amount of electricity that is consumed.

In addition, the 4.4-MW PV array system, shown in Figure 6, also provides increased resiliency to power outages and substantial utility bill savings through demand reduction via on-site generation.

Figure 6. 4.4-MW solar array at Carl T. Hayden VA Medical Center

Source: James Larson; Energy Symposium Presentation (May 2015), Monterey, California.

Table 1. ECMs Deployed in Carl T. Hayden VA Medical Center

ECM	Description	Key Benefits
PV Array	Added a 4.4-MW PV array covering parking lots to capture solar energy. This array can supply 28% of the medical center's power needs and will displace 9.3 million pounds of greenhouse gas emissions per year. The power generated is fed directly to the hospital's power distribution system so the utility electricity demand is lowered, and the energy bills costs are reduced. The total cost of the PV array system was $20 million (*EnerG Magazine* 2013).	Generation Resiliency
Chilled Water Tank	Installed a 1.5-million-gallon chilled water tank (Larson 2017). The chilled water tank is used as thermal energy storage to allow for load shifting and peak management.	Efficiency Load shifting Load shed
Hot Water Boilers	Converted the heating and domestic hot water from steam (operate at about 10%–20% system efficiency) to condensing hot water boilers, which operate at a system efficiency of 70%–80% overall (Avis 2018).	Efficiency
Advanced Direct Digital Controls for Air Handler Units (AHUs)	Utilizing advanced direct digital control strategies on airside economizers for air conditioning contributed to approximately 45% reduction in air-conditioning electricity consumption between 2008 and 2013 (Larson 2017). Chilled water system can be used to "preheat" incoming air from AHUs when the temperature outside is below 55°F because the chilled water temperature remains around 60°F. Using chilled water coils for heating allows the medical center to provide up to 50% of the heating requirement during cold weather from the chilled water system (Larson 2017).	Efficiency Load shifting
Convert Constant Volume 100% Outside Air Systems to Variable Air Volume (VAV) return systems	Converting to a VAV system from a constant volume system saved over 20% of cooling system energy. VAV systems are much better suited for medical center needs because they can meet the heating or cooling needs of different building zones using flow control (Pacific Northwest National Laboratory 2021). They also lead to increased occupant comfort.	Efficiency Increased comfort
BAS and Data Management	Utilized an upgraded BAS and advanced data management system to deploy peak management and load shifting strategies with their HVAC systems (chillers, boilers, and AHUs) and PV system. They also built intuitive data display interfaces to manage energy data and ensure energy efficiency and peak reduction strategies were tracked closely.	Efficiency Load shifting

4.2 Time-of-Use and Peak Management Strategies

The key demand response strategy utilized by the medical facility team is to align energy use with their time of use electricity rate structure and reduce peak load periods as much as possible. They utilized the BAS to maintain a 3 MW energy use during peak periods to avoid demand charges. They relied primarily on the chiller system (thermal storage) and solar PV system to shed loads during peak periods and shift loads to off-peak periods. A key component of being able to manage peak loads effectively is understanding and tracking energy load profiles to the hour and 15-min intervals daily.

Figure 7 shows an example of the medical center's load profile for a high-energy-use day in August 2010. The purple dotted line shows the baseline energy use that the site would consume with no load shifting or solar energy, and the solid blue line shows the final energy use of the site with solar PV generation and load shifting from the chilled water tank. The red highlighted area, from 4–9 p.m., shows a baseline peak of 4.1 MW and a total consumption of 7,075 kWh. The energy consumption costs would be $318 for this day, but because of the high demand charges, an additional $25,800 would be added to the bill for the month, and $285,000 would be added to the bill for the year. Through load shifting and shedding strategies and using the solar energy generated on site, they were able to reduce these peak periods and avoid high ratchet charges, which saved them around $310,000 for this year.

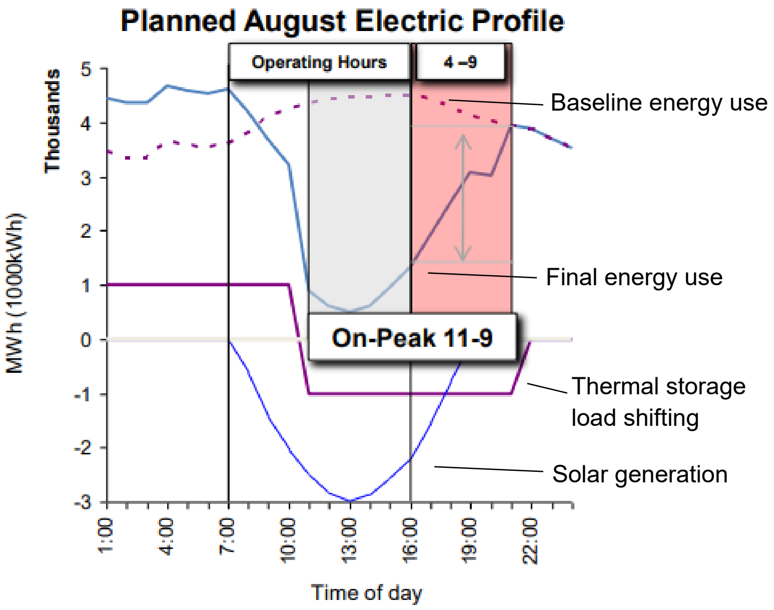


Figure 7. Example load profile for medical center in August 2010

Source: James Larson; Energy Symposium Presentation (May 2015), Monterey, California.

4.3 Energy Savings by Upgrades

The key energy efficiency measures utilized in this project were the installation of a chilled water tank, which was used as thermal storage, converting the steam boilers to low-temperature hot water boilers, and converting the constant volume 100% outside air systems to VAV return systems. In addition, the HVAC systems were optimized through the BAS and data management upgrades. These upgrades costs around $20 million and were the key measures in achieving the 25% overall energy reduction for the medical center. As shown in Figure 8, these three measures achieved a cooling energy reduction of 45% and a heating energy reduction of 27% from 2008 to 2013, leading to overall energy savings of 29%.

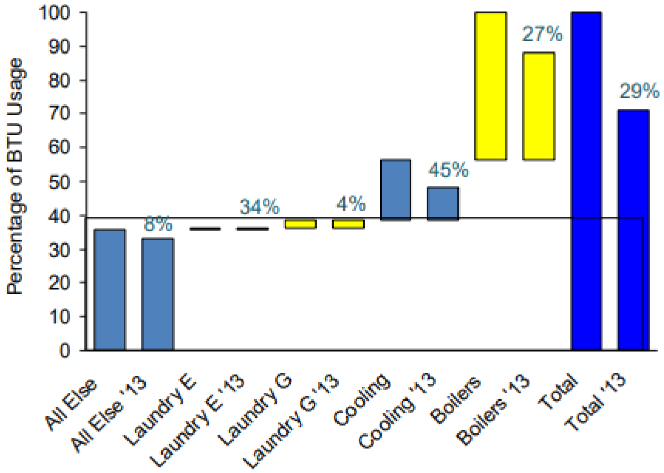


Figure 8. Total energy usage by equipment as percentage of Btu usage

Source: James Larson; Energy Symposium Presentation (May 2015), Monterey, California.

5 Challenges and Lessons Learned

Though this retrofit project was ultimately successful in achieving the energy and cost savings goals and an ENERGY STAR rating of 99, the project development and implementation process faced several challenges. The following list summarizes some the key challenges faced during the retrofit and operations of the site over the 8-year period, as described by the energy management team.

The energy management team needed to complete retrofits without impacting hospital operations or patients care. The top priority of the medical center is to ensure the patients always receive the top care. The building renovations thus needed to be done strategically to ensure the hospital could continue running as normal and no patients were affected by the upgrades. For example, the PV array installed in the parking lot was designed to ensure no parking spaces were eliminated and that parking spaces were not taken up by construction equipment during installation. The contractor team also did much of the installation work at night and made efforts to coordinate with the operations team at the hospital. In addition, the VAV boxes and air handlers were replaced during this renovation project. The contractors completed these retrofits by doing three rooms at a time and working closely with the nurses and hospital staff members to ensure they were not disrupting operations or patients.

The energy management team needed to ensure demand response does not interfere with hospital operations or patients care. Once the new ECMs were deployed, it was also imperative that any strategies to save energy or reduce peak demand did not impact the health or comfort of any patients, and preferably improved patient conditions. Shifting loads through thermal energy storage (chilled water tanks) and on-site generation (PV array) allowed the medical center to manipulate peak demand and shift loads to off-peak periods without impacting the building’s energy operations.

The energy management team had significant challenges with the project team, including the contractors and designers. Ultimately, the energy management team learned they needed a high level of oversight for contractors and designers to ensure they were designing, installing, and commissioning the equipment correctly and per the contract. They also emphasized that challenges could have been avoided by more closely following the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) handbooks. For example, the chilled water plant installation faced substantial challenges because the designer did not complete the required chilled water design study prior to tying the new building into the chilled water loop. This ended up leading to unnecessary additional utility expenses as the chilled water tank ultimately failed to reach the contractual performance requirements. The team also learned that contractors should not receive payment until they have demonstrated that the installation and performance of the equipment meets the contract requirements.

6 Best Practices

As a result of the successes, challenges, and lessons learned of this retrofit project, the energy management team at the medical center put together the following recommended list of best practices. The best practices are intended for other federal facilities or similar medical centers interested in or currently working on energy retrofit projects to achieve energy, cost, and/or sustainability goals. The recommendations and best practices are categorized by project development and management, operations, load shifting and peak management, and HVAC management.

6.1 Project Development and Management

When selecting ECMs, understand the difference between the critical few and non-trivial many. For the medical center, boilers, chillers, and laundry accounted for 64% of total energy Btu consumption. Focusing energy conservation and strategies on reducing these loads was a key strategy in reducing the facility energy consumption by 25%.

Utilize the ASHRAE handbooks as much as possible and ensure contractors are using it. The medical center followed the ASHRAE handbook for the thermal storage and control sequences. They cited this as a key reason for success of the project.

When selecting technologies, look at more benefits than just energy savings. Shifting and reducing the demand during a building's peak periods can lead to higher utility bill savings. In addition, many of the upgrades provided increased comfort to patients and increased the resiliency of the site overall. At the medical center, the PV array provided covered parking to patients and employees as well as substantial energy generation for the facilities. The VAV boxes also provided increased comfort to patients by allowing for more accurate zone-level temperature controls.

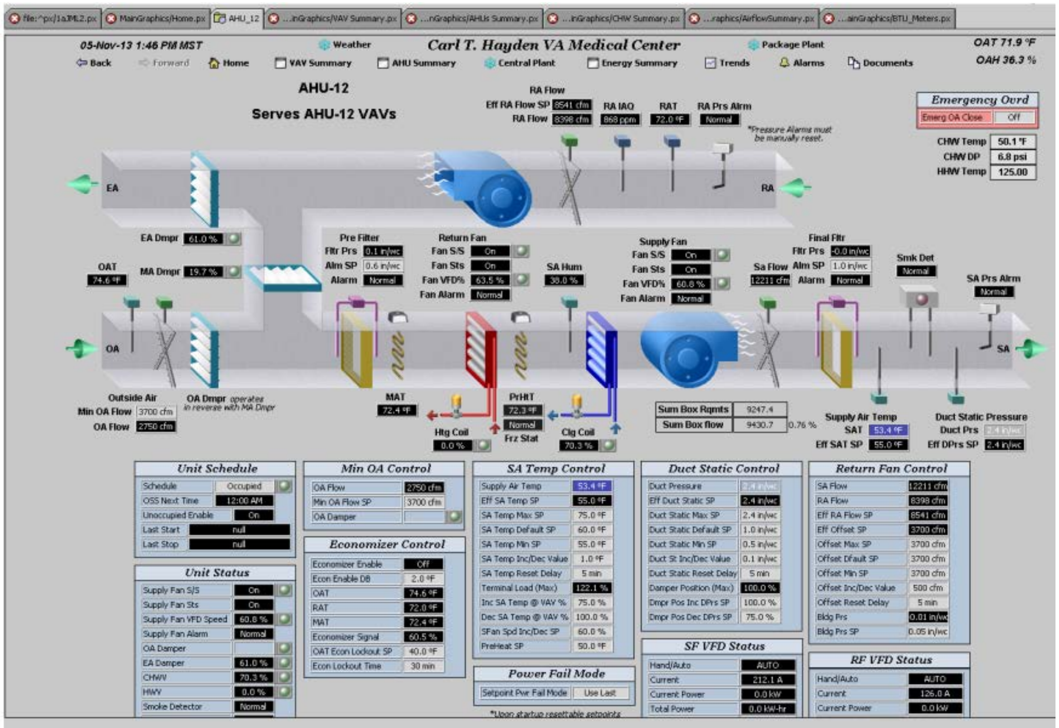
Ensure there is a high level of accountability and oversight for key project roles. Hire staff who can closely review the work of contractors and designers to ensure they are following the ASHRAE guidance and project technical documents.

When designing the contract (performance-based tasks, energy savings performance contract, or utility energy service contract), ensure that payment is made for completion of the project and results, not effort. The technology must be installed, commissioned, and performing correctly before payment. Progress payments or partial payments can decrease the incentive to ensure technologies are commissioned and operating successfully and avoid installation issues.

6.2 Operations

Ensure energy managers understand the technologies, utility rates, and government policies/programs. Energy managers also need to have the time to devote to learning the systems and analyzing the data frequently and granularly (minutes and hours). The energy managers have a substantial impact on the efficiency and overall energy consumption of the facilities.

Invest in intuitive energy data management and optimization systems. The medical center energy management team built data display interfaces to manage energy data and ensure energy efficiency and peak reduction strategies. They used graphics to easily identify system abnormalities for troubleshooting equipment and system issues (Figure 9). In addition, they built a comprehensive energy optimization/minimization system to balance field and plant energy output.



05-Nov-13 1:46 PM MST

OAT 71.9 °F
OAH 36.3 %

AHU-12
Serves AHU-12 VAVs

RA Flow
Eff RA Flow SP 8541 cfm
RA Flow 8398 cfm
RA IAQ 868 ppm
RAT 72.0 °F
RA Prs Alrm Normal
*Pressure Alarms must be manually reset.

Emergency Ovrd
Emerg OA Close Off

CHW Temp 50.1 °F
CHW DP 6.8 psi
HHW Temp 125.00

EA Dmpr 61.0 %
OAT 74.6 °F
MA Dmpr 19.7 %

Pre Filter
Fltr Prs 0.1 in/wc
Alm SP 0.6 in/wc
Alarm Normal

Return Fan
Fan S/S On
Fan Sts On
Fan VFD% 63.5 %
Fan Alarm Normal

SA Hum 38.0 %

Supply Fan
Fan S/S On
Fan Sts On
Fan VFD% 60.8 %
Fan Alarm Normal

Sa Flow 12211 cfm

Final Fltr
Fltr Prs -0.0 in/wc
Alm SP 1.0 in/wc
Alarm Normal

Smk Det Normal
SA Prs Alrm Normal

Outside Air
Min OA Flow 3700 cfm
OA Flow 2750 cfm
OA Dmpr *operates in reverse with MA Dmpr*

MAT 72.4 °F
Htg Coil 0.0 %
PrHtT 72.3 °F
Normal
Frz Stat
Clg Coil 70.3 %

Sum Box Rqmts	9247.4
Sum Box flow	9430.7

0.76 %

Supply Air Temp
SAT 53.4 °F
Eff SAT SP 55.0 °F

Duct Static Pressure
Duct Prs 2.4 in/wc
Eff DPrs SP 2.4 in/wc

Unit Schedule

Schedule	Occupied
OSS Next Time	12:00 AM
Unoccupied Enable	On
Last Start	null
Last Stop	null

Unit Status

Supply Fan S/S	On
Supply Fan Sts	On
Supply Fan VFD Speed	60.8 %
Supply Fan Alarm	Normal
OA Damper	
EA Damper	61.0 %
CHWV	70.3 %
HWV	0.0 %
Smoke Detector	Normal

Min OA Control

OA Flow	2750 cfm
Min OA Flow SP	3700 cfm
OA Damper	

Economizer Control

Economizer Enable	Off
Econ Enable DB	2.0 °F
OAT	74.6 °F
RAT	72.0 °F
MAT	72.4 °F
Economizer Signal	60.5 %
OAT Econ Lockout SP	40.0 °F
Econ Lockout Time	30 min

SA Temp Control

Supply Air Temp	53.4 °F
Eff SA Temp SP	55.0 °F
SA Temp Max SP	75.0 °F
SA Temp Default SP	60.0 °F
SA Temp Min SP	55.0 °F
SA Temp Inc/Dec Value	1.0 °F
SA Temp Reset Delay	5 min
Terminal Load (Max)	122.1 %
Inc SA Temp @ VAV %	75.0 %
Dec SA Temp @ VAV %	100.0 %
SFan Spd Inc/Dec SP	60.0 %
PreHeat SP	50.0 °F

Power Fail Mode

Setpoint Pwr Fail Mode	Use Last

*Upon startup resettable setpoints

Duct Static Control

Duct Pressure	2.4 in/wc
Eff Duct Static SP	2.4 in/wc
Duct Static Max SP	2.4 in/wc
Duct Static Default SP	1.0 in/wc
Duct Static Min SP	0.5 in/wc
Duct St Inc/Dec Value	0.1 in/wc
Duct Static Reset Delay	5 min
Damper Position (Max)	100.0 %
Dmpr Pos Inc DPrs SP	100.0 %
Dmpr Pos Dec DPrs SP	75.0 %

SF VFD Status

Hand/Auto	AUTO
Current	212.1 A
Current Power	0.0 kW
Total Power	0.0 kW-hr

Return Fan Control

SA Flow	12211 cfm
RA Flow	8398 cfm
Eff RA Flow SP	8541 cfm
Eff Offset SP	3700 cfm
Offset Max SP	3700 cfm
Offset Dfault SP	3700 cfm
Offset Min SP	3700 cfm
Offset Inc/Dec Value	500 cfm
Offset Reset Delay	5 min
Bldg Prs	0.01 in/wc
Bldg Prs SP	0.05 in/wc

RF VFD Status

Hand/Auto	AUTO
Current	126.0 A
Current Power	0.0 kW

Figure 9. Carl T. Hayden VA Medical Center energy data management system

Source: James Larson; Energy Symposium Presentation (May 2015), Monterey, California.

Use energy data analysis to forecast energy use to provide the ability to react and make changes in advance, rather than after the fact. If possible, installing building energy data management systems that can also forecast energy use based on current usage and previous years, can identify problems and make changes to operations now and avoid peaks in energy use and high energy bills.

6.3 Load Shifting and Peak Management

Unless there is proof that an ice plant is more efficient than the chiller plant, it should *only* be used for peak shaving. To peak shave effectively, the load profile must be understood by the hour every day (or utility-billed demand increment). Load shifting is typically done only for cost savings. It can often be used for energy savings as well, but the inefficiencies associated with making and melting ice typically consume more energy than running a central plant.

Always start the most efficient equipment first and shut it off last. Do not rotate to maintain equal runtimes. It is typically more cost-effective to "wear out" efficient equipment prematurely by running them harder and more often in a more energy-efficient mode than to run them in a balanced but less-efficient mode.

6.4 HVAC System Management

Design for heating 100°F hot water. This temperature can be efficiently achieved from a variety of sources—heat pump, solar thermal, boiler, steam, etc. Industry sources are reporting that 100°F water can be produced 40% more efficiently than 140°F hot water with heat pumps.

Limit face velocity of VAV box coils to 500 feet per minute at full cooling. This limits the pressure drop at full cooling (the most energy-intensive operating point for most facilities) and supports larger coils that work with lower-temperature heating hot water.

Limit coil thicknesses to six or so rows. Add a second coil and split the load if more than six rows are needed. Separate the coils to allow access for cleaning and split the load appropriately between them.

The air-conditioning plant should never need to run if outside air is lower than 55°F, and all AHUs are designed for 100% outside air-economizing. AHUs are generally designed to deliver 55°F air at highest cooling loads. This temperature provides for proper dehumidification. Items to check: Are there AHUs that cannot economize? Are there spaces that are not designed for the heat load the AHU generates?

When in "cooling" mode, outside air dampers should be 100% open when the return air is a higher temperature than the outside air. It is best practice to have AHUs that can economize when the outside air temperature is below the return air temperature when in cooling mode or above the return air temperature in heating mode. Unless the site is in a high humidity zone, then economizing should be viable when the outside air enthalpy is lower than the return air enthalpy when in cooling mode.

AHU supply air temperature should reset (back off) to keep at least one VAV in the "system" open 100%. Static pressure on AHUs should reset (back off) to keep at least one VAV in the system open 100%.

Chilled water temperature should be reset to the warmest possible temperature so that one AHU chilled water valve is at 100% open if cooling is required. Chilled water differential pressure should be reset as low as possible, so that one chilled water valve is open 100%. Chilled water production is usually the highest energy intensity segment when cooling a facility. Chilled water pumping is usually the next highest. Spooling up the chilled water pumps often causes an additional chiller to turn on—not because additional cooling is required, but because the lesser number of chillers cannot handle the flow required by the pumps trying to maintain the differential pressure and flow in the secondary loops. This is why the systems have a "decoupler."

Reduce ventilation rate to as low as possible (or even zero) when spaces are unoccupied. If ventilation rates cannot be reduced in unoccupied spaces, force off reheat in ventilated but unoccupied spaces. In unoccupied spaces (and spaces with no heat load), the supply air will often be too cold. Reheat will kick in to maintain temperatures, and the systems will be simultaneously cooling and reheating spaces that have no occupants, purely to maintain ventilation requirements of unoccupied spaces.

Design the chilled water coils to operate with as warm chilled water as possible. Design the chilled water coils for as high of a "delta temperature" as possible. Target 48°F chilled water minimum with 20-degree delta temperature minimum. Do not, however, do this in a vacuum. Understand what the impact to the system will be. Warmer chilled water requires less energy to produce. Higher delta temperatures require less energy to pump. The trade-off requires higher capacity and more expensive equipment upfront but can have payback periods between 1-2 years in high cooling requirement climates.

Condenser water temperature should be reset based on wet bulb temperature—generally a few degrees above wet bulb. Condenser water temperature should never be set below wet bulb temperature. The colder the condenser water, the lower the "lift" and the less energy required to operate the chiller. Making condenser water too cold can cause issues with older chillers, generally in the form of "throwing or migrating oil." Most modern machines have a minimum lift requirement (pounds per square inch differential). Condenser water should be as cold as possible without lowering the lift below the manufacturer's requirement.

Run as many variable speed cooling towers as possible, maintaining at least 25% flow, irrespective of the number of chillers running. Fan affinity laws state that running three fans at 70% uses the same amount of energy as running one fan at 100%. Running three cooling towers rather than one provides three times more surface area for water evaporation. Cooling towers will generally need to be cleaned more often. Only run one condenser water pump per running chiller, not per running tower. Be sure to share the flow with all operating towers.

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