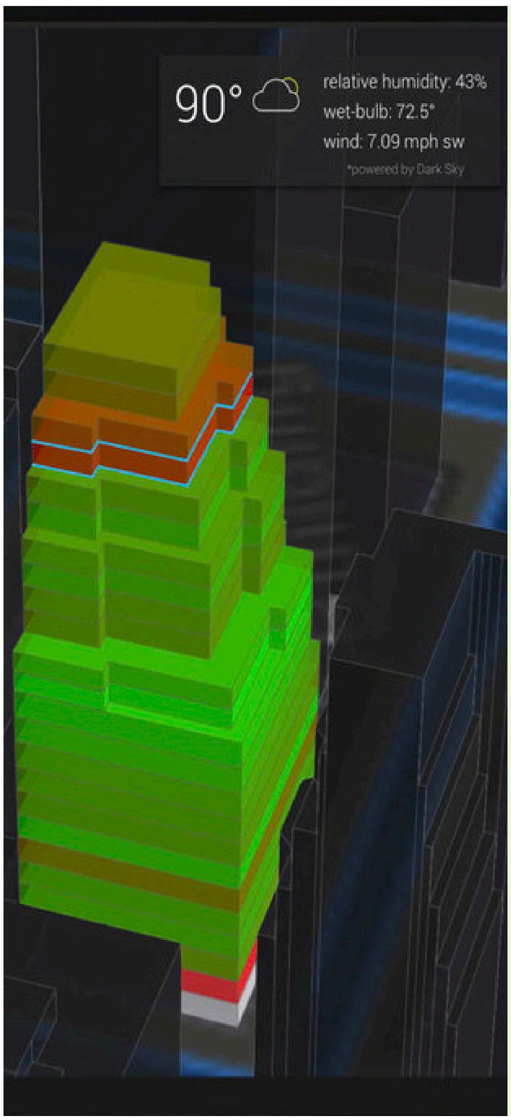
General Services Administration
Public Buildings Service

GPG-050 | SEPTEMBER 2022

EMIS WITH AUTOMATED SYSTEM OPTIMIZATION

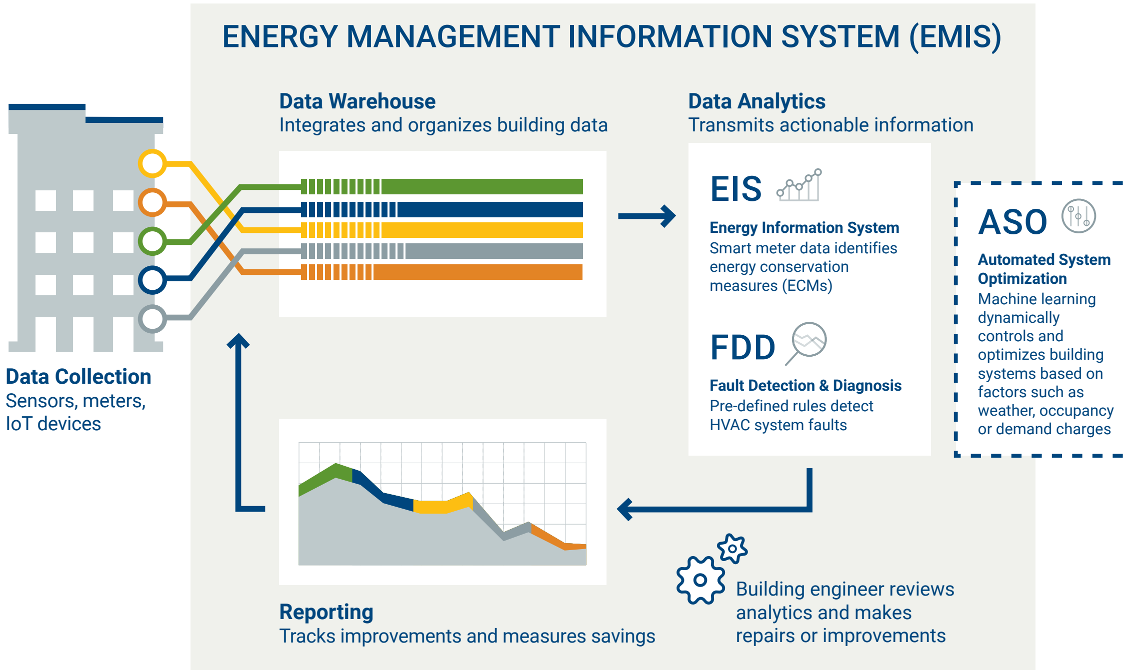


Increases Situational Awareness & Building Efficiency

By combining siloed building systems data with external information sources, like weather, into a single integrated platform, an energy management information system (EMIS) can provide real-time situational awareness and increase building efficiency. GSA Green Proving Ground (GPG) worked with the National Renewable Energy Laboratory (NREL) to perform field validation on a cloud-based EMIS that extends standard EMIS functionality with automated system optimization (ASO) to predict, prescribe and automate operational improvements. GSA identified two primary goals for the evaluation. 1) optimize HVAC efficiency based on occupancy and weather. 2) integrate multiple data streams into a unified user interface to remotely view equipment operation and performance across a portfolio of buildings. For this pilot project, the system was installed at four testbeds representative of a range of GSA facility types, operating conditions, and climate zones. Researchers found that at all four testbeds the system successfully integrated disparate data streams into a single dashboard that enabled remote monitoring, customized data trending, and reporting. Automated system optimization successfully controlled air handling unit (AHU) operation, though due to the impacts of COVID-19, energy savings were modeled rather than measured. Modeling demonstrated that using the EMIS ASO's machine learning to optimize AHUs informed by weather and occupancy (as an indicator of thermal heat load) saved between 5% and 11% of whole-building energy. As buildings become more complex, an EMIS with ASO can simplify building management and provide ongoing energy savings. It should be considered for deployment across the portfolio.

The GPG program enables GSA to make sound investment decisions in next-generation building technologies based on their real-world performance.

INTRODUCTION



Adapted from LBNL (Kramer et al. 2020)[1]

An EMIS with ASO aggregates historical and real-time data with machine learning and thermal modeling to optimize building performance

What Is This Technology?

CONTINUOUSLY ANALYSES DATA TO OPTIMIZE AND CONTROL SETPOINTS

"An EMIS with ASO can help us run our buildings better, reduce our energy costs, and keep demand down during peak hours."

—Tyler Harris
Energy Manager
GSA Public Buildings Service
U.S. General Services Administration

An EMIS with ASO aggregates historical and real-time data with machine learning and thermal modeling to optimize building performance. The system extends EMIS functionality beyond the one-way communication used to identify energy conservation measures (ECMs) and perform fault detection and diagnosis (FDD) to two-way communication and automated system optimization with the building automation system (BAS). The system continuously analyzes data from the BAS, weather forecasts, outside air temperature, indoor air quality, occupancy, and other sources to optimize performance while maintaining occupant comfort. In addition to optimizing building operations for energy savings, the platform can assist operators with other capabilities such as water leak detection and space utilization. A unified user interface aggregates and displays the data across the portfolio.

The ASO capabilities tested during this assessment included an optimum start time for AHUs based on interior and exterior conditions and historical data, and mid- and end-of-day ramps based on occupancy. Although not analyzed in this assessment, the system can also optimize demand management to reduce time-of-use charges. GPG is currently evaluating this capability as part of a grid-interactive efficient building (GEB) testbed assessment at the Foley Courthouse in Las Vegas, Nevada. The technology evaluated was provided by Prescriptive Data and is a cloud-based software as a service (SaaS) application.

WHAT WE DID

Assessed at Four Testbeds with a Range of Operating Conditions

NREL and GSA evaluated EMIS with ASO at four testbeds representative of a range of GSA facility types, operating conditions, and climate zones.

At the four testbed sites, integration included BAS system data, utility data, as well as occupancy and temperature sensor data. Fifteen facilities, all on the Niagara 4 BAS, were also integrated with limited BAS and AMI points (~30 points per building).

Energy savings from optimum start times and mid-and end-of-day ramps for AHU's were modeled rather than measured due to the impacts of COVID, which reduced building occupancy and required HVAC systems to run an additional two hours pre- and post-occupancy. For the optimum start, measured baseline AHU data was compared to the output from the EMIS with ASO's internal model that determined when each AHU should start to meet the desired zone temperature setpoint based on the 2021 building occupancy profile, historic weather, and BAS trend data. For mid- and end-of-day ramps, the connected building OS model relied on whole-building occupancy counting and thermal modeling combined with machine learning.

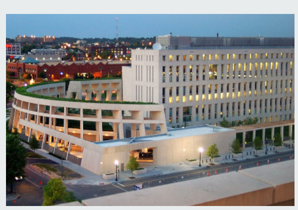
To calculate the accuracy of predicted electricity demand, the daily kW demand reading was compared to the daily kW prediction for approximately one calendar year for the Texas sites and three months for the Washington DC and Maryland sites.

To gather occupant feedback on the unified user interface and automated system optimization, researchers administered surveys and conducted focus groups.

The Austin Courthouse (251k ft^2) was constructed in 2012 and has an Energy Use Intensity (EUI) of 81 kBtu/ ft^2. Implemented feature sets in Austin included whole building occupancy counting via 5 stereoscopic occupancy sensors (vendor: Density), integration of 1,882 BAS (Niagara AX) and advanced metering infrastructure (AMI points), and control of a subset of AHU fans with an optimum start and mid- and end-of-day ramps via static pressure reset.

The Dallas Terminal Annex (253k ft^2) was constructed in 1937, has an efficient EUI of 42 kBtu/ ft^2 and is integrated on GSA's enterprise-level energy management and information system, GSALink. Implemented feature sets in Dallas included whole building occupancy counting via 4 stereoscopic occupancy sensors (vendor: Density), integration of 998 BAS (Niagara AX) and AMI points, and control of all AHU fans with an optimum start and mid- and end-of-day ramps via static pressure reset.

The Harvey Wiley Federal Building (441k ft^2) in College Park Maryland was constructed in 2001 and has an EUI of 201 kBtu/ ft^2. Sixty percent of the facility is office space and 40% is lab space that operates 24/7. Implemented feature sets included whole building occupancy counting via 3 light detection and ranging (LIDAR) occupancy sensors (vendor: FLIR), integration of 4,290 BAS (Johnson Controls) and AMI points, and control of 11 out of 20 AHUs with mid- and end-of-day ramps. An optimum start was not enabled due to COVID restrictions that were put in place in June and required HVAC systems to run two additional hours pre- and post-occupancy.



The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Headquarters (422k ft^2) in Washington DC was constructed in 2008 and has a EUI of 82 kBtu/ ft^2. Feature sets included whole building occupancy counting via one LIDAR occupancy sensor (vendor: FLIR), integration of 1,221 BAS (Schneider Ecostructure) and AMI points. Mid-day ramps were tested but had intermittent issues with running and persistent issues with programming. An optimum start was not enabled due to COVID restrictions.

FINDINGS

5% TO 11% WHOLE-BUILDING ENERGY SAVINGS FROM AUTOMATED SYSTEM OPTIMIZATION
Modeled energy savings for controlling AHU fan speeds based on weather and occupancy found 11% whole-building savings for Austin (EUI 81 kBtu/ft^2) where the majority of savings came directly from AHU fans, and 5% for Terminal Annex (42 kBtu/ft^2) where the majority of savings came from reduced chiller operation in the shoulder seasons. At the Wiley Federal Building, modeling demonstrated 8% AHU fan savings.

SUCCESSFUL INTEGRATION AND VISUALIZATION OF MULTIPLE 3RD PARTY DATA SOURCES
Multiple data streams from third-party vendor applications and building system protocols were successfully integrated into the unified user interface. Protocols included BACnet/IP, BACnet/MSTP, Modbus/IP, Modbus remote terminal unit (RTU), and APIs.

95% OF FOCUS GROUP PARTICIPANTS WOULD CONTINUE TO USE THE UNIFIED USER INTERFACE
The primary benefits that users identified from the unified user interface included access to historical and real-time data, multiple data streams in one place, access to remote facilities, and ease of use. During the evaluation, multiple previously unknown operational issues were discovered through the increased visibility of the integrated dashboard. In focus-group polling, 20 out of 21 participants said they would continue to use the unified user interface functionality if it were available to them.

AUTOMATED CONTROL WORKED AND EASED THE BURDEN ON FACILITY OPERATORS After a testing period to refine operation, the system consistently controlled the AHUs at the Austin Courthouse and Terminal Annex and Wiley Federal Buildings. Mid- and end-of-day AHU ramps based on occupancy ran for more than a year without operational issues. An optimum start was implemented for only four months prior to GSA issuing COVID-19 changes to HVAC operation. Focus group participants said that the automatic control simplified running the building and that they appreciated using kW prediction to optimize the HVAC start-up time and occupancy data to inform automated mid and end-of-day ramps.

PREDICTED PEAK DEMAND WITHIN 5% OF MEASURED PEAK DEMAND Predicted peak electrical demand was within 5% of measured electrical demand for all 4 testbed sites: 1.5% for Austin Courthouse, 3.5% for Harvey Wiley, 2.5% for Terminal Annex, and 4.8% for ATF. The ability to accurately predict peak demand is critical for demand management and will be further assessed in a subsequent GPG study on GEBs.

STRAIGHT-FORWARD INSTALLATION, FASTER WITHOUT ASO AND WITH FEWER BAS POINTS
Installations for the Austin Courthouse and Dallas Terminal Annex were each completed within 10 weeks. Installation took longer for the Harvey Wiley Federal Building (13 weeks) and ATF (14 weeks) due to complications outside the vendor's control, including COVID. Calibrating the system took an additional two weeks. Installation is faster without automated system optimization and when integrating fewer BAS points. Fifteen additional facilities were integrated into the unified user interface in a few hours each. GSA staff gave high marks for ease of installation: 4.5 on a scale of 1 to 5.

UNIFIED USER INTERFACE RECOMMENDED THROUGHOUT THE PORTFOLIO The functionality of having one unified user interface for all building data across the portfolio was universally appreciated by staff who said it made their jobs easier. Prioritize deployment for facilities with open protocol BAS systems. For this implementation, the vendor's technology integrates natively with Tridium Niagara 4 and Schneider EcoStructure BAS and therefore can be installed without hardware and in less time relative to other BAS applications. The installation will also be faster for facilities where meter and sensor data is already integrated into the BAS and where standard GSA point naming conventions are used.

RETURN ON INVESTMENT

ROI FOR AUTOMATED SYSTEM OPTIMIZATION WAS NOT REACHED AT TESTBED SITES For this evaluation, the SaaS annual subscription costs ($0.10/$ft^2$ for automated system optimization) exceeded the annual savings based on the region's low utility costs: Terminal Annex ($0.066/kWh and $5.06/mmBtu) and Austin Courthouse ($0.082/kWh and $5.52/mmBtu). Assuming 10% savings and the average GSA utility rates ($0.11/kWh and $7.70/mmBtu), payback would be less than 5 years.

PRIORITIZE BUILDINGS WITH HIGH EUI AND ENERGY COSTS FOR ASO The EMIS with ASO evaluated is a modular SaaS application with a graduated fee structure for different levels of control. At the time of the evaluation, the SaaS cost was $0.02/$ft^2$ for the EMIS and $0.10/$ft^2$ to include automated system optimization (ASO). For ASO to be cost-effective, prioritize facilities that have:

- high EUI and energy costs.
- been re-commissioned in the last 4 years and have no major operational issues. HVAC control problems need to be fixed prior to automating supervisory control.
- advanced smart building technologies, such as automated lighting controls, plug load controls, or onsite batteries that would benefit from automated optimization.
- If automated demand management is proven successful in the subsequent GPG-evaluation, sites with high-demand charges will have a higher return on investment.

WITH 10% SAVINGS, 64% OF GSA SITES HAVE POSITIVE ROI FOR ASO NREL has conducted a market analysis using blended utility rates at 504 GSA-owned facilities that are subject to energy measures. The analysis found that with an annual subscription cost of $0.10/$ft^2$ and 10% HVAC savings based on occupancy and weather, 64% of the sites would yield a positive cash flow with a total of $9.3M annual savings. At 5% savings, 18% of the sites yield a positive cash flow with a total savings of $1.5M annual savings.

Cost-Effective with 11% Savings and GSA Average Utility Rates

Annual costs can exceed savings with lower utility rates

	Dallas Terminal Annex (~5% savings)	Austin Courthouse (~11% savings)
Installation Cost	$37,082	$42,925
Annual Subscription Cost ($0.10/sf/yr)	$25,311	$25,100
Annual Energy Cost Savings @ local utility rate ($/yr)	$7,343	$23,822
Annual Cash Flow, Testbed ($/yr)	-$17,968	-$1,278
Simple Payback (0.066/kWh Dallas, $0.082/kWh Austin)	N/A	N/A
Simple Payback, GSA Blended Avg Utility ($0.11/kWh)	N/A	4.84 yrs

MODELED SAVINGS

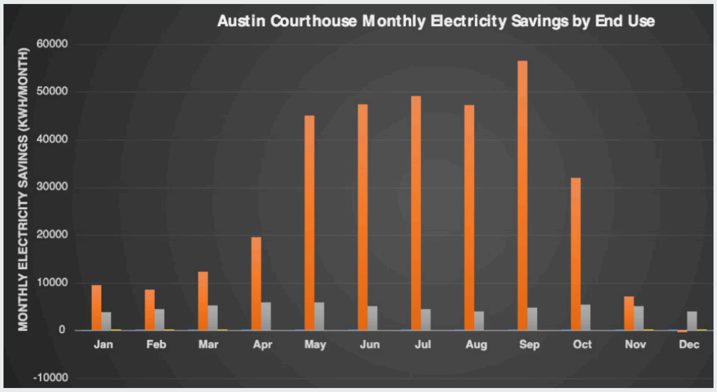
Modeled Monthly Energy Savings

Savings vary depending on building conditions

AUSTIN COURTHOUSE MONTHLY ENERGY SAVINGS

Majority of savings come from reduced fan use

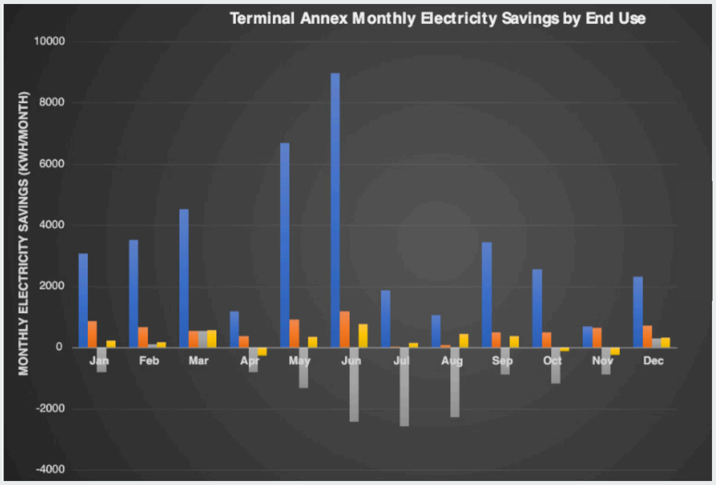
- Fans (kWh/month)
- Pumps (kWh/month)



TERMINAL ANNEX MONTHLY ENERGY SAVINGS

Majority of savings come from reduced chiller use in shoulder season

- Cooling (kWh/month)
- Fans (kWh/month)
- Pumps (kWh/month)
- Heat Rejection (kWh/month)



GSA Market Analysis for Automated System Optimization

Portfolio potential for cash-flow positive facilities based on % cost savings*

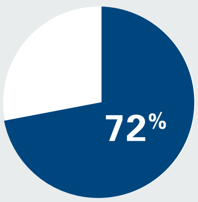
	5% Annual Cost Savings	7.5% Annual Cost Savings	10% Annual Cost Savings	12.5% Annual Cost Savings
Cash-flow positive facilities (total out of 504)	90	223	322	424
Total Building Area (sf)	30,488,470	77,028,119	106,211,953	139,233,885
Gross Annual Cost Savings ($/yr)	$4,538,021	$12,467,287	$19,949,064	$28,689,424
Annual Subscription Cost ($0.10/sf/yr)	$3,048,847	$7,702,812	$10,621,195	$13,923,389
Net Annual Cost Savings after SaaS ($/yr)	$1,489,174	$4,764,475	$9,327,869	$14,766,035

* Break-even point depends on utility costs, annual savings, and geographic region. Does not include installation cost due to varying expenses of integration.

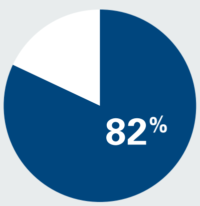
FOCUS GROUP FEEDBACK

To better understand the qualitative benefits of a unified user interface and automated system optimization, GPG hosted four one-hour discussion groups with 23 GSA staff from different buildings and regions.

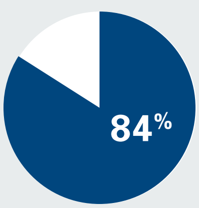
On a scale of 1 to 5, users rated the value of the EMIS with ASO



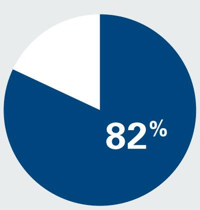
value in day-to-day operations over current practices



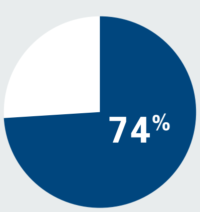
value of historical usage trends & monthly reports



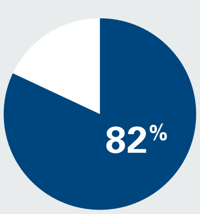
value of metering and sensor data in one location



value of user experience compared to other apps



value in KPI tracking such as energy consumption



value of real-time occupancy data

Consistent themes for the unified user interface included: historical and real-time data, multiple data streams in one place, access to remote facilities, and ease of use.

- *Helps with situational awareness and troubleshooting and scales back guesswork. Sensor data can be used to quickly track anomalies. Data can be shared with O&M to pinpoint issues and then I can remotely track the building to see that issues are resolved.*
- *The ability to see what happens in a remote building in real-time is invaluable. Previously, if I wanted to see what was happening in Gallup, New Mexico I would have to fly to Albuquerque and then drive 3 hours.*
- *I can drill down, go from macro to micro views. And it's aesthetically pleasing which makes the data more useful. Helps in reporting out, though to satisfy KPI, reporting would need a larger subset of buildings represented.*
- *It's much easier and quicker than accessing data in the BAS, which allows me to do more work. Previously I would have to pull a data set from the BAS or meters, tag which buildings I'm interested in, weather-normalize the data, then make a custom graph for it.*
- *One benefit of a SaaS solution is how flexible and dynamic it is. We were able to identify something we wanted to see and have it the following week, which is not something we've had with our other solutions.*

Consistent themes for automated system optimization included: simplification, kW prediction for setting start-up time, and occupancy data for controlling mid and end-of-day ramps.

- *Takes the pressure off running a building. It's impossible to track 30,000 points in a building. The margin of error is small and the scope is huge.*
- *Before using this EMIS with ASO we were just guessing at when we should turn on our buildings to be at the proper temp. And to be on the safe side, we gave our buildings a huge buffer and started our buildings every day at the same time for the worst-case scenario. It's so much better to know that using predictive data, we will hit the temp when we need to.*
- *The most useful function was the end-of-day ramp. Currently, we would need a person in the seat at the right time to manually make it happen.*
- *Definitely an improvement over current practices. By looking at the 24/7 data we found problems with an AHU and saved utility costs after we fixed it.*
- *Because it's real-time it can help protect equipment.*

CONCLUSIONS

These Findings are based on the report, "Field Validation of a Building Operating System Platform" which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

What We Concluded

SIMPLIFIES BUILDING MANAGEMENT AND SAVES ENERGY

An EMIS with ASO can make it easier to manage a large portfolio of buildings. As building systems become more complex, with thousands of individual data points, operators need a way to easily track and visualize data. The EMIS evaluated in this assessment successfully integrated disparate data streams across the portfolio and helped managers remotely see how their buildings were operating. An easy-to-use interface made the data more usable and actionable so that O&M issues could be pinpointed and then tracked to ensure that they were resolved. The system also helped identify long-term trends and facilitated reporting of key performance indicators. With increased complexity, facility managers also benefit from automated system optimization that can take the pressure off running a building, where the margin of error is small and the scope is huge. NREL found that controlling the HVAC system based on weather and occupancy could annually save 5% at the Terminal Annex Federal Building (with an already efficient EUI of 42/kBtu/ft^2) and 11% at the Austin Courthouse where there was more room for energy savings. Without a system that can predictively run the HVAC system based on current conditions, operators make educated guesses and often run buildings based on the worst-case scenarios to make sure that they are maintaining comfort conditions. An EMIS with ASO enables operators to optimize efficiency without sacrificing occupant comfort. As one facility manager said, "An EMIS with automated system optimization seems like the next natural step for building management."

Best Practices/Lessons Learned

- Meet with building operators early on to get buy-in on turning over control to a third-party software tool. Provide adequate training and an accountability mechanism to ensure the technology is used to its fullest capabilities.
- Data mapping can be time-consuming. Facilities on GSALink will be faster to integrate as they already use GSA's standard naming conventions so no remapping is needed.
- Test automated control at night and on weekends to make sure commands are working. At the testbeds, there was some trial and error in getting the AHU ramping working properly.
- The current optimum start algorithm prioritizes reducing electricity consumption. In a hot and humid climate, like Dallas, limiting the pre-cooling of a building can reduce the charging of the thermal mass which can impact peak demand in the summer months. The start-up algorithm should account for both electricity consumption and demand.
- Select an EMIS with ASO that can be integrated across the portfolio with different levels of effort and expense. In the case of the EMIS evaluated, not all sites were cost-effective for automated system optimization.
- The evaluated EMIS with ASO is a cloud-based SaaS application and will need authorization from the Federal Risk and Authorization Management Program (FedRAMP) in order to operate in federal facilities. The testbed pilots were conducted with provisional authorization.

[1]Kramer, H, Lin, G, Curtin, C, Crowe, E, Granderson J. Proving the Business Case for Building Analytics. Lawrence Berkeley National Laboratory, October 2020. https://doi.org/10.20357/B7G022

Technology for testbed measurement and verification provided by Prescriptive Data.