



# Field Demonstration of ASHRAE Guideline 36 High-Performance Sequences of Operation for HCAC HVAC Systems

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UNIVERSITY OF MINNESOTA  
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## Definition of Terms and Acronyms

AFDD – Automatic Fault Detection and Diagnostics

AHU – Air Handling Unit

AMI – Advanced Metering Infrastructure

ASHRAE – American Society of Heating, Refrigeration and Air-Conditioning Engineers

ASO – Automated System Optimization

BACnet – Building Automation and Control Network

BAS – Building Automation System

BTU – British Thermal Unit

C&I – Commercial and Industrial

CARD – Conservation Applied Research & Development

CAV – Constant Air Volume

CDL – Control Description Language

CFM – Cubic Feet per Minute

CGM – General Purpose Modular

CMG – Custom Measure Guidance

CVM – Configurable VAV Modular

Cx – Commissioning

DDC – Direct Digital Controls

DCV – Demand-Controlled Ventilation

DoD – Department of Defense

DX – Direct Expansion

ECO – Energy Conservation and Optimization

ECAM – Energy Charting & Metrics (spreadsheet tool)

EMIS – Energy Management and Information System

EMS – Energy Management System

ERV – Energy Recovery Ventilator

FDD – Fault Detection and Diagnostics

FPB – Fan-Powered Boxes

GSA – General Services Administration

GUI – Graphical User Interface

HRV – Heat Recovery Ventilator

HVAC – Heating, Ventilation, and Air Conditioning

IPMVP – International Performance Measurement and Verification Protocol

IOU – Investor-Owned Utility

LBL – Lawrence Berkeley National Laboratory

LEED – Leadership in Energy and Environmental Design

M&V – Measurement and Verification

MERV – Minimum Efficiency Reporting Value

MPC – Model Predictive Control

NIST – National Institute of Standards and Technology (NIST)

OAT – Outdoor Air Temperature

O&M – Operation and Maintenance

PCG – Programmable Controller – General Purpose

PCV – Programmable Controller – Variable Air Volume

PID – Proportional-Integral-Derivative

RCx – Retro-Commissioning

RFP/RFQ – Request for Proposal / Request for Quote

SAT – Supply Air Temperature

SGPC – Standing Guideline Project Committee

TAB – Testing and Balancing

T&R – Trim and Respond

VAV – Variable Air Volume

VFD – Variable Frequency Drive

## Executive Summary

The Minnesota Department of Commerce (Department) sponsored this field study through its Conservation Applied Research & Development (CARD) program. The objectives of this study were to:

- Evaluate the implementation of ASHRAE Guideline 36 in Minnesota commercial buildings, quantify energy savings, and analyze cost-effectiveness
- Conduct market research on ASHRAE Guideline 36
- Identify opportunities to enhance Minnesota utilities' Energy Conservation and Optimization (ECO) programs.

This research supports the advancement of energy efficiency initiatives statewide by providing actionable insights for utility ECO program improvement.

## Field Demonstration

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This project included field demonstrations at two sites:

### Champlin Library (Hennepin County)

- Site: 8,500 square feet, single-story library with full controls retrofit.
- Implementation: A design engineer was not involved in the process. Controls contractor successfully implemented most ASHRAE Guideline 36 sequences, but spent more time than typical projects, and faced parameter tuning challenges and existing HVAC system limitations. The estimated first cost of the full hardware and software control retrofit is approximately \$10 per square foot. The ASHRAE Guideline 36 sequence was customized by the controls contractor, rather than a design engineer.
- Energy Results: Weather-normalized one-year post-retrofit whole-building energy use increased by 2.8% for electricity (1,812 kWh) and 13.7% for natural gas (567 therms). These estimates do not isolate HVAC energy use impact, and therefore may be unrelated to HVAC energy use, and have high uncertainty.
- Key Issues: Building required unusually high air handling unit supply air temperatures (up to 90°F) in winter operations due to insufficient zone-level reheat capacity, which contradicted Guideline 36 intent.

### George Latimer Central Library (City of St. Paul)

- Site: 83,170 square feet, four-story library with partial 4th-floor retrofit focusing on one air handling unit (AHU) and associated ten (10) variable-air-volume (VAV) terminal units.
- Implementation: ASHRAE Guideline 36 was not implemented due to an energy consultant's perception that it was too complex. A much simpler control sequence, which missed key energy savings measures in ASHRAE Guideline 36, was specified. There were existing mechanical and controls issues that remained unresolved throughout the demonstration. The retrofit cost is not available.

- **Energy Results:** For the weather-normalized seven (7) month post-retrofit period, the AHU supply fan showed a 16.0% energy increase; the return fan showed a 104.3% energy increase. These estimates do not reflect the results of a fully commissioned and correctly implemented ASHRAE Guideline 36 project.
- **Challenges:** Project remained incomplete at report time due to mechanical issues and ongoing commissioning. The controls contractor may not use the BAS manufacturer's ASHRAE Guideline 36 programming library correctly.

## Market Research

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The market research examined two approaches to implementing ASHRAE Guideline 36.

### Traditional Approach Findings:

- The ASHRAE Guideline 36 field demonstrations previously implemented in California achieved energy savings of 11-35% in whole-building electricity when proper engineering oversight was present. In contrast, the Minnesota field demonstration did not realize energy savings or properly implement ASHRAE Guideline 36, primarily due to limited engineering involvement, old and non-standard HVAC system configurations, and insufficient training of controls contractors, along with several other contributing factors.
- **Key Barriers:** Complexity, lack of standardized implementation tools, insufficient contractor training, and missing mechanical engineering input for retrofit projects.
- **Cost:** Costs for retrofits varied in the California field demonstration, with software-only upgrades typically costing around \$0.65 per square foot and yielding simple paybacks between 2 and 8 years, and with hardware and software upgrades typically costing from \$4-\$8 per square foot and yielding simple paybacks of 6-10. For the demonstrations conducted in this California study, full hardware and software retrofits averaged about \$6.40 per square foot with paybacks ranging from 6 to 8 years. The smaller-sized Champlin Library project is estimated to cost approximately \$10 per square foot, for a full hardware and software retrofit.

### Automated System Optimization (ASO) Approach:

- **Core Advantage:** Potentially significantly lower implementation costs (\$0.15-\$0.20 per square foot) with a 6-month to 18-month payback period.
- **Key Benefits:** No hardware changes required, works with existing BAS systems, continuous optimization through cloud-based algorithms.
- **Market Players:** CopperTree Analytics, BTune, BrainBox AI, and Nantum AI offer commercial ASO solutions.
- **Challenges:** BAS warranty concerns, IT security issues, and protocol compatibility limitations.

## Minnesota ECO program opportunities

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Major Minnesota utilities offer custom energy efficiency programs that provide incentives specifically for non-prescriptive, advanced building control-related projects. ASHRAE Guideline 36 projects fit in these programs. These ECO programs could improve their effectiveness by implementing several key recommendations in this report. These include integrating ASHRAE Guideline 36 energy-saving measures into Xcel Energy's custom workbook, providing simplified implementation steps through resources like the upcoming "Guideline 36 Lite" retrofit guide, and requiring certified controls contractors for program participation. The program could also focus on low-complexity measures to boost cost-effectiveness, use data analytics to screen customers, and develop user-friendly tools for calculating energy savings and commissioning. Early engineering design support, streamlined reporting requirements, and appropriate measurement and verification (M&V) rigor would ensure accurate and persistent energy savings. These actions address implementation challenges, enhance program efficiency, and maximize energy savings for participating customers.

## Key Conclusions

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Successful ASHRAE Guideline 36 implementation in retrofit projects requires a comprehensive mechanical engineering review, experienced controls contractors, and thorough commissioning—elements often missing in typical Minnesota projects. ASHRAE Guideline 36's complexity makes it impractical for small buildings with outdated HVAC systems that deviate from their standard configurations. Automated System Optimization (ASO) offers a potentially more cost-effective path to implementing key Guideline 36 measures, especially in existing buildings with legacy control systems, but still faces challenges as an emerging technology that must connect to existing BAS networks and provide supervisory-level control. If implemented properly, Guideline 36 can deliver substantial energy savings, as shown in multiple California studies, yet poor design or execution can prevent projects from actually implementing the sequences and realizing expected benefits. Awareness and adoption are expected to grow, driven by new California Energy Code requirements and increasing availability of tools and guidance, and both traditional Guideline 36 retrofits and ASO-based approaches could fit within Minnesota ECO programs, with ASO offering broader applicability due to potentially lower costs and reduced implementation barriers. Overall, the study shows that realizing ASHRAE Guideline 36's savings potential depends on careful project planning, appropriate building selection, and sufficient technical expertise throughout the process.

## Introduction

The Minnesota Department of Commerce (Department) sponsored an ASHRAE Guideline 36 field study titled “Field Demonstration of ASHRAE Guideline 36-2018 High-Performance Sequences of Operation for Heating Ventilation and Air Conditioning (HVAC) Systems” through the Conservation Applied Research & Development (CARD) program in 2021. The goal of the project is to conduct market research and field demonstrations of control retrofit process improvements by implementing ASHRAE Guideline 36 in several Minnesota commercial buildings. In this project, the research team measured building energy use, determined cost-effectiveness, and estimated energy and carbon reductions through field demonstrations. We also evaluated customer acceptance, met with Xcel Energy, and reviewed online information provided by other Minnesota utilities about their ECO programs related to commercial building controls to identify relevant program opportunities in Minnesota utility Energy Conservation and Optimization (ECO) programs.

## Background

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Building automation systems (BAS) consist of building control hardware, networked through building control networks, running software executing control sequences to manage HVAC equipment operations. BAS is foundational to efficient, optimized building operations and occupant comfort. While an estimated 23% of existing U.S. commercial buildings—predominantly medium and large facilities—use BAS (Trenbath, et al. 2022), effective outcomes hinge on the quality of the control sequences and the specialized expertise required to design, program, test, and use them. Historically, there was no standardization in HVAC control sequences, which led BAS manufacturers to deploy inconsistent and often suboptimal sequences, a gap addressed by ASHRAE Guideline 36, the first high-performance HVAC control sequences that provide uniform, pre-engineered operations for common HVAC equipment and systems. Guideline 36 is intended to maximize energy efficiency, building performance, and control stability while enabling simple real-time fault detection and diagnostics, and supporting compliance with various building codes. By streamlining building control specification, programming, commissioning, and operations—particularly improving the software workflow during design, construction, and commissioning—Guideline 36 aims to reduce time spent across the full building control project lifecycle. This research project seeks to quantify energy savings and implementation costs from deploying ASHRAE Guideline 36 in Minnesota commercial buildings, assess the nationwide market landscape for Guideline 36 adoption, and identify how Guideline 36 can inform and enhance Minnesota utilities’ ECO programs.

## A Typical Building Control Retrofit/Upgrade Process

A typical building control retrofit/upgrade project process involves several key steps: 1) needs assessment; 2) planning and design; 3) selection of vendors and contractors; 4) project implementation; 5) testing and commissioning; 6) training, documentation, and project acceptance.

## *Needs assessment*

The initial step in a building control retrofit or upgrade is a thorough needs assessment. This is often triggered by factors such as: aging or obsolete hardware and software; issues identified through occupant complaints or retro-commissioning studies; facility management's dissatisfaction with the system's performance; or the necessity to meet new building codes, standards, and regulations. This assessment is usually led by facility management in collaboration with an energy or building controls consultant or specialized firm, ensuring that technical gaps, compliance needs, and operational priorities are clearly defined before design and implementation proceed.

## *Planning and preliminary design*

In the planning and preliminary design stage, an engineering firm or building controls consultant is often hired to evaluate different building control upgrade options and approaches. Preliminary system architectures and control strategies may be developed, with potential challenges and risks considered. At this stage, different preliminary control upgrade design and cost options could be proposed, with the recommended option with a detailed proposal outlining the scope of work, timeline, and budget. The building owner then needs to secure the budget for the project.

## *Selection of contractors*

The engineering firm or building controls consultant provides a detailed scope of work for the control upgrade project, including specific goals, desired outcomes, hardware and software requirements, and required control sequences. The scope of work, combined with the building owner's non-technical project requirements, proposal requirements, evaluation criteria, and other general terms and conditions, forms a request-for-proposal (RFP) or request-for-quote (RFQ) document. The RFP or RFQ will then be sent to known local building controls service providers or posted on a public website to seek contractors' bids.

Project proposals are evaluated, and a building controls contractor is selected based on the evaluation criteria in the RFP/RFQ document. Factors considered in the contract selection often include contractors' technical expertise & experience in similar projects; project understanding & approach; project cost and value; project schedule & timeline; and references.

## *Project implementation*

The controls contractor is responsible for the project implementation. A control project implementation includes a detailed system design, control panel design and assembly, hardware and software procurement, field installation, control sequence drafting, customization and downloading to field controllers, and system start-up and functional testing.

For the control hardware, creating detailed control system design drawings, wiring diagrams, and point lists is typically done by control engineers within the controls contractor's organization. Once the control system design is complete, new building control hardware is procured. The field control technician will

work with an electrical contractor to install, wire, and power up the sensors, actuators, and control panels, which house the field controllers.

For the control software implementation, the controls contractor typically copies control sequences from other similar projects or the building control manufacturers' standard programming library, then modifies them based on the control sequence required specifically for the project. The first version of the new control programs could be done by the control engineer or the field control technician. Customization, tuning, and testing of the control programming are typically done by the field technician during the internal start-up and testing of the control programs. The field technician is also responsible for setting up and creating graphical user interfaces (GUIs) for building operators' system monitoring and control.

During the internal system start-up and functional testing, the field control technician will test individual control components and control loops, calibrate sensors and actuators, and test the system under various operating conditions according to control sequence requirements, and fine-tune the control sequence for optimal performance.

### *Testing and commissioning*

External testing and commissioning involve verifying the performance of the new control system through an independent third-party commissioning agent or consultant. While not always mandatory for every project, engaging a third party can enhance the quality of project implementation and help ensure that engineering standards and project goals are achieved. The typical process includes reviewing control design documents, developing detailed testing procedures, conducting tests on individual components and the entire system under various operating conditions, analyzing trend data to confirm system performance, and preparing a comprehensive commissioning report. The commissioning agent then works with the controls contractor to resolve the issues found, often resulting in the controls contractor changing the initial controls programming.

### *Building operator training, documentation, and project acceptance*

At the project acceptance stage, the controls contractor will provide the building owner with the as-built project documents, including control design drawings, a description of the control sequences or control logic implemented, source code or configuration files for system controllers or software platforms, system operation and maintenance manual or instructions, and warranty information. Training for the new system is often provided to the building operator or the facility management team members before the project is officially accepted by the building owner. The building operator will then take over and start to operate the building and maintain the new BAS.

## **Problem**

There are several issues in the typical building control retrofit/upgrade process, especially related to the HVAC control sequences. They are listed below.

## *No standardized HVAC control sequences*

Good HVAC control sequences are essential in energy-efficient operations. For a long time, there has been no standardized control sequence in the building control industry. Each BAS manufacturer has its own internal control sequence logic, programming libraries, or templates, and these control sequences were implemented using proprietary BAS hardware and software. Each building controls contractor may have their own programming templates, often based on previous similar projects. These control sequences may work, but do not provide results that maximize energy savings and demand response.

Mechanical system design engineers also did not have a reference control sequence when specifying HVAC control sequences. This resulted in specified building control requirements being very high-level, vague, and subject to contractors' interpretation and understanding of the detailed control sequence programming and implementations in the field.

## *Long design, implementation, and commissioning time and effort*

The custom-designed and implemented building control sequences made the typical building control retrofit/upgrade project difficult, time-consuming, expensive, error-prone, and not optimized for partial load conditions. Furthermore, there is no guarantee that occupant thermal comfort and building ventilation meet relevant building energy codes and standards either. For small or medium projects, it is not uncommon for building owners to just hire a building controls contractor to do the controls retrofit/upgrade without an engineering firm or third-party commissioning agent involved. This process does not guarantee a successful project outcome in terms of project timeline, budget, system energy performance, and the quality of the final project deliverables.

## **ASHRAE Guideline 36**

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ASHRAE Guideline 36 is titled "High-Performance Sequences of Operation for HVAC Systems." It provides standardized sequences of operation for heating, ventilation, and air conditioning (HVAC) systems to optimize energy efficiency and performance. This guideline is considered the industry's best practice and has detailed instructions on the control and operation of HVAC systems to ensure they operate efficiently while maintaining occupant comfort. The first ASHRAE Guideline 36 was published in 2018. The latest version was published in late 2024.

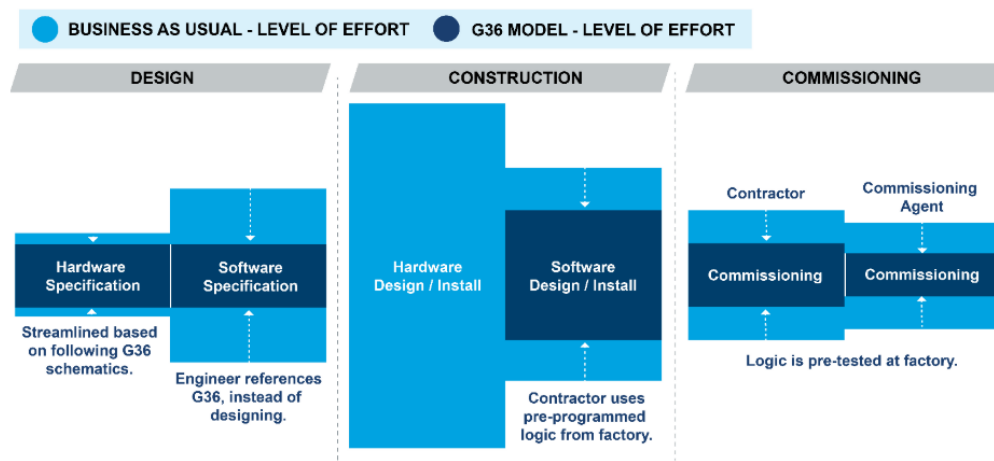
Intended benefits of ASHRAE Guideline 36 include:

- **Energy Efficiency:** By providing standardized sequences, Guideline 36 helps to reduce building energy consumption and costs through rule-based, optimized control strategies.
- **Improved System Performance:** The guideline enhances HVAC system reliability and performance, offering solutions that minimize equipment wear and tear.
- **Simplified Design and Implementation:** With pre-defined sequences, design engineers and contractors can streamline the design and commissioning process.
- **Enhanced Indoor Air Quality and Comfort:** Guideline 36 ensures indoor air quality and occupant comfort meet ASHRAE standards on ventilation and thermal comfort.

- Ease of Maintenance and Troubleshooting: Standardized sequences include fault detection and diagnostic logic that make HVAC system fault diagnostics and troubleshooting easier.
- Scalability and Adaptability: The sequences can be applied to a wide range of building types and sizes, and they are adaptable to various control systems and technologies.

Overall, ASHRAE Guideline 36 is a valuable resource for building professionals aiming to achieve high-performance and sustainably designed and operated HVAC systems. The intended benefits of reducing time and effort for building control system specification/design, implementation, and commissioning are illustrated in Figure 1 .

Figure 1. ASHRAE Guideline 36 Process vs. Traditional Building Control Project Process



## Objectives

To achieve the project goal of conducting market research and field demonstrations of ASHRAE Guideline 36 implementation in Minnesota, this project pursued the following objectives:

- Recruited commercial buildings to participate in field demonstrations of ASHRAE Guideline 36-based control retrofit and upgrade projects. Performed Measurement and Verification (M&V) along with data analysis to quantify energy savings and evaluate cost-effectiveness. Conducted stakeholder interviews to identify barriers, challenges, and lessons learned during project execution.
- Conducted a comprehensive market research on ASHRAE Guideline 36 implementation nationwide, including literature reviews, analysis of other field demonstration reports, and an assessment of the potential and challenges associated with the Automated System Optimization (ASO) approach.
- Researched and engaged with Minnesota utilities to explore opportunities for integrating ASHRAE Guideline 36 strategies into their Energy Conservation and Optimization (ECO) programs.

# The Traditional Guideline 36 Approach and The ASO Approach

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## The Traditional Guideline 36 Approach

The steps in the traditional approach of applying ASHRAE Guideline 36 in existing building control retrofit or new construction projects are listed below.

### *Needs assessment*

This step is the same as a typical control retrofit or upgrade project.

### *Planning and preliminary design*

The building owner must define the project's performance goals by requiring ASHRAE Guideline 36 control sequences to be included in the project requirements and control system specifications. This step is critical because Guideline 36 is not yet mandated by building codes in most states and is currently recommended only for projects pursuing high performance.

### *Selection of contractors*

The engineering firm or building controls consultant integrates the relevant ASHRAE Guideline 36 control sequences into the specifications for bidding by the controls contractor. They can tailor the control sequence requirements by modifying the Word version of ASHRAE Guideline 36, which comes free with the purchase of the Guideline PDF version, or by using free software tools such as ctrl-flow<sup>1</sup> developed by Lawrence Berkeley National Laboratory researchers and sponsored by the U.S. Department of Energy. Proposals should be evaluated against the criteria outlined in the RFP/RFQ documents, with particular emphasis on the contractors' technical expertise and proven experience in successfully implementing ASHRAE Guideline 36.

### *Project implementation*

The controls contractor must select building automation system (BAS) hardware capable of supporting the complex control sequences outlined in ASHRAE Guideline 36. Older controllers may lack sufficient memory or storage for these sequences. For software implementation, contractors usually begin with the BAS manufacturer's ASHRAE Guideline 36-compliant libraries or templates and customize them to fit the specific project needs. This approach reduces programming effort by leveraging standardized, pre-tested sequences. However, customization, tuning, and testing require heightened attention to technical details, including default guideline parameters, due to the increased complexity compared to typical control sequences.

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<sup>1</sup> <https://ctrl-flow.lbl.gov/>

## Testing and commissioning

Both the controls contractor and the commissioning agent must have a thorough understanding of the ASHRAE Guideline 36 control sequences and implement an efficient process for testing the building control system's performance for compliance in the field. At present, standard functional testing forms or field-testing methods do not exist, but the ASHRAE Standing Guideline Project Committee (SGPC) 36, responsible for maintaining the guideline, is actively working on developing these forms and methods.

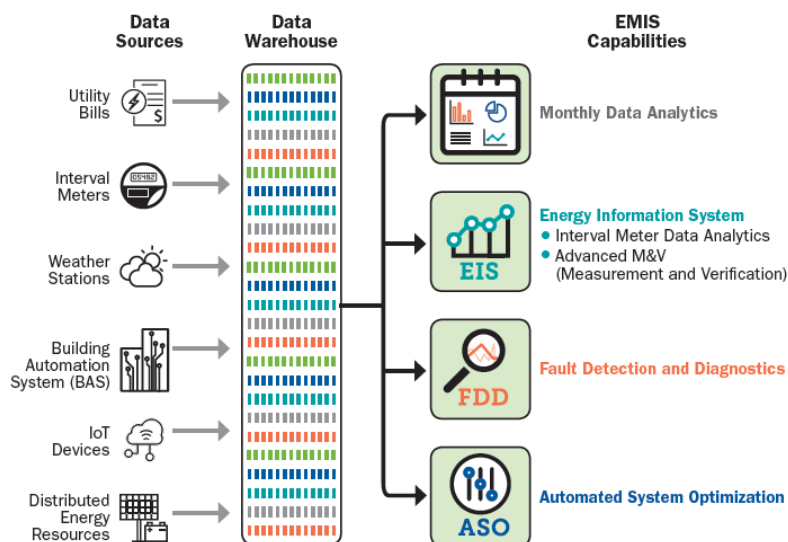
## Building operator training, documentation, and project acceptance

In this step, the controls contractor should provide training to the facility management team on the key concepts of ASHRAE Guideline 36 energy savings measures. Without at least a high-level understanding of these concepts, building operators may turn off or override some of the key energy savings measures.

## The ASO Approach

With recent technology advancements, an Energy Management and Information System (EMIS) provides an alternative way to implement ASHRAE Guideline 36. An EMIS (Crowe, Kramer and Granderson 2020) is an independent supervisory platform that integrates with a BAS to collect, analyze, and manage energy-related data and provides actionable insights. It helps better optimize energy use, improve efficiency, reduce costs, and support operational decision-making through real-time monitoring, diagnostics, and control.

Figure 2. Key capabilities of EMIS, including ASO



An EMIS possesses several key features and capabilities (Figure 2), including Automated System Optimization (ASO), defined as software that continuously analyzes and adjusts building automation system (BAS) control settings to optimize HVAC energy use while maintaining occupant comfort (Kramer, et al. 2020). ASO interfaces with the BAS via two-way communication, reading real-time data,

and automatically sending optimized setpoints to adjust control parameters. Existing ASO solutions apply key energy-saving strategies from ASHRAE Guideline 36 to dynamically update BAS setpoints without requiring any changes to BAS hardware or software.

The ASO implementation process differs from traditional methods. For owners seeking to enhance HVAC performance without replacing the existing BAS, the process begins with an ASO provider evaluating current HVAC systems and BAS controls to confirm Guideline 36 applicability and suitability for an ASO approach. The selected provider then partners with facility management and building IT to resolve cybersecurity and integration requirements, establish two-way BACnet connectivity between the ASO system and the BAS, collect BAS data, run automated optimization algorithms (including Guideline 36 measures such as AHU supply-air static pressure and temperature resets), and issue HVAC system setpoint adjustments back to the BAS. The deployment concludes with systematic testing and commissioning to verify performance and persistence.

## Methodologies

To achieve the project’s goals and objectives, we focused on implementing ASHRAE Guideline 36 through traditional field demonstrations and market research. Due to time constraints, we conducted market research on the Automated System Optimization (ASO) approach but were unable to perform ASO field demonstrations within the current project timeframe.

## Methodology for Field Demonstrations

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### Demonstration Site Recruitment

#### *Site evaluation criteria*

At the beginning of the project, our team compiled a demonstration site evaluation criteria document, which provided the preferred demonstration site building characteristics for both full building control retrofit and software-only retrofit projects. The detailed criteria are listed in Appendix A: Demonstration Site Selection Criteria.

We were looking for Minnesota non-residential buildings committing to either a full controls hardware retrofit or a software-only controls upgrade on a timeline aligned with April 2021–August 2022 installation and completion by mid-2023 for post-retrofit measurement and verification, with no other major renovations or occupancy changes that could confound savings attribution. Core technical fit includes VAV air-handling systems (single- or multi-zone) with minimal process loads or loads that can be cleanly disaggregated, and strong historical energy data—ideally 1–3+ years and whole-building interval metering—to support earlier starts and robust M&V. Priority was given to portfolios or campus owners and to BAS platforms and controllers capable of implementing ASHRAE Guideline 36 sequences, with named BAS manufacturers providing partial or full ASHRAE Guideline 36 libraries (Automated Logic, Trane, Distech Controls, Honeywell/Alerton, Siemens, Johnson Controls, Schneider Electric, as of 2021 and no updates since then). For full retrofit sites, the retrofit must deliver DDC to the zone level with controllers that can run custom Guideline 36 sequences, while keeping other HVAC equipment changes limited or like-for-like to isolate controls savings; for software-only sites, an existing zone-level DDC BAS capable of Guideline 36 is required.

Secondary “soft” criteria help differentiate candidates: owner enthusiasm for research, common ownership across sites to streamline demonstration, diversity in building types and sizes, representation of multiple control system manufacturers, good system condition without deferred maintenance, representativeness of the buildings, and strong local BAS vendor/dealer/contractor support. Full hardware sites should also identify an engineer of record, and software-only sites should provide existing sequences of operation to accelerate implementation and evaluation. These factors collectively aim to ensure technical readiness for Guideline 36, clean measurement boundaries, reliable metering, and smooth delivery with local support across varied but representative commercial facilities.

## *Recruitment process*

Based on the preferred field demonstration site evaluation criteria, we created marketing materials, including a flyer (Appendix B: Demonstration Site Recruitment Flyers), highlighting the benefits of building owners participating in this research project. Then we distributed the marketing materials through various marketing and outreach channels:

- Slipstream website and social media. An email blast to Slipstream customers in Minnesota.
- BAS manufacturers' local or regional representatives (Johnson Controls, Siemens, Alerton/Honeywell, Trane, Schneider Electric, Automated Logic, Distech Controls)
- Local consulting and engineering firms (HGA, SitelogiQ, Sustainable Energy Savings, LHB)
- City and county facility management offices (Hennepin County, City of St. Paul, City of Duluth, City of Rochester)
- Mechanical or controls contractors referred by Xcel Energy (UHL Controls, MMC Controls, Gilbert Mechanical)

We set up multiple meetings with these potential building owners, consulting firm engineers, and building controls vendors or contractors to explore building control retrofit/upgrade project opportunities that were suitable for an ASHRAE Guideline 36 field demonstration within the project timeframe. The recruitment process has been long and difficult, as not many people in Minnesota were aware of this guideline, the potential benefit it can bring, and how to implement it in a real project, even though our project would provide some incentives to the building owner to participate. Another reason is that ASHRAE Guideline 36 is a guideline, not a standard, and not required by building codes. It is intended for building owners who are focused on achieving high-performance and energy and cost savings. The reality is that many facility management staff are already struggling to manage the existing BAS to make it work; they do not have the time, effort, and budget to think about high-performance.

Through these conversations, we identified more than 10 potential control retrofit projects, collected building and HVAC system information, and then conducted engineering assessments, including site visits to selected buildings. Eventually, two building owners agreed to participate in the field demonstration of the ASHRAE Guideline 36 in three full building controls retrofit/upgrade projects:

- Champlin Library in Champlin, MN (Hennepin County)
- George Latimer Central Library (City of St. Paul)
- James Griffin Police Headquarters Building (City of St. Paul)

Unfortunately, the James Griffin Police Headquarters Building controls retrofit/upgrade project was delayed outside of this research project period, so we only conducted field demonstrations of applying ASHRAE Guideline 36 to two building control retrofits/upgrades: Champlin Library and George Latimer Central Library.

## *Participation agreement*

Slipstream signed project participation agreements with Hennepin County and the City of St. Paul. The high-level summary of these agreements is listed below:

- Building control sequences incorporate applicable ASHRAE Guideline 36 sequences
- The research funding provides each project up to \$15,000 in incentives to subsidize the control retrofit cost
- The building owner allows Slipstream to conduct M&V activities
- The building owner allows Slipstream to conduct interviews with facility operators and controls contractors on the experience of implementation of ASHRAE Guideline 36
- Slipstream may pay controls contractors for collecting post-retrofit BAS data or assisting with Slipstream M&V activities

## M&V Planning and Data Collection

### *M&V planning*

Before creating an M&V plan for each of the two demonstration sites, we established key performance objectives and metrics for the M&V activities. They are listed in Table 1.

**Table 1. Performance Objectives and Metrics**

<b>Performance Objectives</b>	<b>Metrics</b>
Annual electricity savings	kWh/year and % savings
Annual natural gas savings (if applicable)	Therms/year and % savings
Carbon reduction	Tons/year and % reduction
Cost-effectiveness	Simple payback (year)
Occupant comfort	Number of occupant complaints
Controls contractor experience	Time, cost, and implementation experience
Operator acceptance	O&M changes or improvements
Utility programs	ECO program applicability and recommendations
Control sequences	ASHRAE Guideline 36 compliance

Guided by the performance objectives and metrics, we developed a Monitoring and Verification (M&V) plan for each of the two demonstration sites after gathering essential building information, including building layout, HVAC, and electrical system design drawings, as well as existing control sequences.

## Champlin Library

Champlin Library is an 8,500-square-foot, 1-story library in Champlin, MN (Figure 3). The library opened in 1994. It has a large open library area with bookshelves, reading tables, and computer workstations. There is an administrative area with offices, workstations, and a break room. There's also a conference room open to the public. Per the Hennepin County Library website, the library is open 12 pm to 8 pm on Tuesdays and from 9 am to 5 pm on Wednesdays through Saturdays. It is closed on Sundays and Mondays.

Figure 3. Champlin Library



The existing HVAC system consists of a large VAV air handling Unit, AHU-1, and a smaller air handling unit, AHU-2. Each AHU is served by a boiler plant and an air-cooled chiller. AHU-1 serves the library and administrative areas. The unit was originally designed for 10,000 Cubic Feet per Minute (CFM) and has a single fan with a VFD. The unit is served by a separate inline return fan, which is also served by a VFD. AHU-1 serves seven VAV boxes, of which three are fan-powered boxes (FPBs) and the remaining four are single duct. Only the FPBs have reheat coils. Each of the four single-duct VAV terminal units has a separate hydronic radiant panel heating system providing zone reheat. AHU-2 serves the conference room and was designed for 1,200 CFM. It is a smaller, constant-volume fan AHU, and the controls are not covered in ASHRAE Guideline 36.

Hot water in this building is supplied through a gas-fired boiler plant that consists of two boilers and two pumps, as well as ancillary equipment. The plant serves both air handling units, the reheat coils, three unit heaters, and the perimeter radiant panels. A 30-ton air-cooled chiller has one pump and provides cooling for both air handling units. The chilled water consists of 40% propylene glycol. The building's electricity is supplied by Xcel Energy. Natural gas is served by CenterPoint Energy.

Before the controls retrofit, the original building control system was Automated Logic's WebCTRL. The control sequences, as was written in their operations manual, already included some energy-efficient operation concepts, such as:

- AHU-1: Optimal Start/Morning Warm-up Cycle
  - Heating: the system will optimally start the air handling unit, based on outside air temperature, space temperature, equipment heating capacity, occupancy time, and the occupancy temperature setpoint.
  - Optimal Start – Cooling: the system will optimally start the air handling unit, based on outside air temperature, space temperature, equipment cooling capacity, occupancy time, and the occupancy temperature setpoint.
- AHU-1: Supply Fan VFD Control - the supply fan VFD speed will be adjusted to maintain at 0.75 inches of water column (in. w.c.) (software adjustable).
- AHU-1: Return Fan VFD Control - return/relief fan VFD to maintain building space pressure at +0.02 in. w.c. (user adjustable.)
- AHU-1: Discharge Temperature Reset - the discharge air temperature PID loop will reset the discharge air setpoint based on the number of cooling requests being received from the terminal VAV zones. The range of the discharge air temperature is from 55°F to 75°F. The BAS will reset the high limit temperature setpoint based on outdoor air temperature.
- AHU-1: Outside, Return and Relief Air Dampers - outside air damper minimum position is 25% Open. Economizer mode is determined based on the differential enthalpy method + outside air enthalpy method (either return air enthalpy is lower than outside air enthalpy, or outside air enthalpy is over 26 BTU/lb.)
- AHU-1: Chilled Water Valve and Heating Water Valve - will modulate to maintain discharge air temperature. The chilled water valve will not be allowed to open if the outside air temperature is below 60°F. The heating coil valve will not be allowed to open if the outside air temperature is above 55°F.
- VAV terminal units with radiant heating: The VAV box damper will modulate from the minimum CFM setpoint toward the maximum CFM setpoint in cooling mode.
- VAV terminal units with radiant heating: when the VAV box damper is 100% open, a "cooling request" will be generated and sent to AHU-1.
- VAV terminal units with radiant heating: the radiation valve will modulate to maintain the space temperature setpoint in heating mode.
- Fan-powered VAV Terminal Units with Reheat: The fan will be enabled to run continuously during occupied mode, or the central station operator can decide to cycle the fan on only when a call for heat is received. The fan will start in heating mode.
- Fan-powered VAV Terminal Units with Reheat: The VAV box damper will modulate from the minimum CFM setpoint toward the maximum CFM setpoint in cooling mode. The VAV box damper will modulate to its heating CFM setpoint in heating mode.
- Fan-powered VAV Terminal Units with Reheat: when the VAV box damper is 100% open, a "cooling request" will be generated and sent to AHU-1.
- Fan-powered VAV Terminal Units with Reheat: The heating valve will modulate open to maintain the space temperature setpoint in heating mode.

- Fan-powered VAV Terminal Units with Reheat: In the morning warm-up mode, the VAV box will maintain its warm-up cycle CFM setpoint. The reheat coil valves will be fully open.

We analyzed the pre-retrofit system performance based on the BAS data collected and compared it with the operation sequences described above. Our findings for the actual BAS performance before the retrofit are summarized below:

- No optimal start/morning warmup cycle observed. AHU-1 On/Off was at pre-determined times, not changing with outside air temperature.
- AHU-1 static pressure was maintained at a fixed 0.75 in. w.c. during the occupied period.
- AHU-1 return fan was running at a fixed speed almost all the time, not maintaining building space pressure at a fixed value.
- In cold winter days, AHU-1 DAT was controlled between 78°F and 86°F, which was very unusual. In summer days, no DAT reset was observed, and DAT was controlled around 60°F.
- AHU-1 minimum OA/RA damper position was about 27.5% Open. However, during spring days, the minimum damper position increased to 40% Open for an unknown reason. Economizer mode was determined based on outside air temperature only at 55°F (or 26 BTU/lb.)
- AHU-1 chilled water valve and heating water valve modulated to maintain discharge air temperature setpoint. In winter, the heating coil valve was between 90-100% Open all the time due to the higher-than-normal DAT setpoint.
- VAV terminal unit with radiant heating: these units' performances varied. Several VAV terminal unit airflows did not change during occupied periods. The "cooling request" generated by VAV terminal units could not be verified due to a lack of related BAS data points. Several VAV terminal unit radiant heating valves were open 100% all the time in winter.
- Fan-powered VAV terminal units: the fan was on only in heating mode. The fan and reheat valve were on at the same time.

These findings indicate that some of the specified energy efficiency measures were not correctly implemented or utilized. Since there were no major changes in HVAC equipment, building operations, or occupancy patterns during the demonstration period, and AHU-1 is the major HVAC equipment besides the chiller, our M&V plan for this building was focused on **comparing the whole-building electric and natural gas energy use and evaluating the AHU-1 and the associated seven VAV terminal units' control performances.**

## George Latimer Central Library

The George Latimer Central Library (Figure 4) is an 83,170-square-foot, four-story public library located in the City of St. Paul. The library was originally built in 1917. The most recent mechanical system renovation was completed in 2000. The library has community rooms, a Youth Services area, the Media and Nonfiction Room, the Magazine Room, administrative offices, and the Ecolab Training Room. Based on the public schedule, the library is open to the public from 10:00 am to 5:30 pm on Tuesdays, Thursdays, Fridays, and Saturdays, and from 1:00 pm to 5:00 pm on Sundays. It is closed on Mondays.

Figure 4. George Latimer Central Library



The existing HVAC system consists of single-zone air handlers, multizone air handlers, fan-coil units, Data Center air conditioning units, perimeter radiators, cabinet unit heaters, and VAVs with reheat coils. Terminal units consist of both volume dampers and standard VAV boxes. However, only one multiple-zone VAV air-handling unit (S-7), which serves the 4<sup>th</sup> floor, runs at variable speeds and can apply ASHRAE Guideline 36 control sequences. There are 10 VAV terminal units with reheat coils associated with S-7 serving 10 zones on the 4<sup>th</sup> floor.

There is no boiler plant or chiller plant in this building. Central Library's heating and chilled water are provided by the local utility company, District Energy-St. Paul. The heating water is exchanged through a brazed plate heat exchanger, and chilled water for most of the equipment is exchanged through a gasketed flat plate heat exchanger with the District Energy St. Paul system. The building's electricity is supplied by Xcel Energy.

Before the controls retrofit, the original building control system was Johnson Controls METASYS, which was integrated with the Tridium Niagara framework at the supervisory layer for coordination between different field controllers, improved data visualization, and enhanced energy management. The summary of the key control sequences for AHU S-7 and associated VAV terminal units before the controls upgrade is listed below:

- AHU S-7: Fan speed control - the fan speed is modulated by the static pressure sensor to maintain the static pressure set point (1.0 in. w.c.). No static pressure reset.
- AHU S-7: Mixed air damper control - the outdoor air, exhaust air, and return air dampers modulate from the ventilation air control unless overridden by the economizer control.
- AHU S-7: Ventilation air control - the minimum outdoor air requirement is set for 500 CFM. The Outside Air/Exhaust Air/Mixed Air (OA/EA/MA) dampers are modulated to maintain the mixed air temperature setpoint, which is the greater of 55°F or the calculated mixed air temperature set point based on the outdoor air temperature, the variable air volume supply air flow, and the return air temperature.
- AHU S-7: Economizer control: when the outdoor temperature is below 68°F, and when the outdoor temperature is lower than the return air temperature, the economizer mode is enabled. The outdoor air, exhaust air, and return air dampers are modulated to maintain the mixed air temperature sensor setpoint.

- AHU S-7: Preheat coil control - the face and bypass preheat coil dampers are modulated to maintain the preheat coil temperature set point of 45°F.
- VAV Terminal Units with Reheat: The space temperature sensor modulates the VAV box air control valve and reheat (and/or radiation) valve in sequence to maintain the space temperature setpoint. The space thermostats are set back from the zone manager during occupied hours.

Based on the information collected above, our M&V plan for this building was focused on **comparing the AHU S-7 supply and return fan power, heating and cooling energy, and evaluating the AHU S-7 and the associated ten VAV terminal units' control performances**. This HVAC equipment serves ten zones on the 4<sup>th</sup> floor.

### Data collection

Based on the performance objectives and metrics in Table 1, and specific building HVAC configurations, we summarized data collection methods used for both demonstration sites, which are listed in Table 2 and Table 3.

## Champlin Library

Table 2. Data Collection Method Summary – Champlin Library

Performance Objectives	Measurement Sample Frequency	Measurement Points and Scope	Data Collection Method
Annual electricity savings	15-minute interval	Whole-building electric power	A new eGauge power meter
Annual natural gas savings (if applicable)	15-minute interval	Whole-building natural gas usage	Adding a pulse output counter to the existing natural gas meter
Carbon reduction	NA	NA	Convert from the whole-building energy savings
Cost-effectiveness	NA	NA	Calculate from energy savings and control retrofit cost

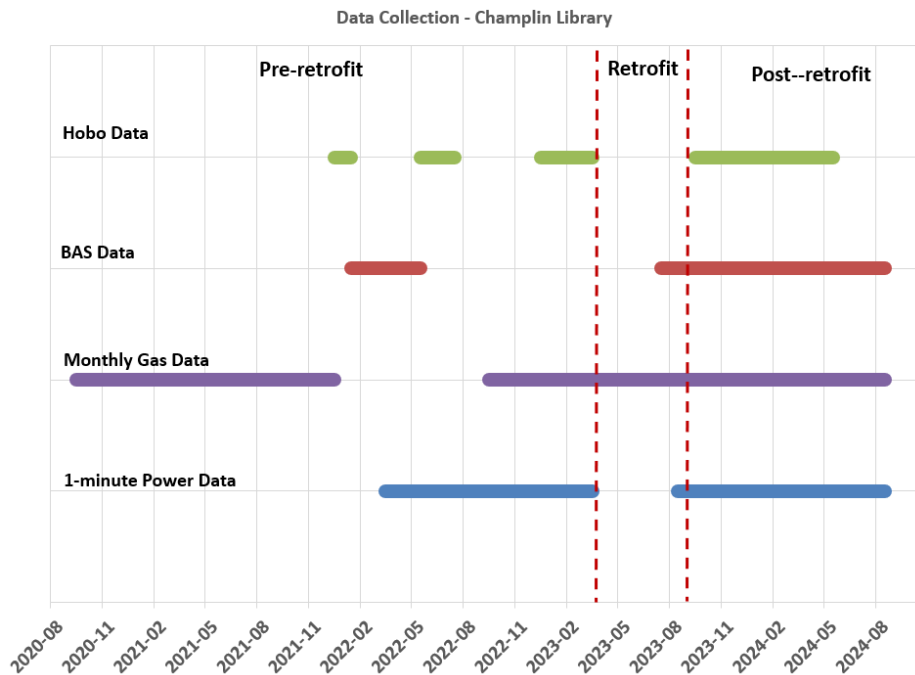
Performance Objectives	Measurement Sample Frequency	Measurement Points and Scope	Data Collection Method
Occupant comfort and IAQ	5-minute interval	Selected zone temperature, RH%, and CO2 level. Number of occupant complaints	New HOBO data logger (Temp, RH%, and CO2)
Controls contractor experience	One time, shortly after the retrofit is complete	NA	Contractor interviews
Operator acceptance	Before and after the retrofit	NA	Operator interviews
Utility programs	Onetime, after the result dissemination	NA	Discussion with MN utilities
Control sequences	1-minute interval	AHU-1: supply air temperature, supply air static pressure, outside air damper, supply/return fan power, OA damper position  VAVs: zone temperature & setpoints, airflow rate, damper positions.	Most data was collected from the new BAS. AHU-1 supply and return fan powers were collected through a new eGauge power meter.

The Champlin Library building controls upgrade / retrofit started around April 2023 and went through several months of a third-party independent commissioning process. The project is considered to be completed in early September 2023. Slipstream collected overall 12 months of post-retrofit period

energy data from 9/16/2023 to 9/18/2024. The post-retrofit period energy data collected includes monthly electric and natural gas usage data from Xcel Energy and CenterPoint, as well as 1-minute interval electric data, including whole-building electric demand, chiller power, and AHU fan power.

The 1-minute interval whole-building electrical demand data was available from 12/3/2021 to 9/18/2024. The minute data were converted to hourly averages for easier data manipulation and energy analysis. From 12/3/2021 to 3/30/2023 is considered the baseline period, and from 9/16/2023 to 9/18/2024 is considered the post-retrofit period. Natural gas consumption at the library was tracked through monthly bills in the pre-retrofit period. However, complications arose during the installation of a new meter for higher-resolution (hourly) data collection, resulting in the library being without new natural gas meter readings from January 2022 through a part of August 2022. During this period, the library recorded zero consumption, with the utility provider maintaining a fixed rate per month. Because of this issue, we included a longer time baseline period from 9/1/2020 to 3/30/2023 and excluded the data from January 2022 to August 2022 for natural gas energy analysis. September 2023 to August 2024 is considered the post-retrofit period. Partial BAS data and occupant comfort data before the retrofit were collected to study the existing building operations and occupant comfort conditions. The new building control BAS data and occupant comfort data were also collected in the post-retrofit period. The various physical data collected for Champlin Library are illustrated in Figure 5.

**Figure 5. Data Collected at Champlin Library**



## George Latimer Central Library

Table 3. Data Collection Method Summary – Central Library

Performance Objectives	Measurement Sample Frequency	Measurement Points and Scope	Data Collection Method
Annual electricity savings	15-minute interval	AHU S-7 supply and return fan power	A new eGauge power meter
Annual AHU heating and cooling savings	5-minute interval	AHU S-7 heating and cooling coil entering and leaving water temperatures. Water flow rates.	New HOBO temperature data loggers. An ultrasonic flow meter to measure water flow rates.
Carbon reduction	NA	NA	Convert from the whole-building energy savings
Cost-effectiveness	NA	NA	Energy savings and control retrofit cost
Occupant comfort	5-minute interval	Selected zone temperature, RH%, and CO2 level	New HOBO data logger (Temp, RH%, and CO2)
Controls contractor experience	One time, shortly after the retrofit is complete	NA	Contractor interviews
Operator acceptance	Before and after the retrofit	NA	Operator interviews

Performance Objectives	Measurement Sample Frequency	Measurement Points and Scope	Data Collection Method
Utility ECO programs	One time, after the project result dissemination	NA	Discussion with MN utilities
Control sequences	1-minute interval	AHU-1: supply air temperature, supply air static pressure, outside air damper, supply/return fan power, OA damper position  VAVs: zone temperature & setpoints, airflow rate, damper positions.	Most data was collected from the new BAS. AHU S-7 supply and return fan powers were collected through a new eGauge power meter.

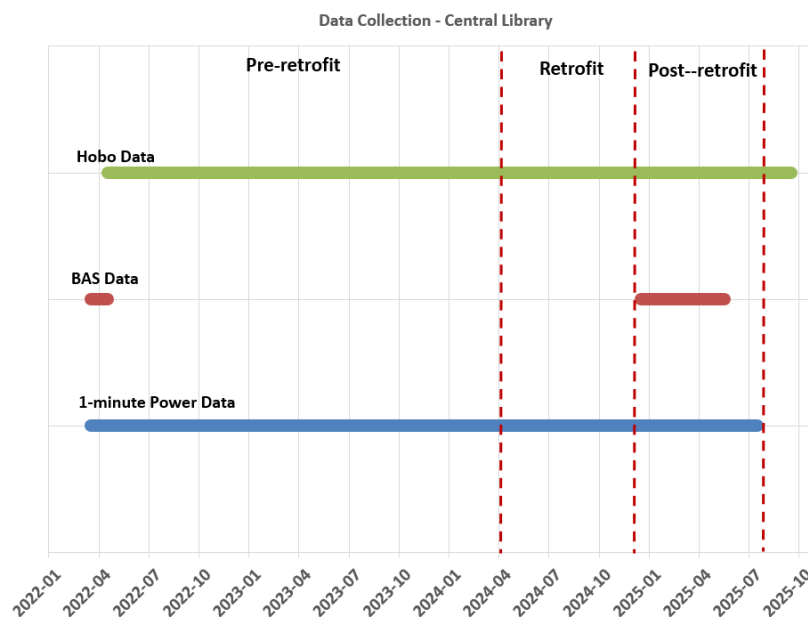
Instead of a whole-building energy use comparison, this project field study is focused on the 4<sup>th</sup>-floor AHU supply and return fan power and AHU heating and cooling energy use comparisons before and after the control retrofit effort, which the controls contractor claimed to have completed in December 2024.

For the baseline AHU fan powers, Slipstream collected more than 24 months of AHU S-7 supply and return fan power data at 1-minute intervals. The post-retrofit data for this project was collected from 12/1/2024 to 7/28/2025 (~8 months). Unfortunately, the building's internal computer network encountered a cyber event during the summer of 2025, and this issue has interrupted our planned data collection for the summer period.

Slipstream installed hobo temperature data loggers to record the 4<sup>th</sup>-floor AHU S-7 heating coil and cooling coil supply and return water temperatures between 2/24/2022 and 4/16/2024. We used the same 24 months from 4/1/2022 to 3/21/2024 for the pre-retrofit period (baseline period), and the post-retrofit data collected for this project were from 12/1/2024 to 7/28/2025 (~8 months). Slipstream also recorded the AHU S-7 preheat hot water loop return temperatures in the same periods. The heating and cooling energy for AHU S-7 would be calculated by using the differences between the supply and return water temperatures and the respective hot water and chilled water flow rates. However, during a site visit in summer 2025, we found out that the heating and cooling valves were recently replaced, and they

were two-way valves instead of three-way valves as the design drawing showed. The heating water flow could not be detected when the AHU heating water coil valves were fully open, indicating potential problems with the heating coil control. The chilled water flows were unstable, given a fixed valve position during the measurement. In addition, our BAS data collection for this building, which was set up by the controls contractor, stopped in June 2025. The occupant comfort data and AHU S-7 heating and cooling coil temperature data were collected through independently installed HOBO data loggers. The various physical data collected for the Central Library are illustrated in Figure 6.

**Figure 6. Data Collected at Central Library**



## Interviews

A few notes on the stakeholder interviews:

- Our project team designed standard interview questions for controls contractors, commissioning agents, and facility operators on the building controls retrofit projects, including the overall project process and experiences, as well as any lessons learned and suggestions for future improvements. These questions are listed in Appendix B: Questionnaire for Stakeholder Interviews.
- For the utility ECO programs that are related to building controls and ASHRAE Guideline 36, we set up multiple meetings with Xcel Energy staff, disseminating project preliminary results and lessons learned, and discussed with them potential ECO program improvements and future research topics that could benefit utility ECO programs.
- For the post-retrofit control sequence check for compliance with applicable ASHRAE Guideline 36 measures, the BAS data and AHU power data were collected and analyzed to determine whether the ASHRAE Guideline 36 measures were implemented, and/or the expected building control operations/performances were achieved.

## Controls Retrofit

### *Typical process*

The general building controls retrofit process is described in the “Introduction” chapter, “Background” section. The following paragraphs describe the specific building control retrofit process for the two selected buildings.

### **Champlin Library**

The primary reason for Hennepin County to upgrade the BAS at this building was that the original BAS hardware was more than 10 years old, it was harder and harder to get the control hardware replacement parts, and the boilers and boiler controls underwent a retrofit at the time. The facility management team had the budget to upgrade the entire BAS hardware. Because this research project offered incentives for implementing ASHRAE Guideline 36, they decided to try the ASHRAE Guideline 36 sequences during the controls retrofit.

For a control retrofit project of this size and complexity, and with no mechanical system change or modification, it is not uncommon that the building owner does not involve an engineering firm to do a full system review and redesign. For this project, the control retrofit was solely implemented by the controls contractor selected, which was the same controls contractor who did the original BAS setup. The contractor selection did not go through a public bidding process. The hardware and software requirements were the same as the original BAS – Automated Logic’s WebCTRL.

A third-party commissioning firm was hired to conduct commissioning of the post-retrofit building controls system.

### **George Latimer Central Library**

In 2021, a Central Library retro-commissioning study sponsored by Xcel Energy was conducted by an energy consultant hired by the City of St. Paul. The findings from the retrofit-commissioning study report showed that many HVAC equipment and controls faults existed, and Energy Conservation and Optimization (ECO) recommendations were proposed to fix these issues. At the same time, the facility operator found it was more and more difficult to manage the building HVAC operations through the BAS. Eventually, the City of St. Paul's facility department got funding to conduct a whole-building control system retrofit in 2024. They agreed to try to implement applicable ASHRAE Guideline 36 sequences on the 4th floor AHU S-7 and associated VAV terminal units.

For this controls retrofit project, the same energy consultant was hired to specify the new control sequences and to check/commission the new BAS system performance. The project went through a public bidding process, and a different controls contractor was selected for the control retrofit project. The new BAS hardware and software required were still Johnson Controls’ system.

## *Incorporating ASHRAE Guideline 36*

### **Champlin Library**

The building owner required the controls contractor to design and program the control sequences for AHU-1 and seven VAV terminal units according to ASHRAE Guideline 36. No specific building control sequence specification was provided, as no engineering firm was involved in this small building control retrofit project.

The control retrofit project design, including the control sequences, was completed by the controls contractor's regional engineering team. They followed ASHRAE Guideline 36 and customized the control sequences for the applicable HVAC equipment in the Champlin Library. The final control sequences were documented on the control retrofit engineering submittals.

For control sequence programming, the controls contractor began with Automated Logic's ASHRAE Guideline 36 library for multizone VAV AHUs and VAV terminal units, which was provided by Automated Logic's headquarters office. The sequences were then customized based on field testing and debugging results and the specific design developed by the regional engineering team for this project.

The third-party commissioning firm conducted project commissioning based on the control retrofit design, including the specific control sequences documented on the engineering submittals.

### **George Latimer Central Library**

In the Central Library controls retrofit project, the building owner hired an energy consultant to specify the new control sequences. This experienced energy consultant was not familiar with ASHRAE Guideline 36 and questioned the necessity of its complex energy efficiency measures. The energy consultant developed his own control sequence specifications, which were simpler than ASHRAE Guideline 36 but included similar concepts such as AHU supply air static pressure reset, AHU supply air temperature reset, AHU air-side economizer, and AHU minimum outdoor airflow control. However, many implementation details and suggested parameters **in ASHRAE Guideline 36 were not included in the specification**. For VAV terminal units with reheat coils, the suggested control sequence resembled the dual-maximum control logic in ASHRAE Guideline 36, but with different implementation details and parameters. Additionally, control sequences for VAV terminal units with radiant heating were provided, though this equipment type is not covered in ASHRAE Guideline 36.

Slipstream created a customized control sequence for AHU S-7 and associated VAV terminal units that complied with ASHRAE Guideline 36, using the LBNL ctrl-flow web-based control sequence specification tool. This was provided to both the energy consultant and the controls contractor. We requested the controls contractor to integrate ASHRAE Guideline 36 sequences wherever feasible, acknowledging that the energy consultant's specification governed the retrofit.

The controls contractor ordered Johnson Controls hardware and software through a local distributor. The software package included program libraries compliant with ASHRAE Guideline 36. However, none of the BAS manufacturers' program libraries are independently verified. During project implementation,

the controls contractor programmed key AHU sequences, such as supply air static pressure reset and supply air temperature reset, through the integrated Niagara Framework platform at the supervisory level rather than directly in the AHU controller. For VAV terminal units with reheat, the contractor **claimed to use** the Johnson Controls ASHRAE Guideline 36 library.

At the time of this report, the control retrofit at this building has not been officially commissioned and accepted by the building owner. The controls contractor reported completing the 4th-floor controls retrofit in December 2024.

## Performance Evaluation

### *Energy savings*

We used a free ECAM (Energy Charting & Metrics) software<sup>2</sup> – a Microsoft Excel-based tool for most of the energy calculation and analysis in this project. ECAM provides a standardized and transparent means for measurement and verification (M&V) of energy savings. It follows the International Performance Measurement and Verification Protocol – IPMVP and uses methods from ASHRAE Guideline 14, Measurement and Verification of Energy and Demand Savings. Based on the specific performance objectives, metrics, and energy data collected, the two demonstration sites’ energy performances were evaluated using the following methods.

### **Champlin Library**

The “normalization” of the whole-building energy use data was done through creating energy models of daily electric energy use (compiled from 15-minute electric demand data) vs. outside air dry-bulb temperature, and monthly natural gas use vs. outside air dry-bulb temperature.

For both the baseline and post-retrofit periods, the whole-building electric energy use models were created by combining three different “Daytypes”: Monday/Wednesday/Friday/Saturday, Tuesday/Thursday, and Sunday, because these days were on different operating schedules. For working days (Monday through Saturday), the ASHRAE four-point (4P) change point model was used. For non-working days (Sunday), the ASHRAE two-point (2P) change point model was used.

To calculate the post-retrofit whole-building electric energy savings compared to the baseline period, the “adjusted baseline energy” was calculated by applying the three baseline whole-building electric use models to the post-retrofit period’s actual day-of-the-week and each day’s recorded daily average outdoor air temperatures. Then, the “adjusted baseline energy” was compared to the actual daily average whole-building electric energy use during the post-retrofit period.

The baseline period for natural gas energy analysis was from 9/1/2020 to 3/30/2023 and excludes the missing data period from January 2022 to August 2022. September 20, 2023, to August 30, 2024, was

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<sup>2</sup> <https://sbwconsulting.com/ecam/>

the post-retrofit period. For both the baseline and post-retrofit periods, monthly natural gas usage vs. monthly average outside air temperature models were created using the ASHRAE three-point (3P) heating change point model (Kissock, Heberl and Claridge 2003).

The “adjusted baseline energy” for natural gas in the post-retrofit period was calculated by applying the baseline monthly natural gas use model to the post-retrofit period monthly average outdoor air temperatures. Then, the post-retrofit period saving was calculated by subtracting the sum of “adjusted” natural gas monthly use from the sum of the actual natural gas monthly use in the post-retrofit period.

## **George Latimer Central Library**

Similar to the Champlin Library energy savings analysis, the “normalization” of the AHU supply and return fan power energy use data pre- and post-retrofit was done through creating energy models. To compare baseline and post-retrofit supply and return fan energy use, supply and return fan models were created for three different “Daytypes”: Weekdays, Saturday, and Sunday, using daily average supply and return fan powers (compiled from 15-minute interval data) and outside air temperature. The ASHRAE five-point (5P) change point model (Kissock, Heberl and Claridge 2003) was used for creating return fan energy models.

To compare the post-retrofit AHU S-7 supply and return fan energy use with the baseline period, the “adjusted baseline fan energy” was calculated by applying the three baseline AHU S-7 supply and return fan energy models to the post-retrofit period actual day-of-the-week and each day’s recorded daily average outdoor air temperatures. Then, the “adjusted baseline fan energy” was compared to the actual daily average AHU S-7 fan energy use during the post-retrofit period.

The pre-retrofit period (baseline period) for this project is from 4/1/2022 to 3/21/2024 (~24 months). The post-retrofit data for this project is from 12/1/2024 to 7/28/2025 (~8 months).

For the AHU heating and cooling coil energy comparisons, due to a potential heating valve control issue, unstable chilled water flow measurement, and unavailable control valve position data after June 2025, we could not establish models correlating water flow and control valve positions. Therefore, we determined we could not complete the comparison of AHU heating and cooling energy before and after the retrofit at this time.

## ***ASHRAE Guideline 36 implementation evaluation***

One key aspect of this project is to see how controls contractors implement ASHRAE Guideline 36 sequences in the field, and if the post-retrofit building control performance meets the intent of the guideline. Since this project was focused on evaluating ASHRAE Guideline 36-2018 version, we were only looking at the applicable control sequences that were available for air-side multiple-zone VAV AHUs and different types of VAV terminal units in the two demonstration sites. In this project, we did not evaluate the algorithms for alarms, Automatic Fault Detection and Diagnostics (AFDD), or any AHU plant requests, as the hot water and chilled water plant control sequences were not a part of the 2018 version.

For multiple-zone VAV AHUs:

- AHU system modes (Occupied/Cooldown/Setup/Warmup/Setback/Unoccupied)
  - Optimal start and morning warmup
- AHU supply fan control
  - Supply air static pressure set-point reset
  - Supply air static pressure control
- AHU supply air temperature control
  - Setpoint reset
  - Supply air temperature control
- Minimum outdoor airflow setpoints
- Minimum outdoor air control
- Relief-Fan or Return-fan control
- Freeze protection
- Air economizer high limits

For VAV terminal units:

- Zone groups (different operating modes)
- Dynamic zone minimum ventilation (occupied standby, demand-controlled ventilation)
- AHU cooling Supply Air Temperature (SAT) reset requests
- AHU supply air static pressure reset requests
- Hot water reset requests (if applicable)
- VAV terminal unit—cooling only
  - Cooling-only VAV control logic
- VAV terminal unit with reheat
  - Dual max control logic
- Fan-Powered terminal unit (if applicable)
  - Constant-volume parallel fan-powered VAV control logic
  - Variable-volume parallel fan-powered VAV control logic
  - Constant-volume series fan-powered VAV control logic
  - Variable-volume series fan-powered VAV control logic

The ASHRAE Guideline 36 implementation evaluation was based on reviewing the trended data from the post-retrofit BAS. By doing trend reviews – comparing relevant BAS points data correlations and patterns – we could have a good assessment of whether the above building controls requirements were implemented or implemented correctly.

## *Stakeholder interviews*

Before the field demonstration started, we compiled a set of stakeholder interview questions for facility staff, controls contractors, and commissioning agents – see Appendix B: Questionnaire for Stakeholder Interviews. We conducted the pre-retrofit interviews with the demonstration site facility staff before the controls retrofit project began, to learn about the existing building operations and basic building information. Shortly after the controls retrofit was completed, we interviewed controls contractors and

commissioning agents on their experience designing, implementing, field testing, and commissioning ASHRAE Guideline 36 control sequences. After 6 months of control retrofit project completion, we interviewed the facility staff again to learn their overall project experience, occupant complaints (if any), user acceptance, and any comments, feedback, and suggestions for future improvements. Notes from the interviews were compiled into summaries of stakeholder feedback.

### *Utility ECO programs*

Please refer to the next section, “Methodology for Market Research - Engagement with Minnesota Utilities.”

## Methodology for Market Research

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The objectives of the market research include understanding nationwide adoption of ASHRAE Guideline 36; identifying best implementation approaches and trends; reviewing activities outside Minnesota; exploring a new deployment path; and assessing utility program integration. Our methodology for market research on implementing ASHRAE Guideline 36, including both the traditional approach and the new ASO approach, consisted of three essential steps: data collection, market analysis, and engagement with Minnesota utilities.

### Data Collection

#### *Literature review*

For the traditional approach, we conducted a literature review of the energy savings potential of implementing ASHRAE Guideline 36. The summary was included as an interim report titled “MN CARD Field Demo of ASHRAE Guideline 36 Demonstration – Literature Review and Savings Potential” (Appendix C: Literature Review and Savings Potential).

For the ASO approach, we did a literature review of the general methods or algorithms used in Automated System Optimization (ASO) software. ASHRAE Guideline 36 is one of the rule-based optimization methods to achieve energy savings, but not many real-world implementations exist yet.

#### *Field demonstration case studies*

Information was collected from field demonstrations of ASHRAE Guideline 36 conducted outside the state of Minnesota. For the traditional approach, data were evaluated from a completed field demonstration project in California. For the new ASO approach, data were obtained from an ongoing field demonstration utilizing an open-source platform, from which preliminary results and observations were also derived.

#### *Interviews*

For the new ASO approach, we reached out to some building owners in Minnesota who managed a portfolio of commercial buildings and conducted interviews with them to see if they were interested in a field demonstration of ASHRAE Guideline 36 using the new approach. They provided their initial thoughts, including potential barriers and challenges to initial market adoption. We compiled and analyzed data collected throughout the recruitment process, including building stock engaged and building owner responses regarding project participation.

## Market Analysis

### *Target market and customers*

For the new ASO approach, we interviewed several ASO providers about their target market for ASO applications. We also compared the pros and cons of implementing ASHRAE Guideline 36 using the traditional approach and the ASO approach to understand what types of commercial buildings and HVAC system design/configurations could be best for ASO applications.

Through interviewing the Minnesota facility managers, we gained an understanding of their needs, preferences, and potential barriers and challenges to implement ASHRAE Guideline 36 using the ASO approach.

### *Key players and stakeholders*

The key stakeholders in using ASO to implement ASHRAE Guideline 36 in a building controls retrofit project are similar to those using the traditional approach, except that the vendors or the ASO providers may not be the traditional building control companies. Besides the two ASO providers we have already connected with, our team members also searched websites for companies that claimed to use ASO software to implement building controls optimizations at the supervisory level. We analyzed their energy savings claims and theory of operations and summarized the findings in the market research report section below.

### *Business case*

The two ASO providers provided typical costs vs. energy savings using ASO to implement ASHRAE Guideline 36 to justify the business case. They are summarized in the market research report section below.

## Engagement with Minnesota Utilities

At the beginning of the project, Slipstream engaged with Xcel Energy, discussing the existing utility ECO programs relevant to building controls, retro-commissioning, and EMS. We also asked them to distribute marketing materials through their sales and marketing channels, recruiting field demonstration sites for this project. Towards the end of the project, we had a couple of meetings with them again, disseminating project preliminary results, including lessons learned and the new ASO approach, and asked them for input and feedback on how the traditional approach and the new ASO approach could fit within the ECO programs, what market research findings would be most valuable for MN utility ECO program managers, and what future research would enhance ECO programs.

# Field Demonstration Results

## Champlin Library

### Energy Savings Analysis

#### *Whole-building electrical energy use*

The hourly whole-building electrical demand history chart for both the pre-retrofit / baseline period and the post-retrofit period is shown in Figure 7. There was data loss during some of the retrofit and commissioning periods in Summer 2023. Fortunately, the data loss does not affect our energy data analysis.

Figure 7. Champlin Library Whole-Building Electric Demand History Chart

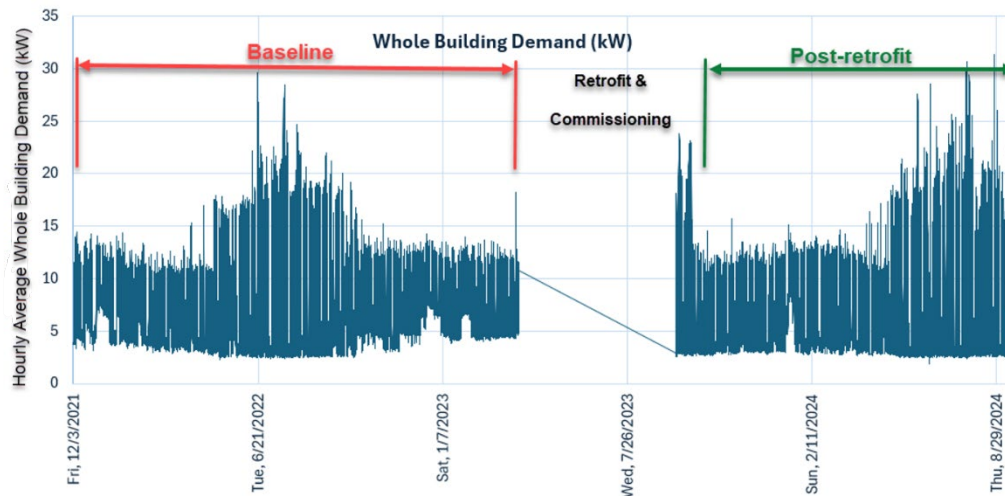


Figure 8 shows the whole-building electric demand scatter plot comparing baseline and post-retrofit periods. Overall, the electric demand vs. outside air temperature patterns are very similar, with more data points in the baseline period. Figure 9 illustrates the daily average whole-building electric demand comparison pre- and post-retrofit, along with modelled baseline in the pre-retrofit period and adjusted baseline in the post-retrofit period, after creating and applying whole-building electric demand models for this building (Appendix D: Champlin Library Energy Models.)

Figure 8. Champlin Library Whole-Building Electric Demand Scatter Plot

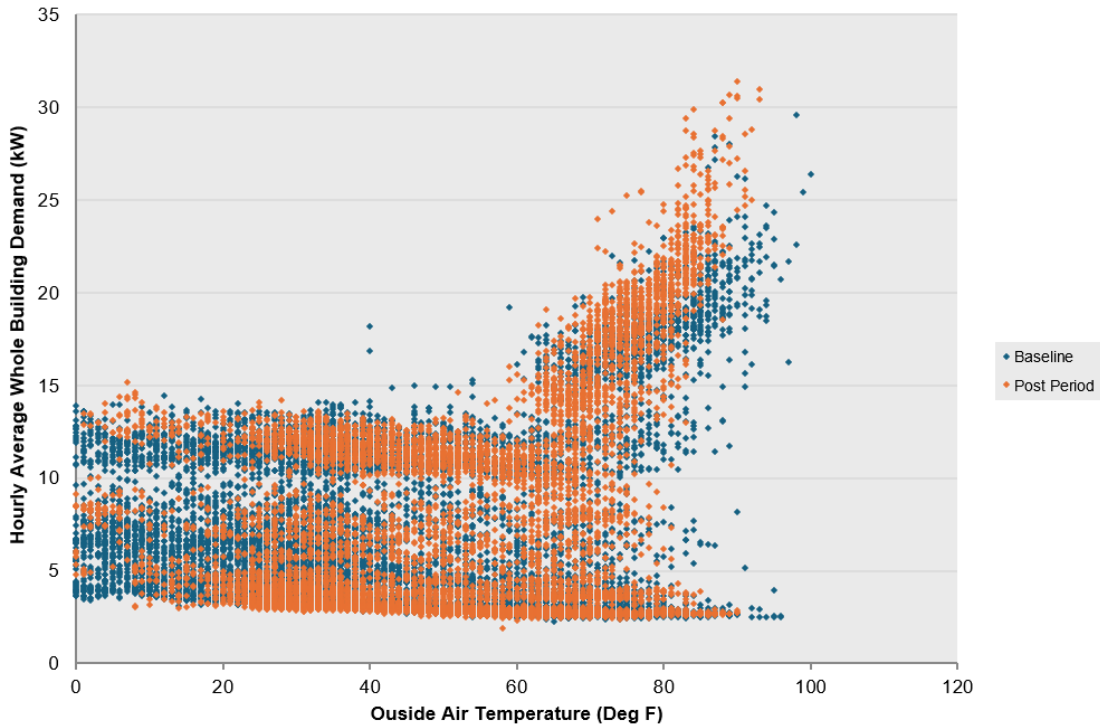
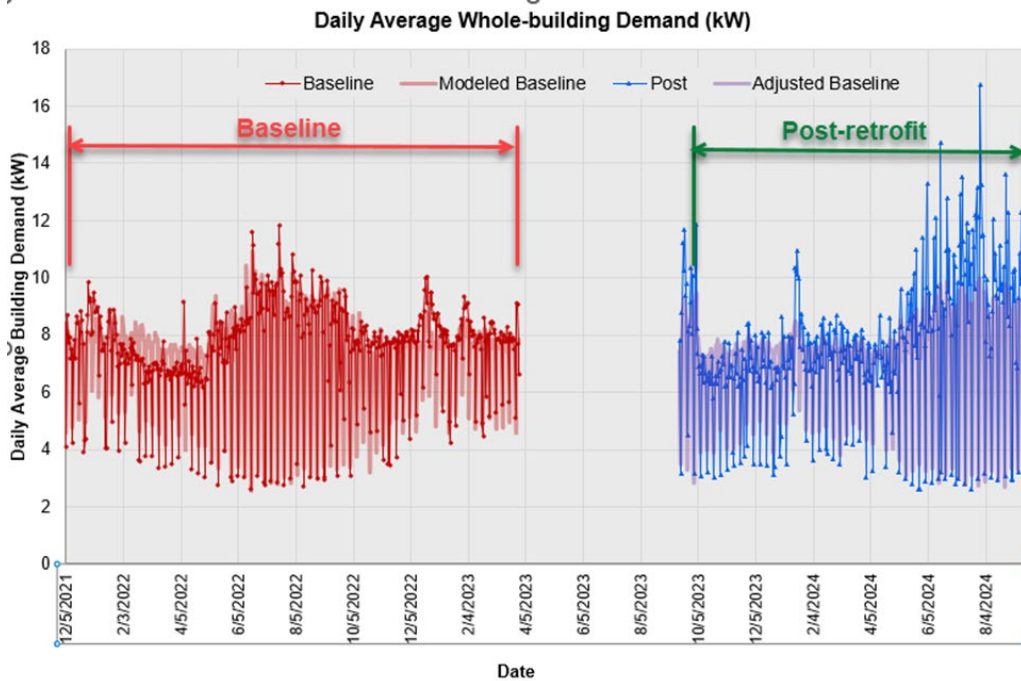


Figure 9. Champlin Library Daily Average Whole-building Demand Comparison



The calculated post-retrofit whole-building electric energy savings and statistics using the ECAM tool are shown in Table 4 below.

**Table 4. Electrical Energy Use Comparison – Champlin Library**

<b>Description</b>	<b>Value</b>	<b>Uncertainty</b>
Adjusted Baseline Energy (post-retrofit)	65,037 (kWh)	±1,027 (kWh) at 80% confidence level
Measured Energy (post-retrofit)	66,849 (kWh)	NA
Avoided Energy Use (post-retrofit)	-1,812 (kWh)	±1,027 (kWh) at 80% confidence level
Avoided Energy Use % (post-retrofit)	-2.8%	±1.6% at 80% confidence level

After applying energy models to calculate the “adjusted baseline energy”, post-retrofit energy use **increased by 2.8% (1,812 kWh)**, with an uncertainty of ±1.6% at 80% confidence.

### *Whole-building natural gas use*

The baseline period for natural gas energy analysis is from 9/1/2020 to 3/30/2023 and excludes the missing data period from January 2022 to August 2022. September 20, 2023, to August 30, 2024, is considered the post-retrofit period.

The chart below (Figure 10) shows the monthly whole-building natural gas usage in therms during the baseline and post-retrofit periods using the monthly data. There is a wide variance in the baseline period and limited sample data in the post-retrofit period.

Figure 11 shows the monthly natural gas usage vs. average monthly outside air temperature (for the monthly billing cycle) scatter plot comparing baseline and post-retrofit periods. Overall, monthly natural gas usage vs. average monthly outside air temperature is very similar except for some discrepancies in the coldest months.

To compare the pre- and post-retrofit whole-building natural gas use, the “adjusted baseline energy” in the post-retrofit period is calculated by applying the baseline monthly natural gas use model to the post-retrofit period’s monthly average outdoor air temperatures. Then, the post-retrofit period avoided energy use is calculated by subtracting the sum of “adjusted” natural gas monthly use from the sum of the actual natural gas monthly use in the post-retrofit period. The post-retrofit monthly whole-building natural gas usage comparison, actual vs. modeled, is shown in Figure 12. The calculated post-retrofit whole-building natural gas use comparison statistics using the ECAM tool are shown in Table 5 below.

Figure 10. Champlin Library Monthly Natural Gas Usage History

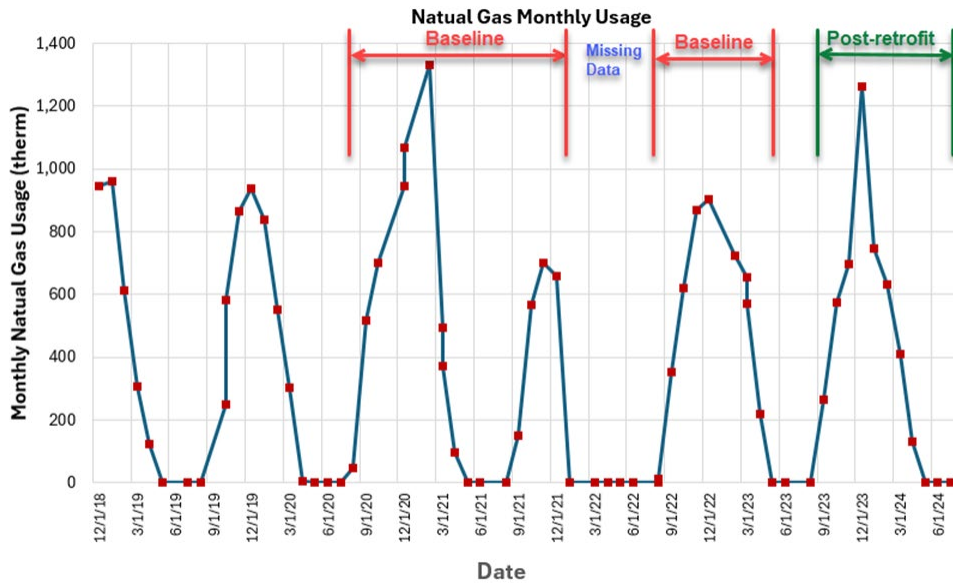


Figure 11. Champlin Library Monthly Natural Gas Usage Scatter Plot

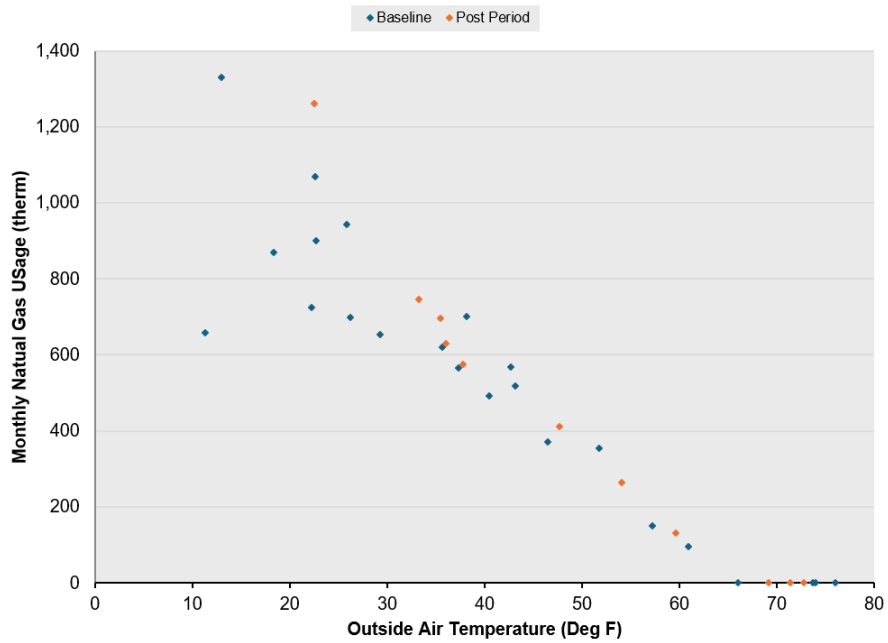


Figure 12. Champlin Library Monthly Natural Gas Usage Comparison

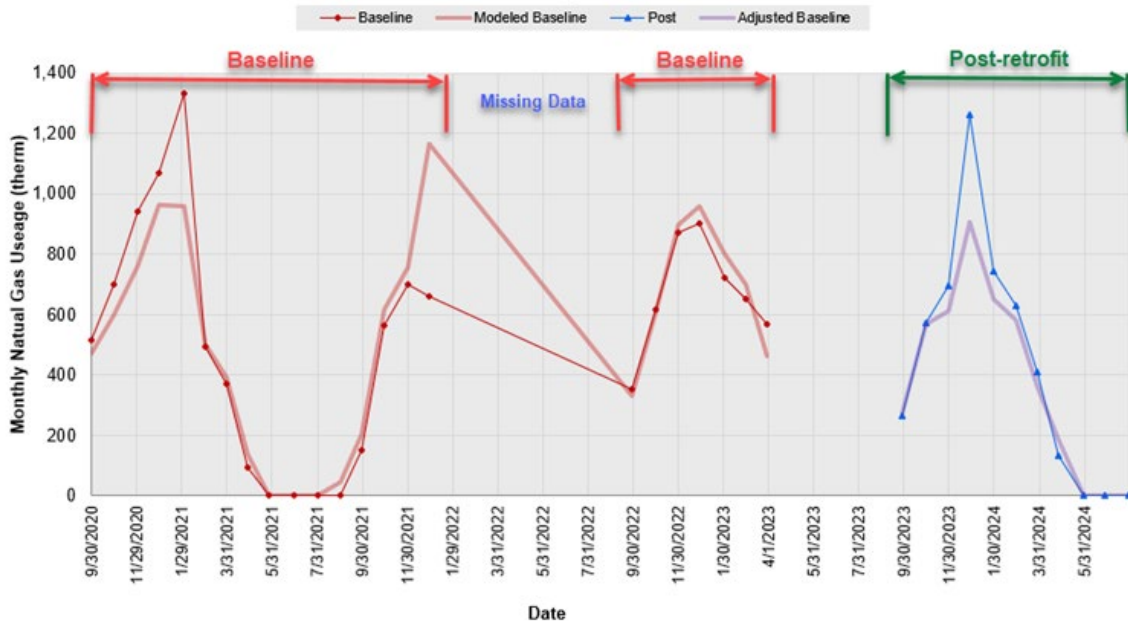


Table 5. Natural Gas Use Comparison – Champlin Library

Description	Value	Uncertainty
Adjusted Baseline Energy (post-retrofit)	4,149 (therms)	±850 (therms) at 80% confidence level
Measured Energy (post-retrofit)	4,716 (therms)	NA
Avoided Energy Use (post-retrofit)	-567(therms)	±850 (therms) at 80% confidence level
Avoided Energy Use % (post-retrofit)	-13.7%	±20.5% at 80% confidence level

After the weather normalization, it is determined that post-retrofit energy use **increased by about 13.7%** with about +/-20.5% uncertainty at an 80% confidence level. Because there is limited monthly data available, the uncertainty of the comparison is relatively large. From the historical monthly natural gas usage data collected in the past several years, the natural gas usage in the winter periods varied significantly.

## ASHRAE Guideline 36 Implementation Assessment

A summary of the ASHRAE Guideline 36 implementation assessment at Champlin Library is listed in Table 6.

Table 6. ASHRAE Guideline 36 Implementation Summary – Champlin Library

ASHRAE Guideline 36 Control Sequence	Assessment	Comments
AHU system modes (Occupied/Cooldown/Setup/Warmup/Setback/Unoccupied)	Different control modes and optimal start/stop were programmed, but not enabled or effective.	AHU On/Off was only operated based on a fixed schedule.
AHU supply fan control	Static pressure reset logic was implemented. However, the parameters were not tuned optimally, and the minimum setpoint was adjusted multiple times (Figure 13).	Recommended minimum setpoint setting is 0.15" w.c.
AHU supply air temperature control	The supply air temperature reset logic was implemented and proved effective during the summer (Figure 15). However, in winter, the setpoint had to be raised beyond the typical range of 55° and 65°F (Figure 14).	Due to an HVAC system design issue, this AHU needs to run at a high supply air temperature to compensate for insufficient heating at the zone level
AHU minimum outdoor airflow setpoints and control	Use a fixed minimum OA damper position (28%) to control minimum OA flow.	No airflow station or DP sensor to measure real-time OA flow.
AHU relief-fan or return-fan control	Return fan direct control building pressure implemented.	Building pressure data was not available to evaluate the quality of control.
AHU freeze protection	Implemented, but never triggered.	AHU-1 runs at high supply air temperature in winter.

ASHRAE Guideline 36 Control Sequence	Assessment	Comments
AHU air economizer high limits	Implemented and effective.	
AHU AFDD	Implemented	Not evaluated
VAV zone groups	Implemented, but not enabled or effective.	
Zone minimum airflow	Initially, they were based on existing HVAC design values, which could result in higher-than-needed airflow rates based on the latest building codes and standards.	Zone minimum airflow was recalculated by a third-party consultant in a later stage of the commissioning.
Dynamic zone minimum ventilation	Implemented using CO2 to dynamically reset the zone minimum.	All zone CO2 levels never reached the setpoint (1000 ppm)
VAV AHU cooling SAT reset requests	Implemented and effective	
VAV AHU supply air static pressure reset request	Implemented and effective	
VAV cooling-only logic	Implemented, but the airflow control loop in heating mode was either not tuned optimally or working effectively (Figure 16).	VAV 1,2, 4, and 5.
VAV constant-volume series fan-powered VAV logic	Implemented. Constant minimum airflow in heating mode.	VAV 3, 5, and 7.

Figure 13. Champlin Library AHU-1 Supply Air Static Pressure Minimum Setpoint – Post-retrofit

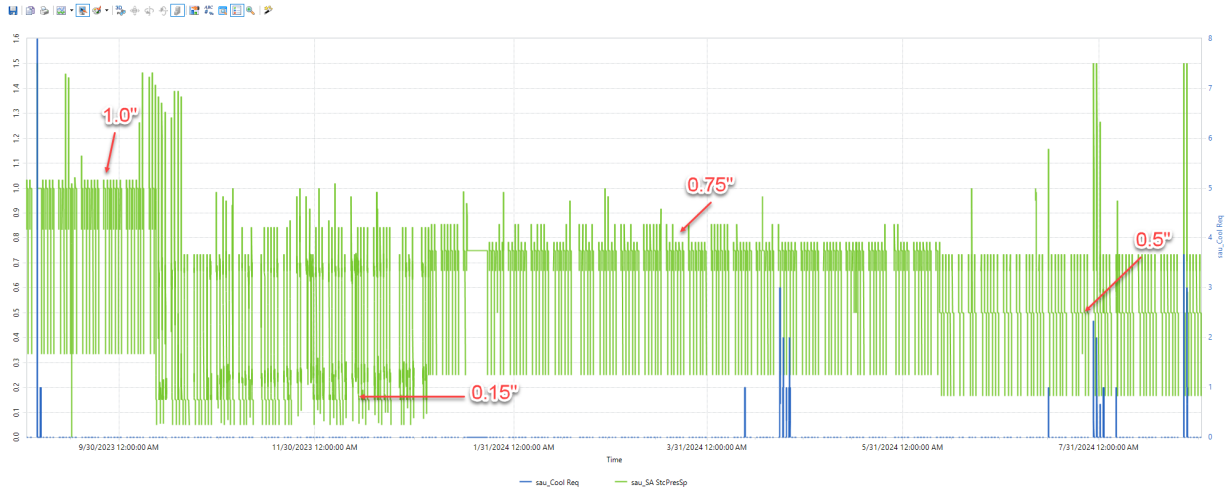
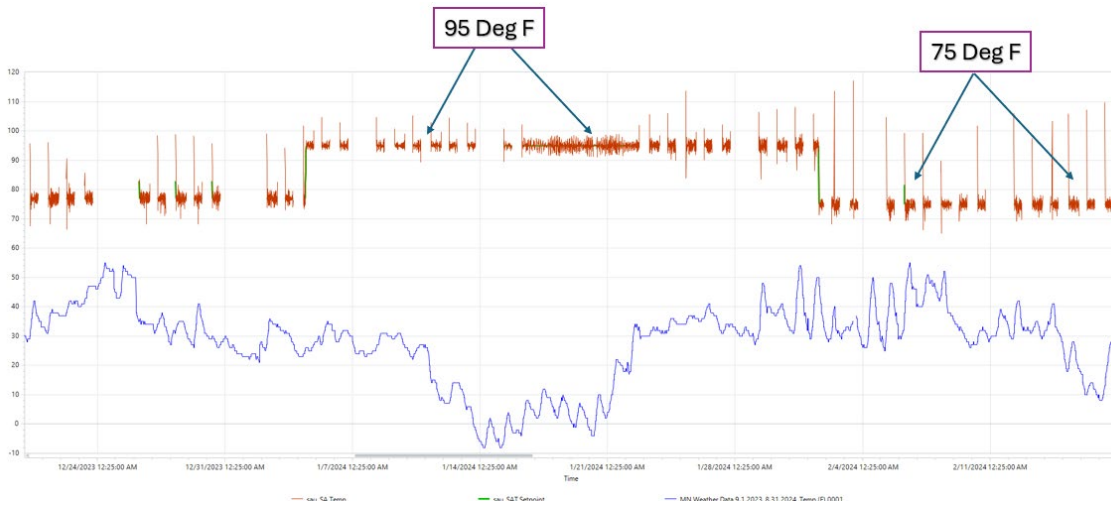
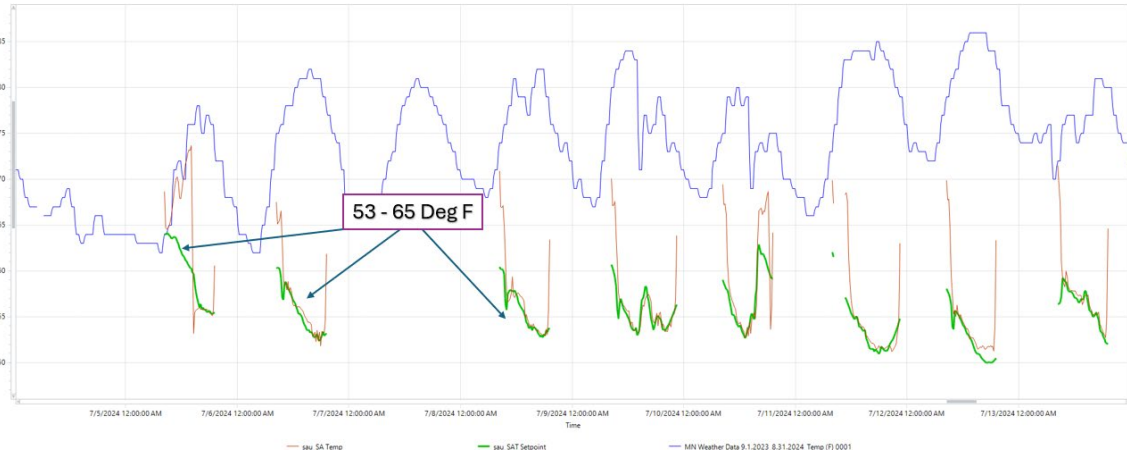


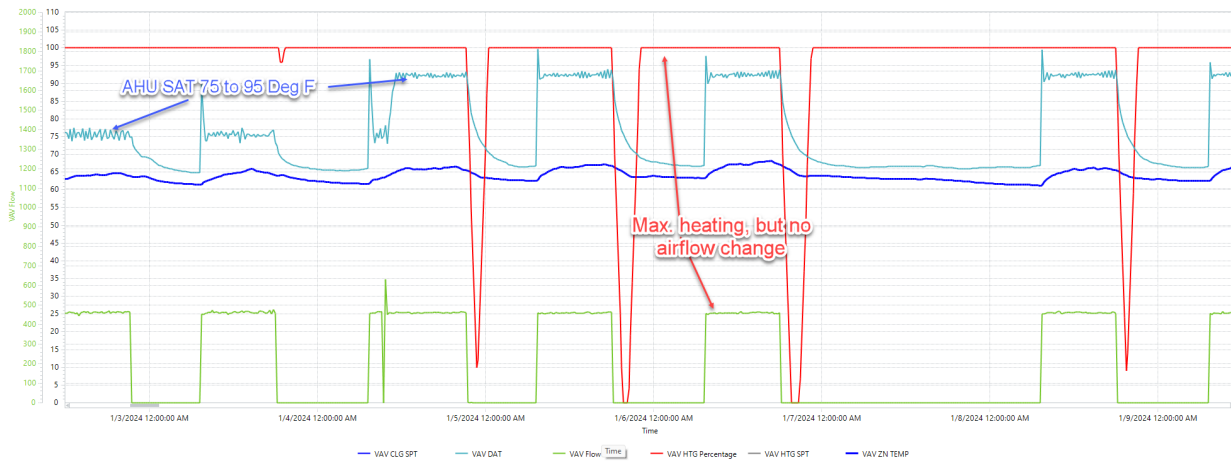
Figure 14. Champlin Library AHU-1 Supply Air Temperature Setpoint – Post-retrofit (Winter)



**Figure 15. Champlin Library AHU-1 Supply Air Temperature Setpoint – Post-retrofit (Summer)**



**Figure 16. Champlin Library VAV-1 Airflow Control – Post-retrofit (Winter)**



Overall, the controls contractor implemented ASHRAE Guideline 36 control logic on AHU-1 and its seven associated VAV terminal units largely as intended, with some adjustments made to account for the existing HVAC equipment and design limitations. However, the parameter tuning appears to be ineffective for certain control loops, and several key functions—such as Cooldown, Setup, Warmup, Setback AHU modes, and optimal start/stop—were not utilized. A significant concern is that this building’s AHU has historically been operated with an unusually high supply air temperature (up to 90°F) during cold winter conditions, likely due to insufficient reheat capacity in the zones served by AHU-1. Even after the retrofit, facility operators continue this operational strategy, which deviates from the intent of ASHRAE Guideline 36 but remains necessary to maintain acceptable zone conditions.

## Stakeholder interviews

- *Facility management interview*

The project team interviewed the facility management team about a year after the controls retrofit was completed. The questions were around the general experience with the control retrofit process implementing ASHRAE Guideline 36, user acceptance, change in O&M, occupant comfort, lessons learned, and suggestions for future improvements.

### *Overall experience*

The facility team mentioned that only the controls contractor and the commissioning agent were involved with implementing ASHRAE Guideline 36 in this project, and they did not hire a mechanical engineer or controls consultant to review the mechanical system and specify the new control sequences, thinking this was a straightforward simple system control hardware and software upgrade project, and existing control settings would not need to be changed. After the retrofit project was complete, there was not much change in the building operations and maintenance processes. Most of the time, the facility team's internal building controls engineer and technician were able to operate the new control system and resolve any issues themselves. The facility team was still tuning the system parameters and noticed that on some days, there was a drop in space temperatures, and occupants felt the space was too cold. They did not pay much attention to the Automated Fault Detection and Diagnostics (AFDD) features embedded in the ASHRAE Guideline 36 implementation at the site. The number of occupant complaints on comfort was similar to before the controls retrofit, and most of the complaints were from Winter dates. The general process to resolve these complaints is the same as before.

### *Lessons learned and suggestions*

In retrospect, the facility management team did not think Champlin Library was the right facility to try the ASHRAE Guideline 36 control sequences. The facility is very small, and the HVAC equipment is very old. It was way overcomplicated to implement the Guideline on such a small and old system. The biggest thing for the building owner was “keep it simple.” For small buildings, even if it could show some energy savings, it is not worth the effort to go through the complicated process.

- *Controls contractor interview*

Shortly after the completion of the controls retrofit, project team members interviewed the controls contractor about their experience with using Guideline 36 on this project. The controls contractor included both the field technician and project manager, as well as a representative from the BAS manufacturer who acted as a technical consultant and assisted in customizing the sequences specifically for the project.

The interview questions focused on the team members' previous control retrofit experience, both broadly and with Guideline 36 in particular, their experience with the process of

implementing Guideline 36 in this project, and their suggestions for how the Guideline itself and its application to projects could be improved in the future.

#### *Past experience with ASHRAE Guideline 36*

While the BAS manufacturer's consultant was quite familiar with Guideline 36, he noted that many of the company's field offices are only just now gaining exposure to it. This was reflected in the experience of the field technician and project manager, who indicated that this was their first time applying Guideline 36 sequences on a job.

When asked about their regular controls retrofit project process, the field technician indicated that controls (application) engineers at the company's regional office would typically use the manufacturer's software tools to build control graphics and apply standard sequences based on the mechanical schedules from the construction drawings first. They most often found the control drawings and sequences provided by the (mechanical) design engineer to be inconsistent, "hit or miss," and too incomplete to be useful as a basis for their work. The control sequences would then be customized and finalized by field technicians in the field.

When asked if they would use Guideline 36 sequences unprompted, when not otherwise specified, they indicated that they would be hesitant to do so until they were more familiar with them, but that they "could see getting there." In particular, they would be more inclined to choose Guideline 36 for a new build project or a retrofit with newer equipment, as opposed to a retrofit where existing equipment was being retained (as is the case with the Champlin Library project).

#### *Experience with this project*

The controls contracting team spoke positively of the Guideline 36 sequences at Champlin Library. They liked the Trim & Respond reset logic and found the Group Manager function in Guideline 36 valuable. However, they indicated that the process of actually investigating, installing, integrating, and commissioning the sequences took substantially longer than expected. Also, the Guideline 36 sequences are more complex than typical control sequences, 5-6 pages per HVAC equipment vs. 1-2 pages.

The primary reason for the longer-than-expected time and effort implementing ASHRAE Guideline 36 in Champlin Library is that the old HVAC equipment and system configurations in this building were not a perfect fit to readily apply ASHRAE Guideline 36. A lot of time was spent on customizing/editing the standard manufacturer ASHRAE Guideline 36 libraries due to the lack of required monitoring and control points. The existing HVAC equipment was described as "simple and basic," and preparing them for the Guideline sequences required installing additional temperature sensors (notably between the heating and cooling coils), airflow measurement stations, and new damper actuators, among other devices. In many cases, there was insufficient physical space to accommodate these installations, and there was no mechanical design engineer or controls consultant hired to review the existing equipment conditions or consider the accommodation that might be required to utilize the standard HVAC

configurations in ASHRAE Guideline 36 before the project started. The controls contractor was asked to simply comply with the ASHRAE Guideline 36-2018 in their control retrofit project by the building owner. This meant that sequence variations for different equipment configurations (e.g., return vs. relief fans) had not been selected and reconciled by a mechanical design engineer or controls consultant, leaving it to the controls contractor to interpret what was necessary based on the existing mechanical drawings and schedules. This significantly increased the time and effort burden on the contractor, but also upon the other team members (including the commissioning agent), as they did not have a proper conforming sequence to refer to during the preliminary stages of their work, and they lacked the previous experience implementing ASHRAE Guideline 36. It was a challenge for the controls contractor to create a full conforming sequence for submittal/records purposes.

More significantly, because the “Information Provided by the Designer” (i.e., Section 3.1 of Guideline 36) was not provided (by the specifying engineer), this forced the control contractor to guess the values that needed to be specified when the system was programmed, such as setpoints and minimum ventilation values, or use the existing building control system settings. While this situation is not uncommon in the context of control installation projects in general, the complexity of the Guideline 36 sequences means that picking setpoints by the “guess and approximate” method does not work well. Engaging a mechanical engineer or controls consultant to review existing HVAC drawings and site conditions, then perform code- and standard-based engineering analysis (including ASHRAE Guideline 36), may increase project cost and extend the schedule; however, it will streamline implementation and testing by reducing the controls contractor’s and commissioning agent’s effort.

#### *Suggestions for future improvement*

When asked about their experience of implementing the Guideline 36 sequences themselves, feedback was generally very positive. The controls contractor said that the depiction of the control charts, reset strategies, and operating state logic was clear and readily understood. They noted that the Trim & Respond logic was easy to work with, but it was important for the engineer of record to specify the Trim & Respond parameters – it was unreasonably burdensome to leave this for the controls contractor to figure out. They also noted that the effectiveness of some features, such as the automated fault detection, would require a longer post-installation period to evaluate. Likewise, the relatively small number of zones in the project made it relatively easy to detect rogue zones. Overall, they indicated that the sequences were well presented with clear intent and did a good job controlling the system, and that they looked forward to gaining more experience with the sequences on future projects. They did not have any suggestions for ways to improve the Guideline 36 sequences of operations.

Their suggestions for the improvement of implementing the ASHRAE Guideline 36 process focused almost entirely on the engineering and specification process that preceded the controls installation process. They wished that an engineer of record had been hired and had fully embraced their role by providing a fully conformed set of sequences. Such a document – edited specifically for the HVAC system and equipment that was present on the site – would have made

it much easier for them to understand the scope of work. More significantly, providing all of the information and setpoints requested in Section 3.1 of the Guideline (“Information Provided by the Designer”) would have saved them a great deal of time that was spent determining this information mid-project. They also wished that, in the process of reviewing the on-site equipment and developing a conforming set of sequences, the specifying engineer would have taken into consideration the physical limitations of the existing equipment in terms of additional sensors, actuators, and other control devices. They felt that a modest up-front investment of time and effort (by hiring a specifying engineer) would have saved them many hours of interrupted and inefficient execution during the new control system installation process.

- *Commissioning agent interview*

Shortly after the completion of the commissioning process in the summer of 2023, project team members interviewed the commissioning agent about his experience with Guideline 36 on this project. As with the controls contractor, this interview focused on the agent’s previous experience with Guideline 36, his experience with commissioning the sequences at the Champlin Library, and his feedback and suggestions for how the process could be improved.

*Past experience*

The commissioning agent for this project is an experienced individual who has commissioned many buildings over his career. While this was his first experience with the Guideline 36 sequences, he indicated that most of the concepts and strategies involved were ones he had seen before.

*Experience with this project*

The agent’s approach to commissioning can be described as reasonably comprehensive. He performed point-to-point verification of all points (not just a sampling), script-based functional testing, and trend reviews. He also tested select parts of the Guideline sequences, including Trim & Respond, demand-controlled ventilation, and hierarchical fault suppression, by observing responses to BAS overrides. He expressed interest in returning for additional testing in the alternate (winter) season. He did note that every commissioning agent does this process slightly differently. Somewhat alarmingly, he said that “half” of the commissioning agents in the local area would not touch the BAS, meaning that a typical project in the region would be subject to much less rigorous testing and verification.

He consistently noted that the commissioning process for this project took significantly longer than would normally be expected for a project this size. He placed some of this upon the length and complexity of the Guideline 36 sequences themselves. He also expressed a desire for up-front effort and more internal quality checks on the part of the controls contractor and programmer, noting in particular that some time was lost due to programs that were initially delivered with incorrect building monitoring and control point “labels” in the control contractor’s programs, due to the lack of internal quality control.

His most consistent complaint, however, was about the engineering, or lack thereof. He noted that for a retrofit project of this sort, it is often assumed that no engineer is required at all, with the project treated from a technical perspective as a simple substitution of new for old. While that is arguably a poor practice, the complexity of Guideline 36 makes that approach entirely unviable.

Echoing much of the controls contractor's experience, the commissioning agent said that a lack of preliminary engineering design and documentation led to a great deal of delay and iteration during the installation and commissioning process. He said that the absence of engineering records led to "many back and forth" communications with the county and the owner. He noted in particular delays that arose from a lack of planning around the installation of new airflow measurement stations. He also spoke, again echoing the controls contractors, specifically of the need for the engineer of record to provide a fully conformed sequence of operations with all the required setpoints and other variables specified as called for in the Guideline.

Project commissioning documents described another significant challenge that arose from insufficient project engineering. Specifically, the existing mechanical equipment (VAV terminal units) was not adapted to the Guideline 36 dual-max VAV logic and SAT reset strategy. The zone ventilation minimums were retained from their historical values, set as a percentage of the cooling maximum airflow, and thus higher than what was required for ventilation. This, coupled with a seasonal lockout of the boiler, resulted in overcooling of several zones when the SAT setpoint was reset based on a high outdoor temperature. This would have been avoided if the engineer had recalculated the zone minimum airflow setpoints to actual ventilation requirements, as Guideline 36 recommends. In the later stage of the commissioning, the building owner hired a consultant to recalculate the zone minimums.

#### *Feedback and suggestions*

Overall, the commissioning agent's feedback strongly echoed that of the controls contractor: A modest additional investment of time and effort on the part of the engineer of record would have saved a great deal of time and effort on the part of the installation and commissioning team, and would have sped up the completion and turnover of the project. However, he also reiterates that Guideline 36 is fundamentally more complex than the typical sequence of operations that have come before it, and that commissioning budget and timeline expectations must be adjusted accordingly. He also suggested that controls contractors could do a better job on internal quality control, so the control sequences implemented in the field do not have basic errors like wrong control point labels. Any automated commissioning tools or scripts would be very helpful in expediting the testing process. Finally, a simplified version of the control sequence at the concept level would help building owners and operators understand the intent of the sequence, rather than a carbon copy of relevant sections in ASHRAE Guideline 36.

# Central Library

## Energy Savings Analysis

### AHU S-7 Supply and Return Fan

The AHU S-7 supply fan power history chart for both the pre-retrofit / baseline period and the post-retrofit period is shown in Figure 17. The AHU S-7 return fan power history chart for both the pre-retrofit / baseline period and the post-retrofit period is shown in Figure 18. The post-retrofit pattern for the return fan power does not show a seasonality change, which is not typical.

Figure 17. Central Library AHU S-7 Supply Fan Power History Chart

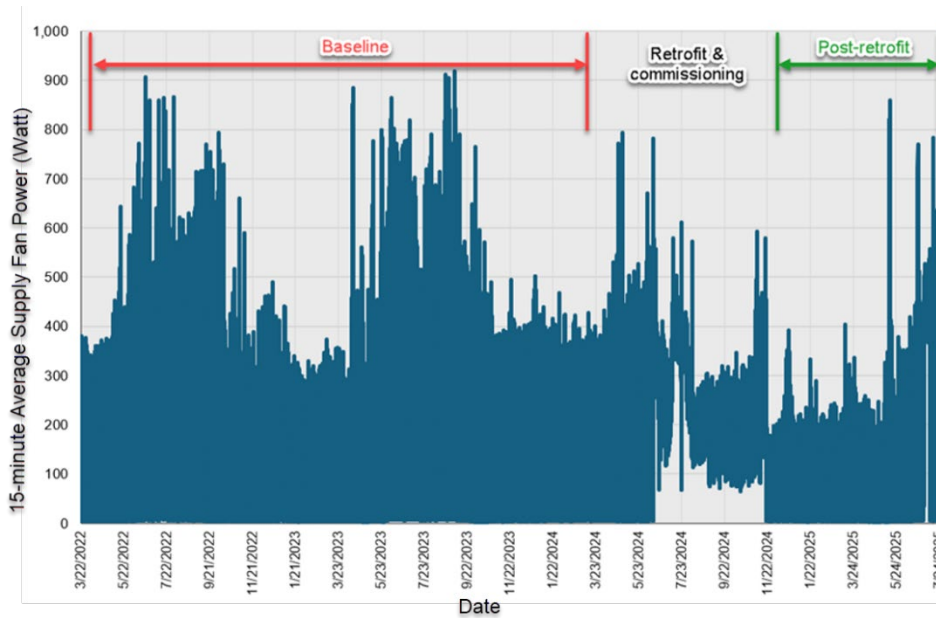
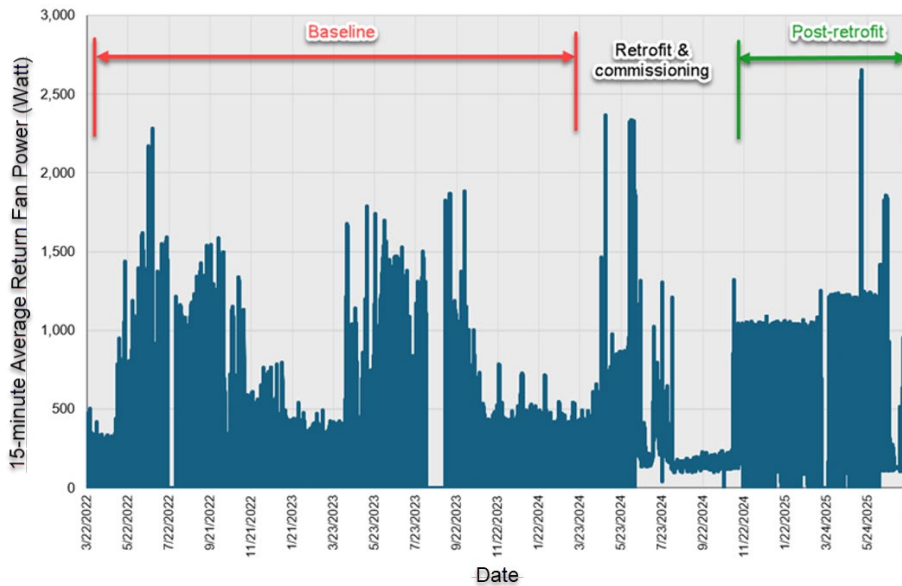


Figure 18. Central Library AHU S-7 Return Fan Power History Chart



Hourly supply fan and return fan power profiles were created for each day of the week during both the pre-retrofit and post-retrofit periods to study the changes in fan operations and fan power. They are shown in Figure 19 to Figure 22. By reviewing these charts, we can see that:

- In the baseline period, the supply fan power seems varied based on the following schedule: Monday, fan on from 7:00 am to 2:30 pm with an average about 350 watt; Tuesday to Friday, fan on from 7:00 am to 5:00 pm with an average of 400 watt; Saturday, fan on from 9:00 am to 3:00 pm and with an lower average power of 200 watt; and Sunday, fan off all day. However, in the post-retrofit period, there was a significant change in both the supply fan power value and the fan operating schedule. The supply fan was on every day from 5:00 am to 10:00 pm with an average of 220 watts.
- In the baseline period, the return fan power seems varied based on the similar schedule for the supply fan: Monday, fan on from 7:00 am to 2:30 pm with an average about 480 watt; Tuesday to Friday, fan on from 7:00 am to 5:00 pm with an average of 550 watt; Saturday, fan on from 9:00 am to 3:00 pm and with a lower average power of 320 watt; and Sunday, fan off all day. In the post-retrofit period, the return fan was on every day from 5:00 am to 10:00 pm with an average of 200 watts. The fan was also unexpectedly run between 10:30 pm and 5:00 am every day, with an average of 1000 watts. This is also a very unusual operation. In normal operations, the return fan should be off when the building is unoccupied.

The atypical operating behavior of AHU S-7's supply and return fans observed during the post-retrofit period suggests that the HVAC equipment scheduling may not have been properly implemented or optimized, or that the return fan control logic experienced issues when the fan command was in the OFF state.

Figure 19. Central Library AHU S-7 Supply Fan Power Hourly Profile - Baseline

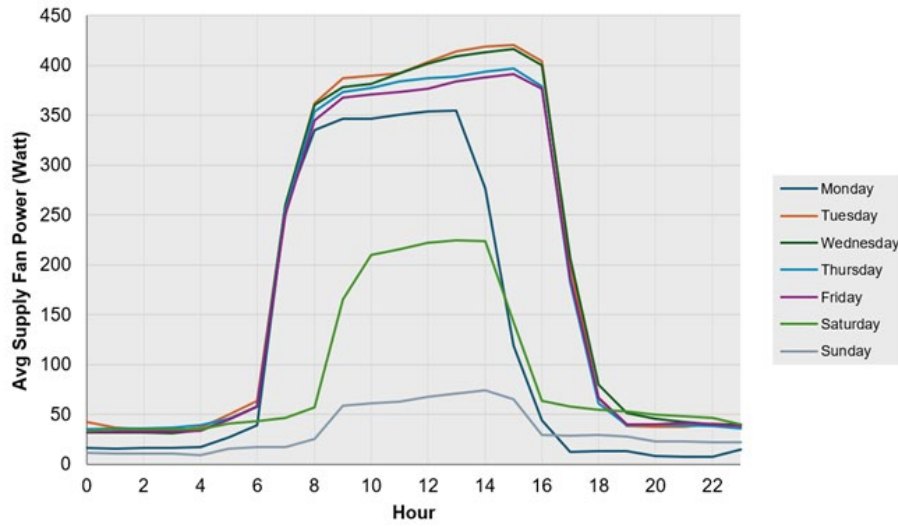


Figure 20. Central Library AHU S-7 Supply Fan Power Hourly Profile – Post-Retrofit

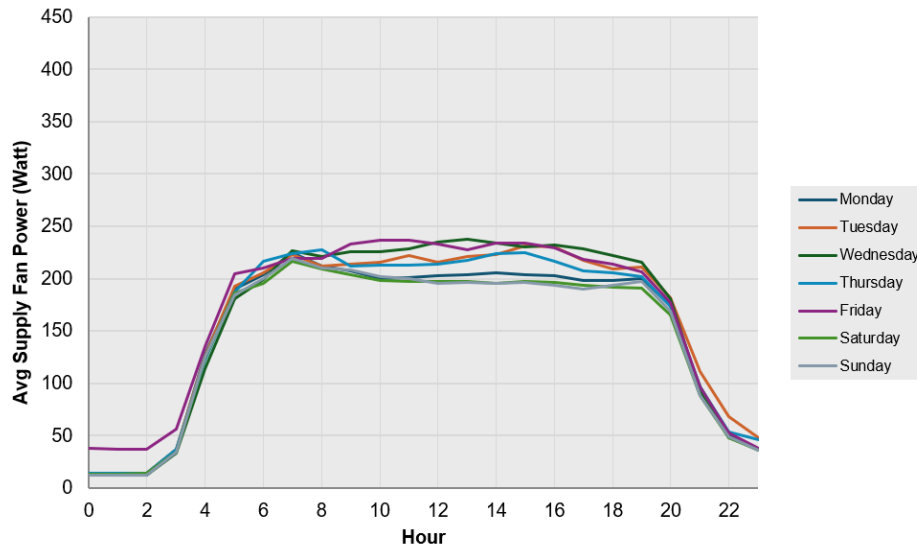


Figure 21. Central Library AHU S-7 Return Fan Power Hourly Profile – Baseline

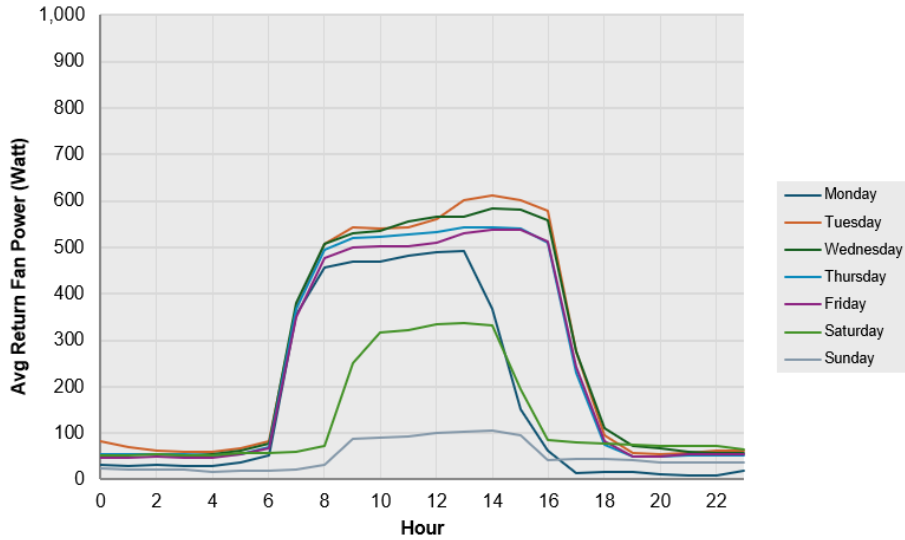


Figure 22. Central Library AHU S-7 Return Fan Power Hourly Profile – Post-Retrofit

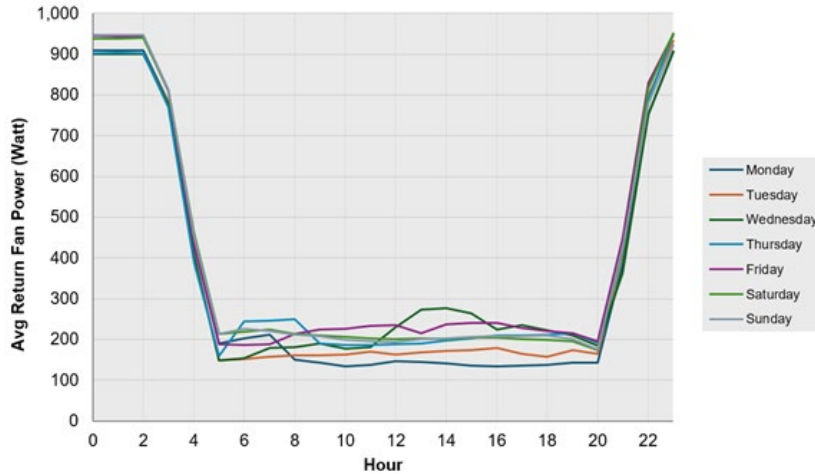


Figure 23 and Figure 24 are the supply and return fan power scatter plots comparing baseline and post-retrofit periods.

For the supply fan, the scatter charts for both the baseline and post-retrofit periods generally follow a typical ASHRAE 3-point inverse model, which is a type of change-point regression model used to analyze building energy consumption based on outside air temperature. When the outside air temperature is above a certain threshold, the fan power increases proportionally with the outside air temperature. When it falls below a certain temperature, the fan power becomes a constant. The average hourly supply fan powers for the post-retrofit period are generally lower than those from the baseline period.

For the return fan, the scatter chart for the baseline period generally follows the same ASHRAE 3-point inverse model. However, the post-retrofit period pattern is not typical. The return fan power in the post-retrofit period does not show a strong correlation with the outside air temperature, indicating its unusual operations. In general, the average return fan power is also higher than that in the baseline period.

Figure 23. Central Library AHU S-7 Supply Fan Average Hourly Power Scatter Plot

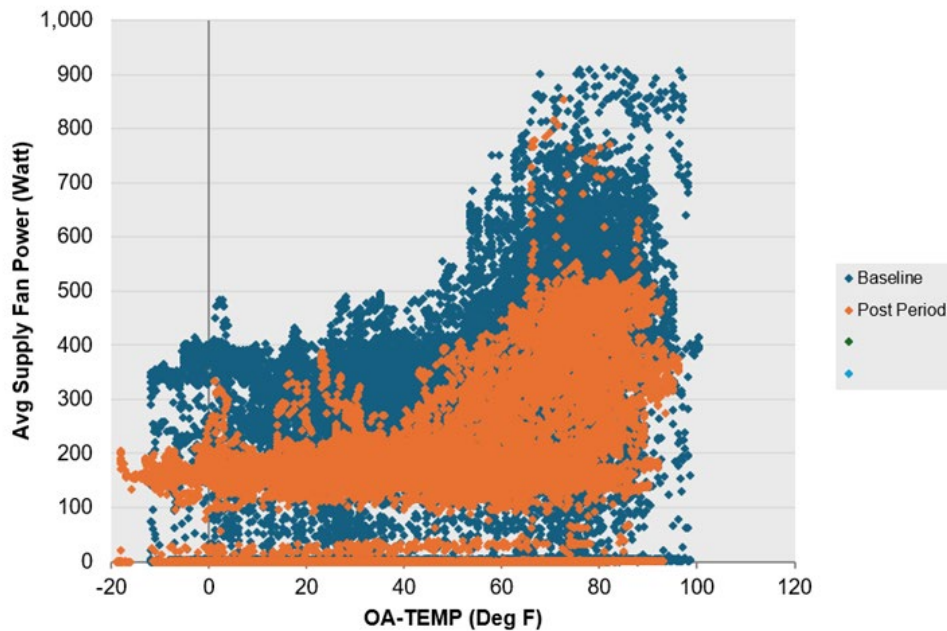
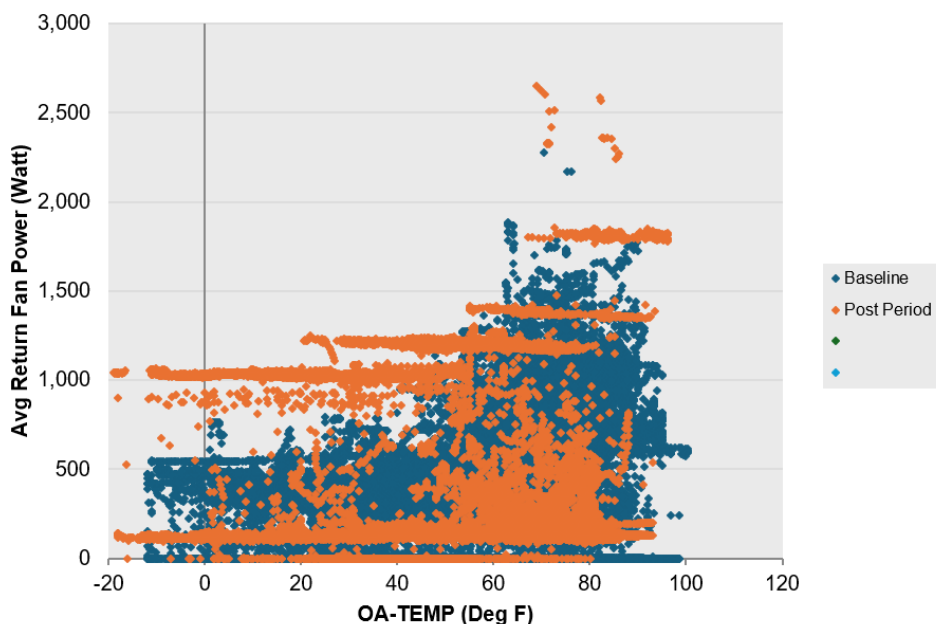


Figure 24. Central Library AHU S-7 Return Fan Average Hourly Power Scatter Plot



After applying the baseline supply fan power model (Appendix D: Champlin Library Energy Models) to the post-retrofit period weather conditions, we can obtain the “adjusted baseline” supply fan power for the post-retrofit period. Figure 25 illustrates the baseline and post-retrofit daily supply fan power comparison, including the adjusted baseline predicted using the baseline supply fan power model and the weather conditions during the post-retrofit period. On average, the post-retrofit daily supply fan powers are slightly higher than the adjusted baseline supply fan power.

While the baseline daily return fan power model (Appendix D: Champlin Library Energy Models) for weekdays exhibits the typical ASHRAE 3-point model pattern, the post-retrofit period return fan model deviates from this behavior. By applying the baseline return fan power model to the post-retrofit period weather data, an 'adjusted baseline' for return fan power during the post-retrofit period can be established. Figure 26 presents a comparison between the baseline and post-retrofit daily return fan power, including the adjusted baseline prediction. On average, post-retrofit daily return fan power is significantly higher than the adjusted baseline, as the return fan operates nearly continuously and at elevated power levels during unoccupied hours between 10:30 p.m. and 5:00 a.m.

**Figure 25. Central Library AHU S-7 Supply Fan Daily Power - Adjusted Baseline vs. Post-Retrofit**

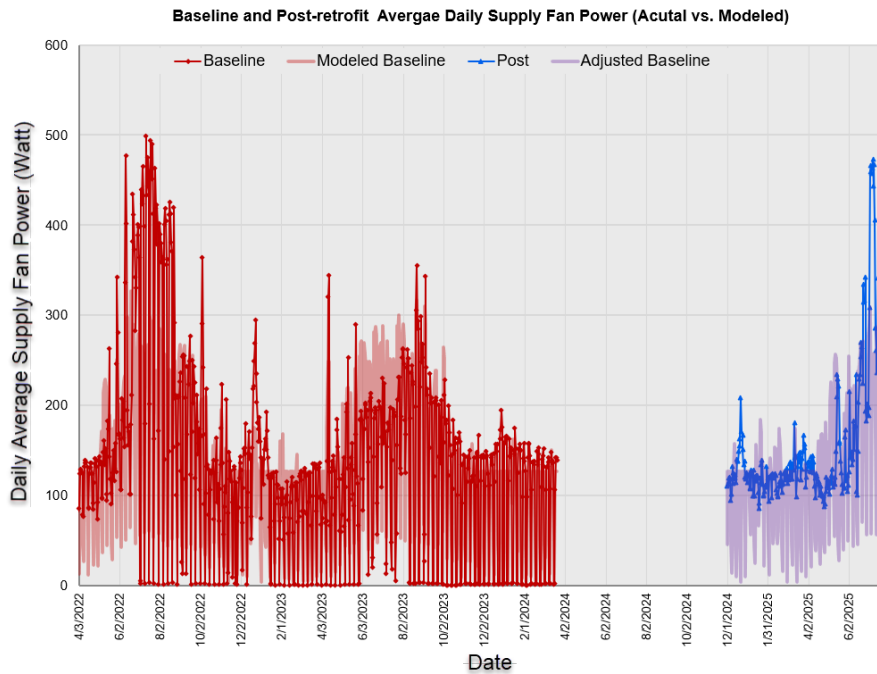
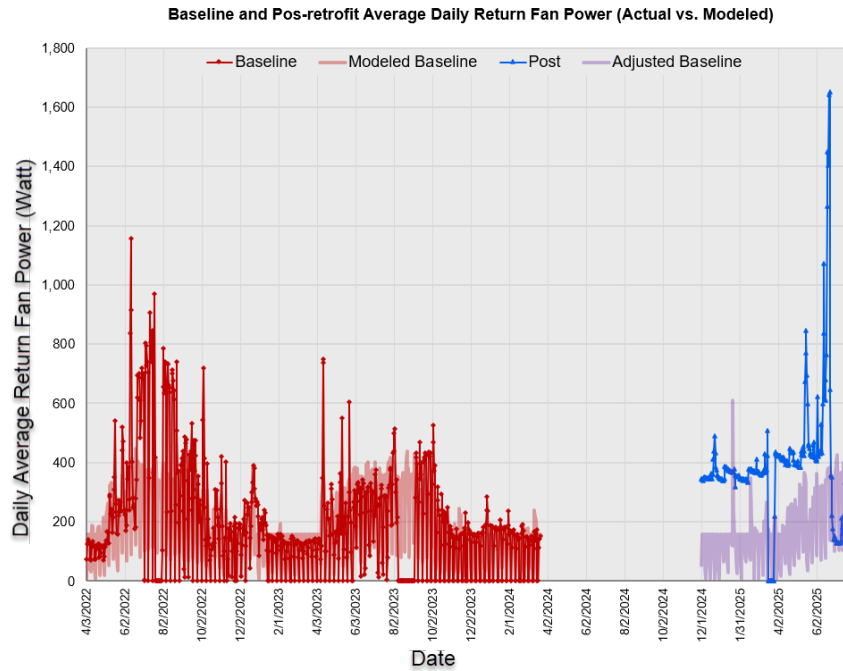


Figure 26. Central Library AHU S-7 Return Fan Daily Power - Adjusted Baseline vs. Post-Retrofit



By comparing the measured supply fan energy used in the post-retrofit period with the adjusted baseline supply fan energy, the supply fan energy in the post-retrofit period used **16% more energy** (Table 7.) The adjusted baseline uncertainty at a 90% confidence level is about 10.1%.

Table 7. AHU S-7 Supply Fan Energy Use Comparison – Central Library

Description	Value	Uncertainty
Adjusted Baseline Energy (post-retrofit)	772.5 (kWh)	±77.9 (kWh) at 90% confidence level
Measured Energy (post-retrofit)	895.9 (kWh)	NA
Avoided Energy Use (post-retrofit)	-123.4 (kWh)	±77.9 (kWh) at 90% confidence level
Avoided Energy Use % (post-retrofit)	-16.0%	±10.1% at 90% confidence level

By comparing the measured return fan energy used in the post-retrofit period with the adjusted baseline return fan energy, the return fan in the post-retrofit period used **104% more energy**. The adjusted baseline uncertainty at a 90% confidence level is about 18.0%.

**Table 8. AHU S-7 Return Fan Energy Use Comparison – Central Library**

<b>Description</b>	<b>Value</b>	<b>Uncertainty</b>
Adjusted Baseline Energy (post-retrofit)	1,080.7 (kWh)	±194.7(kWh) at 90% confidence level
Measured Energy (post-retrofit)	2,207.9 (kWh)	NA
Avoided Energy Use (post-retrofit)	-1,127.2 (kWh)	±194.7 (kWh) at 90% confidence level
Avoided Energy Use % (post-retrofit)	-104.3%	±10.1% at 90% confidence level

## Implemented Control Sequence Comparison to ASHRAE Guideline 36

For this project, a very experienced building energy consultant was hired to specify the building control sequences and commission the building control retrofit project performance. He is a professional engineer and a certified building commissioning professional. However, his view on ASHRAE Guideline 36 can be summarized as “too complex, doomed to fail.” He provided a control sequence for the AHU S-7 and ten associated VAV terminal units on the 4<sup>th</sup> floor that was much simpler than the ASHRAE Guideline 36 sequence, and Slipstream provided a custom control sequence created using the ctrl-flow<sup>3</sup> high-performance controls design tool. The controls contractor was asked to compare the two versions and incorporate the ASHRAE control sequences as much as possible in the project programming and testing.

The energy consultant’s version of the control sequence contains some elements of the energy-saving concepts in the ASHRAE Guideline 36, such as AHU supply air static pressure reset and temperature reset, but the detailed sequences differ. The control contractor also got the Johnson Controls ASHRAE Guideline 36 library for AHU and VAV terminal units from a local distributor and used the library for VAV terminal units programming. For the AHU control sequence, the controls contractor programmed in both the AHU field controller and the supervisory layer of the Tridium Niagara framework.

Because of the way the control sequence was specified and implemented, the project did not qualify for a full ASHRAE Guideline 36 implementation. The following Table 9 assesses if the key control sequence in ASHRAE Guideline 36 was implemented in this project.

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<sup>3</sup> <https://ctrl-flow.lbl.gov/>

Table 9. Implemented Control Sequence Comparison to ASHRAE Guideline 36 – Central Library

ASHRAE Guideline 36 Control Sequence	Assessment	Comments
AHU system modes (Occupied/Cooldown/Setup/Warmup/Setback/Unoccupied)	Not implemented.	AHU On/Off mode only, and is based on a fixed schedule.
AHU supply fan control	The static pressure reset concept was implemented, but the minimum was set too high (0.75 in. w.c.)	Recommended minimum setpoint setting is 0.15 in. w.c.
AHU supply air temperature control	The supply air temperature reset logic was implemented, but different than that in ASHRAE Guideline 36. The temperature control quality was not good. The reset ranges are also different from the recommended range.	Perhaps due to a bad control valve or no hot water/chilled water supplied on some days.
AHU minimum outdoor airflow setpoints and control	Used a fixed minimum OA damper position (20%) to control minimum OA flow. Not an option in ASHRAE Guideline 36.	No airflow station or DP sensor to measure real-time OA flow.
AHU relief-fan or return-fan control	Return fan to control building pressure is specified. No BAS data was available to evaluate the performance.	
AHU freeze protection	A different freeze protection logic was specified.	
AHU air economizer high limits	Economizer is implemented. No data available to evaluate the high limit lockout.	
AHU AFDD	Not specified.	

ASHRAE Guideline 36 Control Sequence	Assessment	Comments
VAV zone groups	Not specified.	
Dynamic zone minimum ventilation	Implemented using CO2 to dynamically reset the zone minimum.	All zone CO2 levels never reached the setpoint (1000 ppm)
VAV AHU cooling SAT reset requests	Implemented, but not exactly as specified in ASHRAE Guideline 36.	Based on zone temp vs. setpoint only.
VAV AHU supply air static pressure reset request	Implemented, but not exactly as specified in ASHRAE Guideline 36.	Any two VAV damper positions > 95%, reset to maximum setpoint.
VAV with reheat dual-max logic	A different version of dual-max logic was specified and implemented (Figure 29).	The heating max airflow setpoint increases with VAV discharge air temperature (when it exceeds 85°F)
VAV with radiant heating	This VAV configuration is not available in ASHRAE Guideline 36	

As shown in Figure 27 and Figure 28, AHU S-7 supply air temperature was not controlled well or at all on some winter and spring days, though the supply air temperature setpoint did show some reset logic during the occupied period.

Figure 27. Central Library AHU S-7 Supply Air Temperature Control - Winter

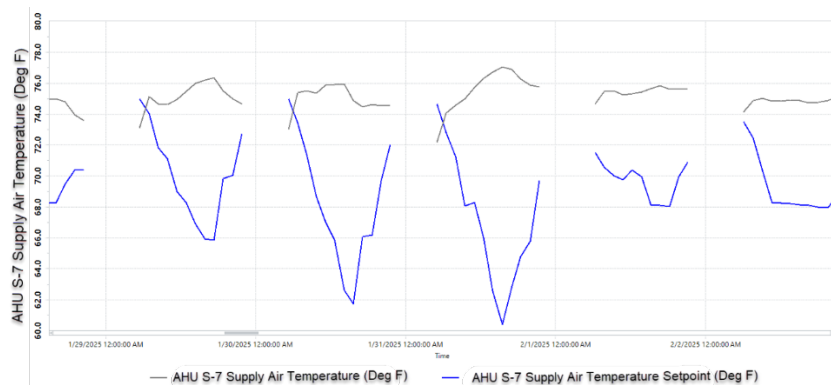
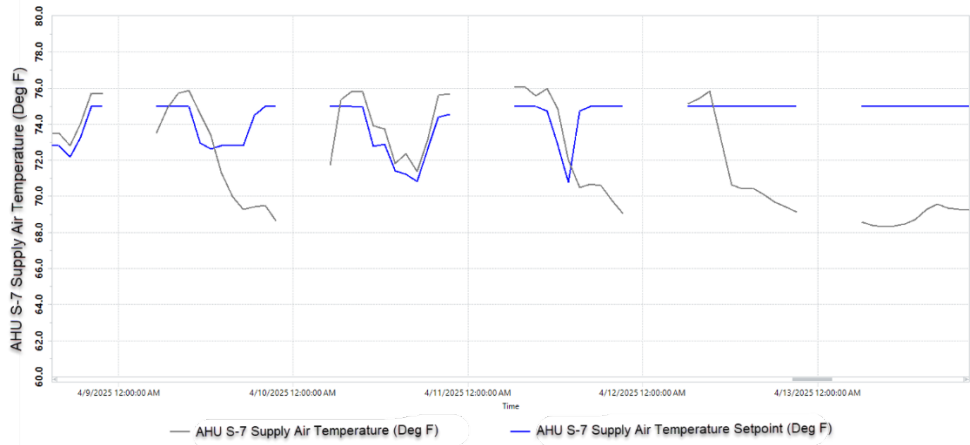
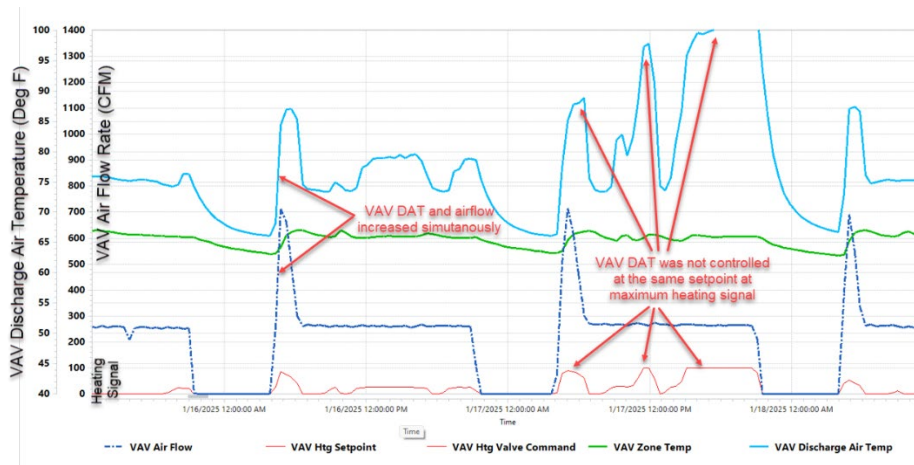


Figure 28. Central Library AHU S-7 Supply Air Temperature Control – Spring



For the VAV terminal unit with reheat control, ASHRAE Guideline 36 uses the “dual-max control” logic, which introduces two independent maximum airflow settings: cooling maximum airflow and heating maximum airflow. In heating mode, the system starts with minimum heating airflow and modulates the reheat coil (hot water or electric) to increase the VAV discharge air temperature up to a specified constant maximum VAV discharge air temperature (DAT) setpoint. If the space requires additional heating beyond what can be provided at minimum flow, the damper gradually opens up to the heating maximum airflow. Figure 29 indicates that the implemented VAV control sequence showed some dual max control behavior, but not exactly as described in ASHRAE Guideline 36. In heating mode, the VAV DAT and airflow rate increase simultaneously, and the VAV DAT was not controlled at a specified constant setpoint when the heating signal (heating valve command) reached 100%.

Figure 29. Central Library VAV Dual Max Control – Winter



Overall, the control sequence specified and implemented was not exactly in ASHRAE Guideline 36, but some key energy savings measure concepts were in the specification. The main issues for this controls retrofit project were that there were some mechanical issues found that needed to be fixed during the

retrofit, such as AHU heating and cooling control valves that were not working and needed to be replaced. At the time of this writing, the project was still not fully accepted by the building owner.

## *Stakeholder interviews*

- *Facility management interview*

The project team interviewed the facility management team in September 2025 - about 9 months after the controls contractor claimed to have completed the 4th-floor retrofit. The questions focused on the general experience with the control retrofit process, user acceptance, changes in operation and maintenance (O&M), occupant comfort, lessons learned, and suggestions for future improvements.

### *Experience with this project*

The facility team expressed disappointment that the energy consultant did not incorporate ASHRAE Guideline 36 control sequences into the project specifications for the 4th-floor HVAC equipment. They explained that the building and its mechanical systems are outdated, with multiple issues that require resolution before further upgrades can proceed. The team anticipated the full building controls retrofit would be commissioned and completed by the end of 2025.

In early July 2025, the building experienced a cybersecurity incident that may have caused local network disruptions and was still being addressed at the time of the interview. Following the claimed completion of the 4th-floor controls retrofit, there was little change in overall building operations and maintenance procedures. However, resolving existing mechanical and controls deficiencies has already led to improved performance. The building operator can now automate certain daily operations and only needs to check the BAS interface once per day. As of this report, the controls contractor continued to refine and modify the BAS for other parts of the building.

The number of occupant complaints regarding thermal comfort was down in the post-retrofit period compared to pre-retrofit levels. The general process for addressing these complaints remained the same as before the retrofit.

- *Controls contractor interview*

The project team members interviewed both the project manager and the field technician about their experience with applying Guideline 36 on this project. The interview questions focused on their experience with the process of implementing Guideline 36 in this project, and their suggestions for how the implementation process could be improved in the future.

### *Past experience*

The controls contractor manager leads a small team of three to four field controls technicians and one controls engineer. He was personally familiar with ASHRAE Guideline 36 before this project, though most of his team members were not. He had implemented Guideline 36 once previously, based on sequences provided by a consulting engineer who had customized the standard ASHRAE Guideline 36 sequences.

For typical projects, he uses Johnson Controls (JCI) predefined system templates for AHUs, VAVs, fan coils, heat pumps, and multizone systems, etc., and then programs additional energy-saving sequences—such as AHU supply air temperature and static pressure reset—at the supervisory level Tridium Niagara platform, which is very common in many BAS. Building control communication between Niagara supervisory controllers and JCI field controllers occurs through BACnet integration.

If not following Guideline 36, he would still apply key energy efficiency strategies like trim and respond, zone grouping, and AHU supply air temperature reset strategies, though he might skip the VAV discharge temperature reset, a part of the dual-max control algorithms for VAV terminal units with reheat.

### *Experience with this project*

The project manager said he used the JCI ASHRAE Guideline 36 library in this project, but found it complex and difficult to navigate due to numerous configuration options in the Guideline 36 library with limited explanations in the documentation. He suggested that JCI should provide better documentation or training videos. He obtained the JCI software package through a local building control software distributor rather than directly from the BAS manufacturer and typically implements the specifying engineer's version of Guideline 36 rather than the verbatim ASHRAE Guideline 36 control sequences.

In his experience, implementing ASHRAE Guideline 36 significantly increased programming and setup time because of the learning curve and complexity. Although programming efficiencies may improve with experience, the first few projects require more time. The project manager noted that control contractors often face timeline pressure to complete projects quickly and move on to new ones.

In this project, the Guideline 36 implementation required major controller hardware upgrades. The old Programmable Controller – VAV (PCV) model was replaced by a newer Configurable VAV Modular (CVM) model, which was first released in 2013. The old Programmable Controller – General Purpose (PCG) model for AHU control was replaced with a newer Configurable General Purpose Modular (CGM) model, which was first released in 2021. The controls retrofit also needed to add a VAV discharge air temperature sensor for each of the ten VAV terminal units to implement dual-max control logic, as required by Guideline 36.

The implementation was nearly complete at the time of the interview, based on the controls contractor, though there were still a few ongoing mechanical issues. The project manager noted that the energy consultant was expected to review and evaluate system performance once those issues were resolved. He identified mechanical issues and testing and balancing (TAB) processes as major factors affecting the control retrofit implementation schedule. Often, similar to any building control retrofit project, building owners are unaware of pre-existing mechanical problems until discovered during the control retrofit phase.

*Suggestions for future improvements*

The controls contractor suggested that JCI should provide better documentation or training videos for its ASHRAE Guideline 36 library.

## Market Research Report

This section of the report describes project activities related to market research on ASHRAE Guideline 36 implementations beyond the field demonstrations in Minnesota. This includes market research for implementing ASHRAE Guideline 36 using the traditional approach and the ASO approach.

### The Traditional Approach

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#### Target users

The primary users of ASHRAE Guideline 36 include HVAC system designers / mechanical engineers, building controls specifiers, controls engineers and technicians, commissioning agents, and building operators or facility managers. HVAC system designers and controls specifiers can apply the guideline when developing control sequence requirements and writing project specifications. Controls engineers and technicians can use the detailed logic and implementation guidance to program, tune, and verify HVAC control sequences in the field. Most major BAS manufacturers now offer built-in ASHRAE Guideline 36–based libraries, providing engineers with standardized starting points that help reduce programming, debugging, and field adjustment time. Commissioning agents can reference the guideline to confirm that control logic and operation sequences align with project intent during startup and functional testing. Finally, building operators and facility management teams can use it to better understand the design intent and operational logic behind the installed control systems. In summary, ASHRAE Guideline 36 serves as a valuable reference for all stakeholders involved in HVAC control design, implementation, and optimization throughout new construction or retrofit projects.

#### Typical building control retrofit process

A typical building control retrofit/upgrade project process involves several key steps: 1) needs assessment; 2) planning and design; 3) selection of vendors and contractors; 4) project implementation; 5) testing and commissioning; 6) training, documentation, and project acceptance. For a detailed summary of each of these steps, please refer to the “Introduction” chapter of this report.

#### Incorporating ASHRAE Guideline 36

In the “Introduction” chapter, we also outlined the key steps in incorporating ASHRAE Guideline 36 in a traditional controls retrofit project. In the “Field Demonstration Results” chapter, we presented detailed ASHRAE Guideline 36 implementation results as well as lessons learned from the two Minnesota field demonstrations.

#### Benefits of incorporating ASHRAE Guideline 36

ASHRAE Guideline 36 is considered the industry’s best practice and has detailed instructions on the control and operation of HVAC systems to ensure they operate efficiently while maintaining occupant

comfort. The first ASHRAE Guideline 36 was published in 2018. The latest version was published in late 2024.

As described in the Introduction, the intended benefits of ASHRAE Guideline 36 include:

- **Energy Efficiency:** By providing standardized sequences, Guideline 36 helps to reduce building energy consumption and costs through rule-based, optimized control strategies.
- **Improved System Performance:** The guideline enhances HVAC system reliability and performance, offering solutions that minimize equipment wear and tear.
- **Simplified Design and Implementation:** With pre-defined sequences, design engineers and contractors can streamline the design and commissioning process.
- **Enhanced Indoor Air Quality and Comfort:** Guideline 36 ensures indoor air quality and occupant comfort meet ASHRAE standards on ventilation and thermal comfort.
- **Ease of Maintenance and Troubleshooting:** Standardized sequences include fault detection and diagnostic logic that make HVAC system fault diagnostics and troubleshooting easier.
- **Scalability and Adaptability:** The sequences can be applied to a wide range of building types and sizes, and they are adaptable to various control systems and technologies.

The energy savings potential with a full building automation system (BAS) retrofit that uses control logic from ASHRAE Guideline 36 may vary based on several important factors. There are a few key data points that indicate significant energy-saving opportunities. In addition to the improved sequences of operation, control retrofits provide a synergistic opportunity to address deferred maintenance and other measures that may deliver additional energy savings.

TRC, along with Taylor Engineering, Lawrence Berkeley National Laboratory, and Integral Group, conducted a California Energy Commission-funded research project where they implemented BAS retrofits with Guideline 36 sequences of operation in two buildings and Guideline 36 with existing BAS hardware in two buildings in California. NYSERDA is funding a similar demonstration in four buildings in New York State. For more detailed information about these field demonstrations, please refer to the next section, “Other ASHRAE Guideline 36 field studies.”

Two other existing building demonstrations implemented *a portion* of the zone sequences of operation from Guideline 36 using the existing modern BAS. In one of these studies, researchers implemented time-averaged ventilation sequences of operation and found average heating, cooling, and fan power savings to be 41 percent, 23 percent, and 15 percent, respectively, over a baseline of single-maximum VAV logic (Kaam 2018). In the other study, researchers reduced VAV box minimum airflow setpoints to around 10 percent, resulting in 10 - 30 percent HVAC energy savings and improved occupant thermal comfort (Arens, Zhang and Hoyt 2015). A simulation study on the ASHRAE Guideline 36 strategy also show 15 – 30 % HVAC energy savings, depending on climate and load scenario, compared to conventional practice (Wetter, et al. 2018).

Finally, a case study by Taylor Engineering<sup>4</sup> showed that an end-of-life replacement for an obsolete BAS with sequences of operation similar to Guideline 36 in a large office building in San Mateo, California, resulted in measured savings of 15 percent of whole-building electricity and over 50 percent natural gas, with an overall simple payback of seven years. The existing BAS already had direct digital controls (DDC) down to the zone level, indicating the energy savings were mostly from the optimized control sequences.

## Other ASHRAE Guideline 36 field studies

In 2017, the California Energy Commission (CEC) funded a project to demonstrate the energy savings, occupant comfort benefits, investigate further technological advancements for controls retrofits, and recommend strategies and initiatives to address market barriers. The demonstration focused on two common building control systems. Buildings without modern direct digital control systems required a full control retrofit, and buildings with modern direct digital control systems only required software retrofits.

Four buildings had a full demonstration, with two buildings receiving full-control retrofits and the other two having only software retrofits. The retrofits all followed the traditional approach to implementing ASHRAE Guideline 36 and included a design engineer. There was a range of existing conditions and existing control logic across the sites. At the two full-control retrofit sites, which would have some inherent savings just doing a new control system without ASHRAE Guideline 36, had whole-building electricity savings of 26 to 35 percent, with 6-to-8-year simple payback. The software-only retrofits had whole-building electricity savings of 11 to 17 percent, with 2- to 7-year simple payback. ASHRAE Guideline 36 also generated significant natural gas savings in these projects due to reduced zone-level reheat needed.

### *Kaiser Permanente Vallejo Medical Office Building*

This 200,000-square-foot medical office building is located in Vallejo, California, and is a two-story facility with offices, exam and procedure rooms, outpatient surgery, with accompanying space for staff and customer waiting rooms. The building had 12 VAV air handlers, one constant air volume (CAV) air handling, and used cooling coils and airside economizers for cooling, and reheat terminal units for heating. This required full controls retrofit and showed a whole-building electricity savings of 26 percent and a HVAC energy savings of 60 percent.

### *Kaiser Permanente Whittier Medical Office Building*

This 33,640-square-foot medical office is located in Whittier, California, and is a two-story building split into equal wings separated by a common lobby space. This included offices, exam and procedure rooms, and waiting rooms. It had two VAV air conditioning units and used direct expansion (DX) cooling

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<sup>4</sup> [https://taylorenge.egnyte.com/dl/W4bt0bq4vc/2018-09-18\\_Advanced\\_HVAC\\_Controls\\_Case\\_Study\\_-\\_555\\_County\\_Center.pdf](https://taylorenge.egnyte.com/dl/W4bt0bq4vc/2018-09-18_Advanced_HVAC_Controls_Case_Study_-_555_County_Center.pdf)

and air-economizing and reheat terminal units for heating. This required a full controls retrofit and showed a whole-building electricity savings of 35 percent and a HVAC energy savings of 58 percent. The measured post-retrofit period was during the COVID-19 pandemic, which would provide higher-than-expected potential energy savings.

### *Contra Costa College Student and Administration Building*

This 50,000-square-foot administration building is in San Pablo, California, and has offices, commercial kitchens, food service, and a store for students. The building is served by four multi-zone VAV air handlers with reheat terminal units. The air handlers had chilled and hot water coils and an airside economizer. Because this building already had a modern direct digital control system, only a software retrofit was required. The demonstration showed whole-building electricity savings of 11 percent and HVAC energy savings of 11 percent.

### *Kaiser Permanente Pleasanton Data Center*

This 76,000-square-foot data center is located in Pleasanton, California. The retrofit was only done on the office space, which was 23,700 square feet. The office space is served by a chilled water VAV air handler with an airside economizer and has reheat terminal units for heating. This building had a modern direct digital control system, so only a software retrofit was required. The building showed whole-building electricity savings of 17 percent and HVAC energy savings of 23 percent. The measured post-retrofit period was during the COVID-19 pandemic, which would provide higher-than-expected potential energy savings.

## **Relevant building codes and standards**

### *ASHRAE Standard 90.1, 62.1, 55, and 241*

ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, is the primary benchmark for energy efficiency in commercial and institutional facilities. It establishes minimum prescriptive and performance-based requirements covering the building envelope, HVAC systems, lighting, service water heating, and system-level controls to promote energy-efficient design and operation. ASHRAE Guideline 36 aligns closely with Standard 90.1's control-related provisions, particularly those addressing HVAC scheduling, setback and setup modes, demand-controlled ventilation (DCV), temperature and pressure resets, and economizer sequences—ensuring that implemented control strategies meet the standard's intent for energy-efficient operation.

ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, defines minimum outdoor air ventilation rates and other design measures necessary to maintain healthy and comfortable indoor environments. By following ASHRAE Guideline 36 sequences, building operators can ensure that ventilation control strategies remain compliant with the airflow and indoor air quality requirements established by Standard 62.1.

ASHRAE Standard 55, *Thermal Environmental Conditions for Human Occupancy*, specifies the environmental conditions needed to achieve thermal comfort for occupants in mechanically conditioned spaces. Implementing Guideline 36 control logic helps maintain thermal conditions—temperature, humidity, and airflow—within the comfort ranges prescribed by Standard 55, enhancing overall occupant well-being and productivity.

ASHRAE Standard 241, *Control of Infectious Aerosols*, sets minimum requirements for the reduction of airborne disease transmission risk in occupiable spaces of new and existing buildings, including healthcare and high-risk environments. It emphasizes ventilation effectiveness, filtration, and air cleaning to reduce infectious aerosol exposure. Standard 241 introduces an Infection Control Mode that temporarily elevates ventilation rates and increases filtration or air disinfection measures to minimize the risk of infection transmission. If mechanical modifications—such as upgrading to high-MERV (Minimum Efficiency Reporting Value) filters or adding air-cleaning devices—are made, the resulting airflow changes can affect HVAC system performance and control sequences. In such cases, it is advisable to engage a qualified mechanical engineer to recalculate system loads and minimum airflow rates, and revise the control design to ensure continued compliance with applicable standards, especially ASHRAE 62.1 requirements for ventilation and indoor air quality under Operational Mode (normal operating conditions).

### *California Title 24-2025*

California Title 24 is a set of California building standards primarily on energy efficiency and conservation in residential, commercial, and public buildings. Title 24 aims to reduce energy consumption, lower greenhouse gas emissions, and provide cost savings for building owners and tenants. The 2025 version of the Title 24 now references non-residential buildings that have direct digital controls to follow ASHRAE Guideline 36 control sequences wherever applicable. Furthermore, it is proposed that BAS manufacturers need to “self-certify” their ASHRAE Guideline 36 programming libraries for their building control products to be used in new building control projects.

## **Market adoption barriers, challenges, and lessons learned**

Implementing ASHRAE Guideline 36 correctly and successfully has been shown to save significant energy in the California field demonstrations. However, there are many market adoption barriers, challenges, and lessons learned from the Minnesota field demonstrations.

### *Awareness*

Since the release of ASHRAE Guideline 36 in 2018, awareness of this guideline has steadily increased, but the building controls industry is slow to adapt to change. Members of the ASHRAE Guideline 36 committee have conducted numerous in-person seminars, workshops, and short courses at ASHRAE conferences and local chapter meetings. Additionally, free online training courses are offered by various BAS manufacturers, the U.S. Department of Energy (DOE), the U.S. Department of Defense (DoD), Slipstream, Pacific Energy Center, and the BEST Center. Despite these efforts, many building owners, mechanical design engineers, and building controls engineers have only heard of the guideline and have

not yet applied it in any projects. One reason is that ASHRAE Guideline 36 is a guide for high-performance buildings, rather than a building code or standard that is required for every project. Ongoing education and training on how to effectively implement ASHRAE Guideline 36 are essential to maintain momentum and further enhance energy savings and cost reduction. Utility programs that leverage Guideline 36 are a potential solution that could significantly raise awareness.

## Complexity

The ASHRAE Guideline 36 is notably complex, surpassing the complexity of traditional building control sequences typically used by BAS manufacturers. Its detailed technical instructions make it challenging for mechanical engineers, controls engineers, building controls specifiers, technicians, and commissioning agents to fully understand and accurately implement the sequences during design, programming, tuning, adjustments, and on-site testing. Without effective tools to simplify these processes, applying and customizing the sequences for specific project conditions can demand more technical knowledge than most mechanical designers readily possess.

The core goal of standardizing control sequences is to enable designers, control engineers, technicians, and commissioning agents to utilize software tools that generate requirement documents, deploy pre-programmed control sequences, and automatically test them in the field. Such tools can break down complex sequences into simpler, manageable tasks, reducing time and effort for design engineers and controls contractors. One such tool exists for generating plain language sequences of operation that comply with ASHRAE Guideline 36 - called *ctrl-flow*—but its adoption remains limited, as commissioning agents and building operators still prefer traditional, simpler sequences of operations that are more understandable/approachable.

ASHRAE Guideline 36 implementation is most effective on projects with standard HVAC system design as described in ASHRAE Guideline 36. Many leading BAS manufacturers have also created control programming libraries that comply with Guideline 36. The control sequence complexity is embedded in the BAS manufacturer's programming libraries, and minimal customization is needed. However, the validation of these libraries is not yet fully standardized. If the HVAC system is not standardized, an experienced designer or control engineer needs to be involved with the customization of the control sequences and the engineering calculations. For small-sized buildings with old or atypical HVAC system designs, it may not be worth the effort. It is worth mentioning that a project implementation best practices guide exists (Cheng, Eubanks and Singla, *Advanced Building Automation Systems Best Practices Guide 2022*), which can help practitioners navigate the complexity of ASHRAE Guideline 36 project design, implementation, testing, and commissioning.

## Design review and specification

Successful implementation of ASHRAE Guideline 36 requires collaboration among multiple stakeholders. A controls contractor depends on accurate design information from the mechanical engineer who designs or modifies the HVAC system, as well as input from the testing, adjusting, and balancing (TAB) contractor who verifies system performance. In conventional control retrofits—especially in small to medium-sized buildings—formal engineering input is often lacking. However, given the complexity and

strict performance requirements of Guideline 36, applying its control sequences without review by a mechanical design engineer can lead to operational difficulties, inefficiencies, and compliance issues.

Revising or recalculating airflow rates, capacities, and control logic to align with the guideline is a critical—but often overlooked—step. ASHRAE Guideline 36 tends to be more straightforward to adopt in new construction or complete system redesigns, where standard HVAC design and control sequences in the guideline can be readily applied to these projects from the outset with minimal customization. Customized control sequences are often required when existing or legacy HVAC systems do not match the standard configurations outlined in ASHRAE Guideline 36. Adapting these non-standard systems to align with Guideline 36 demands a tailored approach, which incorporates its principles to ensure high-performance operation. Bringing in a professional engineer to redesign system controls in these controls retrofit projects may increase upfront costs, but offers the benefit of accurate design and more efficient implementation by controls contractors and commissioning agents. This approach helps streamline the deployment process and ensures that the advanced control strategies are rigorously and correctly applied.

### *Controls contractor training*

A potential disconnect exists between BAS manufacturers, who develop and distribute ASHRAE Guideline 36–compliant programming libraries, and the controls contractors who apply them in real-world projects. It is often unclear how contractors are trained to use these libraries, how well they understand the purpose and function of each module, or whether sufficient documentation accompanies the programming libraries. Findings from the Minnesota field study show that many contractors faced uncertainties during implementation and had to interpret the sequences on their own. Each major BAS manufacturer may conduct training differently, and contractors’ familiarity with ASHRAE Guideline 36 libraries still varies significantly. This variability is understandable, as these programming libraries are relatively new and not validated or certified through a rigorous method of test procedure. The upcoming California Title 24 requirement for BAS manufacturers to self-certify Guideline 36 libraries may help improve standardization and ensure more comprehensive training and support for contractors.

The quality and consistency of controls contractors’ work can vary significantly. While some contractors pay close attention to technical details and follow best practices, others prioritize completing installations as quickly as possible, provided the work meets the minimum acceptance criteria of the building owner or commissioning agent. Given the technical depth and precision required for implementing ASHRAE Guideline 36, selecting a controls contractor with demonstrated experience, a solid understanding of the guideline, and a proven track record on similar projects is essential. Evaluating proposals solely on cost can lead to performance issues, rework, or incomplete implementation. Instead, emphasis should be placed on technical qualifications, prior successful experience with Guideline 36, and the contractor’s ability to execute complex, high-performance control sequences accurately.

## *Value proposition*

The building owners and facility operators may not fully understand or realize the benefits of using ASHRAE Guideline 36 in building control upgrade or retrofit projects, given its complexity. Several field demonstrations gave different energy-saving results. The California demonstrations were more successful in terms of demonstrated energy savings because the engineering firm involved was very familiar with ASHRAE Guideline 36, and those projects had enough budget to cover their involvement. The Minnesota demonstrations did not show significant energy savings, primarily because no engineering firm or consultant who is familiar with ASHRAE Guideline 36 was involved to look at the existing HVAC system design, redo the calculations, or enforce the implementation of control sequences suggested. From guideline awareness, HVAC design, control sequence specification, control sequence programming, field testing, adjusting, commissioning, and contractor training - everything has to go right before a successful project implementation of ASHRAE Guideline 36 is possible. Without the demonstrated additional energy savings and cost-effectiveness, it is hard for building owners to justify requiring ASHRAE Guideline 36 in new or existing building control projects.

## *HVAC technician and building operator training*

HVAC systems naturally degrade over time and require ongoing maintenance—including periodic sensor calibration—to sustain energy savings and reliable operation. In practice, HVAC technicians often perform maintenance reactively, addressing issues only after they become apparent. To support the broader adoption and long-term success of ASHRAE Guideline 36, it is important to provide comprehensive training for on-site HVAC staff. This training should cover key Guideline 36 concepts, how to recognize proper system performance using graphics and trend data, and which maintenance tasks are essential for maintaining high performance. Proactive education and training for HVAC technicians and building operators are critical to ensure the sustained benefits and effectiveness of advanced control sequences.

## *Focused and standard commissioning*

Due to its complexity, ASHRAE Guideline 36 is challenging to properly commission. It is easy for issues to slip if not properly documented and tracked. Standardizing the functional tests and performance verification requirements brings a common roadmap to the commissioning process. Although there will always be edits to standards, having a common template to start from will put everyone on equal footing from the beginning of the project.

In addition to standardization, the commissioning agent should be involved with the project throughout the project to ensure understanding of the system and how it should be commissioned. Including the lead design engineer in functional testing and trend reviews provides valuable support from someone who understands why the system was designed the way it was. Bringing the right stakeholders into the commissioning process, along with active punch list documentation, will lead to better project outcomes.

## ASHRAE SGPC 36 activities

ASHRAE Standing Guideline Project Committee (SGPC) 36 consists of staff from BAS manufacturers, design consultants, ASHRAE Guideline 36 users, and people with a general interest. This committee is responsible for maintaining Guideline 36, publishing addenda fixing existing control sequence bugs, and adding control sequences for new HVAC equipment. SGPC 36 members typically meet twice per year in person to discuss major issues, addenda, and revisions. Ad-hoc working groups were also formed to address larger issues, such as lab system control sequences or new heat pump control sequences. The working groups may meet multiple times a year virtually, on an as-needed basis.

ASHRAE SGPC 36 committee members are aware of the many barriers and challenges to the market adoption of ASHRAE Guideline 36 and have tried to resolve these issues. Currently, major SGPC 36 committee activities are listed below.

### *Heat pump sequences*

A working group was formed to develop standard control sequences for heat pumps for cost saving, security, and resilience. Heat pump systems under consideration include air-source heat pump plant with 4-pipe heat pumps with internal fluid crossover, and 2-pipe heat pumps with switchover valves; central heat pump plant with external conditioning loop and thermal energy storage systems; and central condenser water loop system with distributed equipment (water source heat pumps, etc).

### *Lab system sequences*

A working group is working on new control sequences for laboratory systems, which may have more stringent temperature, humidity, pressure, and ventilation control requirements.

### *Functional testing working group*

A working group is working on developing functional testing scripts that can be used to verify BAS manufacturers' ASHRAE Guideline 36 programming libraries. In California, the 2025 Title 24 requires ASHRAE Guideline 36 programming in all new or replacement systems, starting January 1, 2026. BAS manufacturers may need to submit a 'self-certification' of ASHRAE Guideline 36 compliance before their building control product can be used in projects.

### *Cold climate working group*

A new cold-climate working group was just formed to address cold-climate-specific issues, such as freeze protection, VAV with radiant panels, preheat and heat recovery, pressurization & winter infiltration challenges, etc.

## MN utility ECO programs – Xcel Energy

In this project, we met with Xcel Energy and discussed their ECO programs related to building controls. Xcel Energy offers a comprehensive custom energy efficiency program<sup>5</sup> specifically for Minnesota commercial and industrial customers. The custom energy efficiency program provides flexible rebates for energy-saving projects that don't qualify for standard prescriptive rebates. This applies to many of the energy-saving measures in ASHRAE Guideline 36, as well as general building controls applications, Retro-commissioning (RCx), and Energy Management Systems (EMS).

### *Custom energy efficiency projects related to building controls*

- Controls – applications
  - CO2-based ventilation
  - Energy management systems (EMS)
  - Morning preheat/cool down
  - Night setback, day setup
  - Start/stop
  - Temperature resets
- Controls – concepts
  - Match system operation to occupancy or line speed
  - Reduce equipment operational hours
- Cooling and heating – concepts
  - Eliminate simultaneous heating and cooling
  - Match operation and equipment with current occupancy
  - Minimize supply and return fan amps
  - Optimize enthalpy control of economizer function
  - Optimize mixed air control based on occupancy
  - Optimize operation during periods of low occupancy
  - Optimize supply air temperature and relative humidity
  - Reduce CFM during periods of low occupancy
  - Restore or improve the economizer function

### *Participant benefits*

Participants can get up to \$450/system peak demand kilowatt (kW) of electricity saved, plus \$200/non-peak demand kilowatt in excess of system peak demand kilowatts saved. Rebates will be provided up to \$5/dekatherm (Dth) of natural gas saved. Efficiency controls custom rebate will add an additional \$.02/kWh saved.

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<sup>5</sup> <https://mn.my.xcelenergy.com/s/business/cost-savings/custom-efficiency>

## *Application process*

Pre-approval is required for all custom efficiency projects. Building owners need to fill out an Xcel Energy custom workbook on the proposed project's general information and technical information about the building control-related energy-saving measures compared to the existing baseline. Then Xcel Energy will review and conduct professional engineering analysis (for complex projects), as well as check compliance with Minnesota building codes and energy standards. Each project has to pass an economic analysis and cost-effectiveness threshold to be approved.

The professional engineering analysis and evaluation of building controls or energy management system-related projects are often required and quite involved, due to the complexity of these projects. Xcel Energy staff typically need a few weeks to a few months to complete the assessment. The applicants sometimes need to provide their own justification of expected energy savings calculations, some using an energy modeling approach.

## *Custom workbook*

For building control or energy management system-related projects, the custom workbook has several pre-determined energy efficiency measure options to select from:

- Existing and proposed HVAC operating schedule
- Existing and proposed fan speed control
- Existing and proposed pump speed control
- Hot water temperature reset
- Chilled water temperature reset
- Condenser water temperature reset
- AHU supply air temperature reset
- Unoccupied temperature setback and setup
- CO<sub>2</sub>-based Demand Controlled Ventilation (DCV)
- Reduce AHU minimum outside air damper position
- New temperature and humidity sensors
- Eliminate simultaneous heating and cooling

For other energy-saving measures that are not on the list, applicants can describe them in the space designed for the “additional control components” section of the workbook.

## *Applicability to Implementing ASHRAE Guideline 36*

Existing building controls retrofit or upgrade projects fit into the Xcel Energy custom energy efficiency program, and can apply for the Xcel Energy custom rebate. For projects implementing ASHRAE Guideline 36, some of the energy-saving measures that are not on the list of standard options in the workbook can be added to the “additional control components” section of the workbook. Examples of such measures may include, but are not limited to:

For multiple-zone VAV AHUs:

- AHU system modes (Occupied/Cooldown/Setup/Warmup/Setback/Unoccupied)
  - Optimal start and morning warmup
- AHU supply fan control
  - Supply air static pressure set-point reset
  - Supply air static pressure control
- Minimum outdoor airflow setpoints
- Minimum outdoor air control
- Automatic Fault Detection and Diagnostics (AFDD)
- Plant requests
- Air economizer high limits

For VAV terminal units:

- Zone groups (different operating modes)
- Dynamic zone minimum ventilation (occupied standby, demand-controlled ventilation)
- Zone-level demand limiting features
- AHU supply air static pressure reset requests
- VAV terminal unit—cooling only
  - Cooling-only VAV control logic
  - Reduce minimum airflow
- VAV terminal unit with reheat
  - Dual max control logic
  - Reduce minimum airflow
- Fan-Powered terminal unit (if applicable)
  - Constant-volume parallel fan-powered VAV control logic
  - Variable-volume parallel fan-powered VAV control logic
  - Constant-volume series fan-powered VAV control logic
  - Variable-volume series fan-powered VAV control logic

Most of these energy-saving measure concepts are known to design engineers and controls contractors, but the real energy-saving impact will depend on the detailed implementation steps and optimal parameter adjustments in the field. ASHRAE Guideline 36 standardizes industry best practices on these detailed implementation steps and initial recommended control parameters. Without paying attention to these details, the project's results may not reflect the initial control design intentions.

For the Champlin Library controls retrofit project, the facility manager applied to Xcel Energy's custom energy efficiency program by filling out a custom workbook. Xcel Energy evaluated the project, including energy savings potential as well as cost-effectiveness. Eventually, the application was rejected because the project did not meet the cost-effectiveness criterion for the program.

## MN utility ECO programs – Minnesota Power, Otta Tail Power, and CenterPoint Energy

Due to time constraints, we did not have time to meet with other Minnesota Investor-Owned Utilities (IOUs) to discuss their ECO programs that apply to ASHRAE Guideline 36. We did background research on their ECO programs related to commercial building controls through online search, and they are listed below.

### *Minnesota Power*

Minnesota Power’s Energy Conservation and Optimization (ECO) programs related to commercial building controls focus on helping businesses use energy more efficiently to conserve electricity and natural gas while reducing carbon emissions.

- The New Construction Energy Efficiency Rebate Program encourages energy-efficient building practices, including the installation of electric heating systems and ventilation with heat/energy recovery ventilators (ERV/HRV) to optimize building energy use. However, ASHRAE Guideline 36 does not apply to this program.
- The Multifamily Efficiency Program offers energy analyses, project design assistance, and rebates for existing and new multifamily facilities. Rebates can be applied for Lighting Control Projects, Motor Control Projects, and HVAC and EMS (Energy Management Systems) Control Projects. ASHRAE Guideline 36 may apply to the HVAC and EMS (Energy Management Systems) Control Projects category, depending on whether the multifamily HVAC system is a centralized system design and the HVAC equipment types are covered in ASHRAE Guideline 36.
- The Business Energy Conservation Program offers custom rebates to projects related to Lighting Control, Refrigeration Control, Motor Control, and HVAC and EMS (Energy Management Systems) Control Projects. Again, ASHRAE Guideline 36 may apply to the HVAC and EMS (Energy Management Systems) Control Projects, as long as the building HVAC system is a centralized system design, and the HVAC equipment types are covered in ASHRAE Guideline 36 and controlled through a modern BAS. Minnesota Power’s commercial, industrial, and agricultural customers can fill out a custom project application online<sup>6</sup> and go through their internal review process. Incentives are based on \$200 per kW saved. The customer must contribute an amount greater than or equal to the estimated annual first-year savings, and Minnesota Power may require pre- and post-energy use verification. It’s unclear what specific energy efficiency measures related to building controls qualify for these custom projects, and how Minnesota Power evaluates them.

### *Otta Tail Power*

Otta Tail Power’s Energy Conservation and Optimization (ECO) programs provide a broad range of offerings aimed at helping commercial, industrial, and agricultural customers reduce energy

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<sup>6</sup> <https://save.mnpower.com/OnlineApp/#enrollment/?programId=13>

consumption and improve operational efficiency. The most relevant programs related to ASHRAE Guideline 36 are their Commercial Energy Management Program<sup>7</sup>, which provides businesses with a comprehensive suite of energy-saving services and incentives designed to optimize operational efficiency and reduce energy costs

- The Facility Turn-Key Efficiency Program provides an on-site energy assessment conducted by an energy engineer who evaluates all key building systems, such as lighting, HVAC, controls, motors, refrigeration, and processes. Following the assessment, a detailed report is created outlining energy-saving opportunities, estimated costs, savings, and available rebates. If recommended improvements are implemented within 12 months, participants can receive a 50% bonus on top of standard rebates. Importantly, if the energy audit identifies building control issues, this can serve as a valuable first step toward adopting ASHRAE Guideline 36 to enhance system performance and energy efficiency.
- Custom Efficiency Grants Program allows commercial and industrial customers to propose their own energy-saving projects tailored to their unique operations. Grant amounts are based on the energy saved (measured in kilowatt-hours and kilowatts of demand reduction) and project costs. The grants will not exceed 75% of project costs or 90% of the incremental costs, with some caps potentially applying. Otta Tail Power customers can work with an Energy Management Representative to develop a custom grant plan and receive assistance in submitting proposals. The program covers diverse projects, including upgraded motor efficiency with adjustable-speed drives, installation of high-efficiency lighting and refrigeration equipment, advanced heating and cooling systems, and other energy-saving improvements not covered by prescriptive rebate programs. This program complements the Facility Turn-Key Efficiency Program, which provides onsite energy audits and recommendations to identify opportunities for energy conservation, including potential HVAC controls optimization per ASHRAE Guideline 36.
- There are other programs providing rebates for variable frequency drives, motors, compressed air controls, or high-efficiency refrigeration, but they are less relevant to ASHRAE Guideline 36.

## *CenterPoint Energy*

CenterPoint Energy's Energy Conservation and Optimization (ECO) programs deliver a comprehensive suite of rebates and incentives that help electric and natural gas customers improve efficiency through equipment upgrades, advanced HVAC systems, enhanced insulation, and adoption of high-performance technologies.

Within these offerings, the Custom Rebates Program serves commercial and industrial (C&I) customers with complex or unique process needs. This flexible, performance-based initiative supports non-prescriptive efficiency projects—particularly in manufacturing and industrial environments—to reduce energy use, modernize systems, and lower operating costs across Minnesota.

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<sup>7</sup> <https://www.otpc.com/ways-to-save/business/programs/>

Most natural gas-saving projects are eligible for custom rebates, including control system retrofits that adhere to ASHRAE Guideline 36. ASHRAE Guideline 36 minimizes simultaneous heating and cooling, which significantly decreases zone-level reheat demand and yields substantial natural gas savings.

Rebate incentives under this program can cover up to 50% of incremental equipment cost, 25% of total equipment cost, or provide a buy-down to a one-year payback period, depending on project characteristics and savings potential. In addition, CenterPoint Energy's Engineering Assistance Study Funding Program offers up to \$5,000 to offset engineering, design, and installation costs for qualifying high-efficiency projects.

## Recommendations for future research

The State of California leads research related to ASHRAE Guideline 36. Past research includes several ASHRAE Guideline 36-related field demonstrations. Ongoing research is listed below:

- The CalNEXT program<sup>8</sup> sponsors a project developing a guide for how high-impact ASHRAE Guideline 36 measures can be implemented into existing buildings.
- The CalNEXT program sponsors a project developing a test method for validating that ASHRAE Guideline 36 programming libraries by building controls manufacturers comply with ASHRAE Guideline 36.
- The CalNEXT program and NYSERDA<sup>9</sup> sponsor projects related to optimizing AHU supply air temperature reset logic based on energy cost.
- The CalNEXT program sponsors a field demonstration of implementing ASHRAE Guideline 36 using the ASO approach.

Xcel Energy has identified several future research topics that could enhance the design and evaluation of its custom energy efficiency program offerings:

- Identifying which energy-saving measures in ASHRAE Guideline 36 result in the greatest energy savings, enabling better recommendations to customers
- Improving energy modeling techniques to estimate savings from ASHRAE Guideline 36 measures more accurately.
- Developing and implementing new control sequences for additional HVAC equipment types, such as heat pumps, and guidance for controls contractors on these implementations.
- Using EMIS to validate existing control strategies
- Estimating the market size, including the number of buildings and total square footage applicable to these energy-saving measures
- Establishing methods to identify and manage rogue zones—zones that consistently operate improperly and cause inefficiencies or disruptions

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<sup>8</sup> <https://calnext.com/>

<sup>9</sup> <https://www.nyserdera.ny.gov/>

Research addressing these questions would support Xcel Energy in refining its program offerings to maximize energy efficiency and operational effectiveness.

## Recommendations for future MN ECO program improvements

Based on our project experience, market research, and conversation with Xcel Energy, here are our recommendations for future MN ECO program improvements related to ASHRAE Guideline 36:

- Incorporate some of the key energy-saving measures in ASHRAE Guideline 36 as standard options in the Xcel Energy custom workbook. As mentioned previously in the section, some of these key Guideline 36 measures are covered by the Xcel Energy custom workbook, and others could be added. The methods used by Xcel Energy to calculate custom control-related project energy savings were not reviewed as part of this study. We recommend that Xcel Energy and other Minnesota utilities look into tools that have the ability to accurately model Guideline 36 measures to pinpoint potential areas for improvement and identify opportunities to add new measures.
- Emphasize detailed implementation steps and recommended optimal parameters to follow ASHRAE Guideline 36. To help overcome implementation challenges, CalNEXT is funding the development of a “Guideline 36 Lite (G36 Lite)” retrofit guide which provides simplified implementation steps and recommended controls logic focused on: (1) key Guideline 36 measures, (2) sequences of operation (SOO) for various HVAC system types, and (3) SOO workarounds for existing system control, memory or sensor limitations. This study is scheduled to be completed in 2026<sup>10</sup>.
- Require participating customers to partner with a controls contractor who has completed training or obtained certification in ASHRAE Guideline 36 implementation. This training or certification could serve as a prerequisite for inclusion on the utility’s approved contractor list or within its trade ally network.
- Limit offerings to low-hanging measures (VAV minimums, SAT Reset, etc.) This will reduce the complexity of implementing and commissioning Guideline 36 in existing buildings and increase program and project cost-effectiveness (Tonielli 2016).
- Use data analytics of utility data and assessment of customer needs to identify potential sites. The customer screening for Guideline 36 projects is multi-dimensional in that programs need to understand the potential to save energy, qualify customers as good candidates, assess the level of engineering support required, identify the limitations of existing control equipment, and account for the impacts of non-energy related project needs (e.g., O&M issues). An early assessment of these considerations gives program implementers an opportunity to develop a

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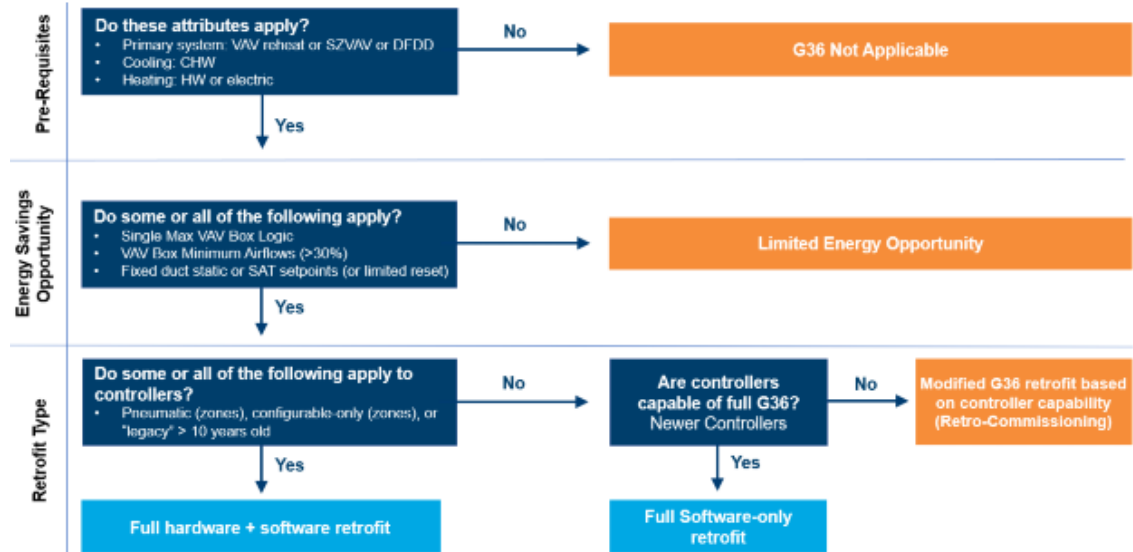
<sup>10</sup> <https://calnext.com/approved-projects/> - Project # ET25SWE0013 “Simplified HVAC Control Retrofits”.

preliminary work plan that will help determine the timing and level of program intervention and define the necessary requirements and commitments of contractors and customers. The Champlin Library project shows that the absence of early engineering design support and control setpoint specifications led to project delays, increased costs, and incomplete or ineffective implementation of some of the recommended Guideline 36 measures.

Since Guideline 36 sequences associated with reduced VAV reheat are often the highest performing measures (i.e., Dual min/max VAV control and SAT reset), review of monthly gas billing is a quick and easy identifier of potential savings. Energy Use Intensity (EUI) data from ASHRAE Standard 100-2024 and Commercial Buildings Energy Consumption Survey (CBECS) can also be employed as a first step in targeting potential buildings. Research has shown that complex HVAC control measures can be reliably evaluated using a simplified estimation tool, which maintains flexibility for various building designs and offers a quantifiable level of accuracy (DeBlois, et al. 2024). Unfortunately, public tools of this type are still under development and not market-ready. As an alternative, Minnesota utilities might want to consider partnering with a private company that provides RCx pre-screening services based on advanced metering infrastructure (AMI) data.

After determining the potential for energy savings, a customer needs screening should be conducted to establish the project baseline and the appropriate level of program support. Common BAS retrofit scenarios include: (1) full hardware and software, (2) software-only upgrades, and (3) partial software-only (RCx projects). These measure types are sometimes classified as Normal Replacement, Add-on Equipment, and Behavioral, Operational, and Retro-commissioning. Each measure type often has its own set of standard baseline requirements, incentive rates, effective useful life assumptions, and eligible incremental measure costs, which are parameters used to determine measure, project, and program cost-effectiveness, and overall program influence. The Advanced BAS Best Practices Guide (Cheng, Eubanks and Singla, Advanced Building Automation Systems Best Practices Guide 2022) suggests the following decision process (Figure 30) for screening and classifying airside systems. A similar approach could be applied to chilled and hot water systems.

Figure 30. Identifying Opportunities for Guideline 36 Airside Control Retrofits



- Employ or develop easy-to-use ASHRAE Guideline 36 energy efficiency measure savings calculation and commissioning tools and make them publicly available for design engineers and controls contractors. Guideline 36 and RCx tools currently available or in development are summarized below:
  - One of the most impactful improvements in building HVAC performance is accurate estimates of ventilation requirements and dual min/max VAV setpoint control. A research project funded by the California Public Interest Energy Research (PIER) program (Cheng, Wendler and Raftery, Hot Water Heating: Design and Retrofit Guide 2024) highlight the potential heating load reductions from reduced VAV minimum airflows, SAT reset, improved morning warmup performance, DCV, and discharge air temperature control. This study includes a free spreadsheet tool for determining zone ventilation airflow requirements in accordance with either ASHRAE Standard 62.1 (simplified approach) or California Title 24. Dual min/max VAV control with low minimums is one of the most impactful Guideline 36 measures, but also one of the most commonly overlooked or improperly specified and commissioned opportunities. At Champlin Library, historical values of airflow minimum requirements were initially used in ASHRAE Guideline 36 implementation, likely resulting in higher than required ventilation.
  - Some of the implementation challenges discussed in the report can be addressed by improving the Guideline 36 commissioning process. Automated test methods are being developed to help ensure BAS programming libraries are consistent with the Guideline 36 sequences. For the Central Library, Slipstream provided a custom control sequence created using the ctrl-flow. Use of these specifications was not required. However, they did ask the controls contractor to reference and incorporate the ASHRAE control sequences as much as possible. Unfortunately, many of the key sequences implemented did not comply with ASHRAE Guideline 36 (Table 9).

- HVAC-Cx is another publicly available, semi-automated commissioning software tool developed by the U.S. National Institute of Standards and Technology (NIST) to facilitate performance testing for commercial building HVAC systems (Ferretti, et al. 2024). Use of this type of commissioning tool should be considered to standardize the sequencing verification process, especially for RCx-only scenarios.
- Two CalNEXT research projects<sup>11</sup> have tested (Phase 1) and are enhancing (Phase 2) a publicly available spreadsheet tool used by RCx programs in California Yiyi, et al. 2024). The enhancement work is scheduled to be completed in 2026. This tool calculates savings for many standard RCx measures, which may currently be covered by Xcel’s custom workbook. This tool differs from the Xcel workbook in that it is a stand-alone calculation spreadsheet available to anyone. It allows users to model RCx savings performance by specifying system setpoints and/or inputting detailed trend data for individual AHU, CHW, and HW systems. The enhancement study plans to improve how the tool calculates savings from dual max VAV logic with low minimums and add new HVAC system types and measures. The current version is limited to California climate zones.
- Define verification requirements by measure type and size. The appropriate Measurement and Verification (M&V) rigor for Retro-Commissioning (RCx) measures involves a balance between the cost of M&V and the desired accuracy/risk mitigation. The appropriate rigor level is determined by several factors:
  - Complexity and Interaction of Measures: If multiple RCx measures interact, a whole-facility approach (IPMVP, Option C) may be more effective in capturing the combined impact. Commercial Strategic Energy Management (SEM) programs are well-suited for this verification approach because of their level and duration of customer engagement, and their utility meter-based approach to verifying savings.
  - Magnitude of Expected Savings: Small savings measures may only warrant SOO implementation verification and stipulation of energy savings (Option A). Standardized calculation tools offer significant benefits in this context. Measures with larger expected energy savings often justify a higher level of M&V rigor to ensure the savings are accurately realized (Option B).
  - Cost vs. Accuracy: The expense of rigorous M&V must be balanced with the need for accurate data and practical budgetary limitations.
  - Persistence of Savings: RCx measures often involve control changes that may degrade over time. Ongoing monitoring-based commissioning can help track and sustain performance.

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<sup>11</sup> <https://calnext.com/approved-projects/> ET23SWE0060 “PG&E HVAC Tool Validation” and ET25SWE0045 “PG&E HVAC Tool Validation Phase 2”.

- Type of Equipment and Operation: For equipment with a well-defined, constant load and schedule, short-term measurements and simple engineering analysis (Option A) might suffice. Whereas variable and seasonal loads typically require pre- and post-trend data that cover the range of operations common to the HVAC end-use.

Data requirements and M&V rigor are typically based on energy savings and/or incentive levels, as exemplified by the RCx Custom Measure Guidance (CMG) document.<sup>12</sup> Use of a standard Guideline 36 calculation tool can help establish common expectations of potential energy savings, the necessary level of M&V rigor, and data requirements to estimate and verify savings.

- Simplify reporting requirements. As demonstrated in this study, the process of identifying, scoping, and implementing Guideline 36 measures is complex, labor-intensive (i.e., coordination between building operators, design engineers, control contractors, and commissioning agents), and time-consuming. Aligning program engagement and reporting requirements with this process is critical to providing meaningful technical and financial program support. Evaluation studies have shown that for RCx projects, the technical resources provided to a customer are often of greater value and importance than savings-based incentives (Tso, Baker and Willems 2010). This is especially true of mid-sized buildings between 150,000 and 400,000 square feet, where customers have limited time and financial resources to implement RCx measures, let alone Guideline 36 (Tonielli 2016).

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<sup>12</sup> <https://www.caltf.org/tools-custom/#cmg>

# The ASO Approach

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## What ASO is

### *Definition*

EMIS, which is briefly described in the “Traditional vs ASO Approach” section, is a set of tools that control, monitor, and analyze building energy use. They provide advanced HVAC system control beyond the traditional BAS abilities. EMIS capabilities include data analytics, energy information systems, fault detection and diagnosis (FDD), and automated system optimization, which is the newest addition to the EMIS family. ASO is software that optimizes HVAC system energy usage and efficiency by examining and tweaking BAS control settings in real-time (Figure 2). It also considers factors such as weather conditions, building occupancy, and demand charges when performing advanced building and system-level optimization. Unlike other EMIS tools that only read BAS data, ASO enables two-way communication with the BAS and can dynamically adjust HVAC system settings based on real-time load conditions (Kramer, et al. 2020). This software is frequently utilized to optimize reset strategies for chilled water plants and air handling units.

### *Common methods*

Common methods used in ASO include rule-based algorithms, machine learning, and model predictive control (MPC).

Rule-based methods are a conventional approach that follows pre-defined rules to make decisions. In ASO, these are referred to as expert rules, which were compiled by industry experts. One example of a rule-based algorithm is the ASHRAE Guideline 36 high-performance control sequences for HVAC systems. These rule-based algorithms are easy to implement at the supervisory level/ cloud-based control platform, as they typically don't require extensive computing power, high-end controller hardware with sufficient memory or data storage, or specialized optimization or simulation software packages. Using ASO to implement ASHRAE Guideline 36 can dynamically adjust HVAC parameters, such as AHU supply air static pressure, AHU supply air temperature, and optimal system start/stop times based on real-time occupancy, building load, and weather data.

Machine learning techniques are a subset of artificial intelligence that learn from data and adapt over time, improving performance without the need for explicit programming. Specifically, some ASO solutions utilize neural networks, reinforcement learning, genetic algorithms, and support vector machines to predict energy consumption, optimize HVAC system parameters, and identify potential system issues.

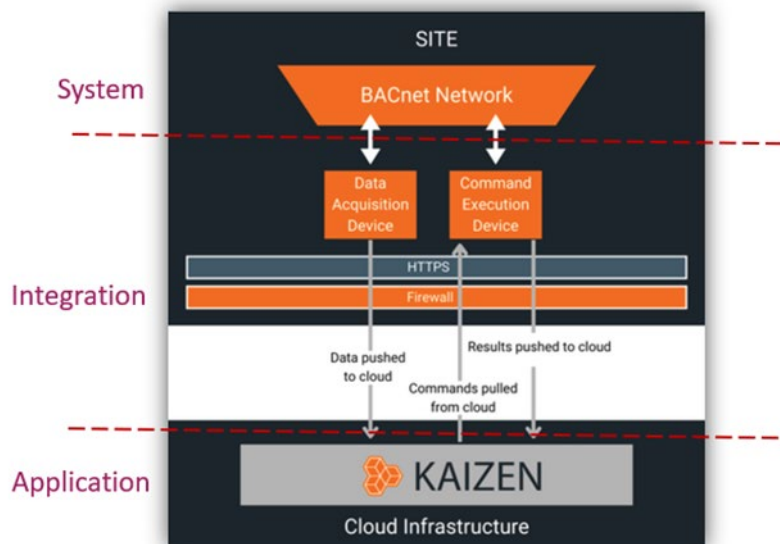
Another ASO method is model predictive control, which uses a dynamic model of a system to evaluate and optimize different control input sequences over a defined time horizon, while adhering to a set of constraints. MPC operates using two time horizons: a control and a prediction horizon. The prediction horizon is the time span the model considers when forecasting future behavior, and the control horizon is the duration over which control actions are implemented. This forward-looking approach enables

MPC to incorporate future data, such as weather forecasts, into its decision-making process. Compared to rule-based methods, both machine learning and MPC require more computer or controller hardware and software resources. They are currently less commonly used in real buildings due to the significant time and effort needed to create models, the complexity of formulating the optimization problems, and the hardware and software resources needed to run machine learning and MPC algorithms in near real-time.

### ASO architecture

An ASO software implementation architecture example from CopperTree Analytics is shown in Figure 31.

Figure 31. An ASO Software Implementation Architecture Example



In a conventional BAS upgrade, both the control hardware and software are fully replaced with new components. By contrast, the ASO approach retains the existing BAS infrastructure and adds an external ASO hardware device—typically a network gateway or computer—to collect real-time and historical BAS data via the BACnet communication protocol. This data is securely transmitted to the cloud, where ASO software, such as Kaizen ASO, analyzes system performance metrics using ASHRAE Guideline 36 sequences. The ASO software then issues supervisory control commands back to the BAS control network via BACnet to optimize HVAC setpoints dynamically. The Kaizen ASO platform applies energy-saving strategies consistent with ASHRAE Guideline 36, such as air handling unit (AHU) supply air static pressure reset and supply air temperature reset. It reads BAS data to calculate the number of cooling requests from each variable air volume (VAV) terminal and adjusts the AHU setpoints accordingly to minimize energy use while maintaining comfort.

Compared with traditional full BAS replacements, implementing ASHRAE Guideline 36 through ASO is generally simpler, focusing on targeted supervisory-level optimization measures rather than full system reprogramming. However, its effectiveness depends on several key factors:

- Availability of required BAS data points for ASO analytics.
- Operational condition and reliability of existing HVAC equipment and controls.
- Proper management of network and cybersecurity protocols.

While this approach offers promising efficiency potential, third-party field validation studies of its real-world performance are still limited, and ongoing research is needed to fully assess its energy savings impact.

## Market Overview

### *Current state of the market and key players*

ASO has a relatively small number of commercial offerings and users in the market today. In the commercial buildings sector, the current landscape includes a mix of proprietary vendor platforms and early open-source supervisory control approaches, with several solutions explicitly leveraging ASHRAE Guideline 36 sequences.

### *Commercial vendors using Guideline 36*

CopperTree Analytics and BTune are two of the main companies implementing ASO solutions based on ASHRAE Guideline 36. CopperTree's Kaizen ASO platform integrates with the BAS through a three-step process: implementing Kaizen FDD data collection and analytics, deploying two-way communication hardware, and configuring target systems to enable ASO. Kaizen ASO provides bi-directional supervisory optimization, an action log with time-stamped ASO commands and status results, and built-in safety features such as an allow-list, priority array, and time-expiration command management. The platform reports 15%–30% energy savings in commercial buildings (CopperTree Analytics 2024).

BTune's ASO software sits on top of the BAS and continuously modifies control settings to optimize HVAC performance, deploying savings opportunities zone by zone and monitoring and correcting building operation 24/7. BTune connects to the BAS through a BTune edge computer that handles bi-directional data acquisition and command execution, with one Chicago deployment achieving a 12.9% whole-building monthly average energy reduction, 12% total energy bill reduction, and targeted annual cost savings of \$75,000–\$90,000 (BTune 2024).

### *Other major proprietary ASO platforms*

Several additional vendors provide ASO-type capabilities to improve building efficiency and automate building systems, including Nantum AI, BrainBox AI, and Ecopilot. BrainBox AI, which has been in the market since 2019 and was acquired by Trane in late 2024, has been deployed in more than 100 million square feet of commercial space, including over 600 Dollar Tree stores across 18 U.S. states, where it has delivered over \$1 million in annual electricity savings and reduced HVAC energy consumption by

more than 7.9 million kWh (BrainBox AI n.d.) BrainBox AI integrates either through existing networked control systems (such as a BAS) or via cloud-connected, AI-enabled thermostats, using an artificial neural network to predict building thermal behavior and optimize HVAC operation using inputs such as weather forecasts, utility tariffs, grid emissions factors, and occupant density, while continuously interacting with HVAC equipment to learn and adapt to changes.

Nantum AI (formerly Prescriptive Data) is an EMIS with ASO capabilities that supports four main smart building application areas: grid-interactive efficient buildings, automated demand response and peak load management, portfolio-wide energy and carbon management, and building-level optimization of HVAC, lighting, indoor air quality, shades, and dynamic glass. In a U.S. General Services Administration (GSA) Green Proving Ground deployment across four testbeds, Nantum AI used AHU fan speed control and other strategies to deliver 5%–11% energy reductions, while maintaining predicted demand within 5% of measured demand (Powell, et al. 2022). Nantum collects data from BAS/BMS and other sensors, uses machine learning to model air-side system relationships (for example, AHU supply duct airflow versus total pressure), and applies model predictive control to optimize static pressure and supply air temperature setpoints, coordinate multiple AHUs, optimize schedules, and control HVAC based on real-time greenhouse gas intensity.

Ecopilot delivers ASO functionality through its iBOS energy optimization strategy, which integrates with the BAS and focuses on leveraging building thermal mass. The iBOS model is proprietary, but the vendor reports that its AI algorithm analyzes building thermodynamics, BAS data, and weather forecasts to predict daily heat gain and loss, determine a balance-point temperature, and dynamically adjust HVAC supply air temperature setpoints to reduce energy use and exploit free cooling opportunities. Ecopilot reports typical energy savings of around 25%, with the potential to achieve up to 40% in some buildings (EcoPilot Canada | USA n.d.)

### *Open-source ASO and Guideline 36*

Alongside commercial proprietary platforms, researchers are exploring an open-source ASO approach for implementing ASHRAE Guideline 36 supervisory controls. Under the CalNEXT-sponsored project “ASHRAE Guideline 36 Open-Source Supervisory Control Technology Development and Demonstration,” TRC, UC Berkeley, and Taylor Engineers developed and field-tested an open-source supervisory control framework that performs advanced Guideline 36 calculations for hydronic systems (hot water and chilled water plants). Instead of vendor-specific ASO software, the project uses standardized Control Description Language (CDL) for programming monitoring and control logic and applies Brick ontology to map between the control logic and existing BAS points, streamlining deployment in an ASO-provider-agnostic way and avoiding the need to re-implement Guideline 36 measures in each proprietary platform.

In late-stage field tests focused on ASHRAE Guideline 36-2021 hydronic system sequences, preliminary results showed annual energy savings of 4% and 10% at two hot water plants, corresponding to cost savings of approximately \$0.065 and \$0.156 per square foot per year, respectively, and 19% energy savings at a chilled water plant, corresponding to about \$0.28 per square foot per year. These results

demonstrate that an open-source, standards-based supervisory control implementation can deliver meaningful energy and cost savings while reducing market dependence on any single ASO vendor.

### *The business case*

ASO is an emerging practice that delivers a range of benefits. It enables facility managers to monitor real-time data across multiple buildings, enhancing data reporting and providing faster insights into operational issues, which ultimately helps extend equipment lifespan. Additionally, ASO automates tasks such as measurement and verification, and supports autonomous building optimization and coordination. These automated systems enhance and streamline workflow by increasing efficiency, scalability, and ensuring consistent performance. Ultimately, these advantages contribute to improved occupancy comfort, energy savings, and reduced emissions. Several ASO providers have done their own internal analysis or case studies on energy savings and cost-effectiveness of implementing ASO solutions. For example, CopperTree Analytics estimated that (in an email communication with Slipstream), for a 250,000 square foot building, the cost for implementing ASO with ASHRAE Guideline 36 would be \$17,185 in Year 1 and \$8,815 per year for subsequent years. The expected savings would be \$67,500 after 2 years. For a 100,000 square foot building: Year 1: \$7,375, Years 2+: \$3,685 per year, with expected savings: \$27,000 after 2 years. This would result in a simple payback period of about 5 months and an average cost of implementation and operation of \$0.10-\$0.11 per square foot for the first two years. A BTune's ASO own case study in a 383,000 square feet (40-story high-rise) Chicago building showed 12.9% whole-building monthly average energy reduction and 12% total energy bill reduction, and targeted \$75k-\$90k annual cost savings (BTune 2024). The above estimated implementation and operation cost per square foot and energy savings numbers should be very attractive to building owners, as the simple payback periods are much shorter than traditional ASHRAE Guideline 36 implementations. According to the CEC-sponsored ASHRAE Guideline 36 field study the average retrofit cost for a hardware and software retrofit is \$6.40 per square foot, and for a software-only retrofit, the average cost is \$0.65 per square foot. ASO implementation is potentially significantly cost-effective because only some existing building control software may need to be reconfigured; no existing building control hardware or software needs to be replaced or modified.

## **Other ASHRAE Guideline 36 ASO field studies**

CalNEXT, a California initiative to grow technologies for decarbonization, funded an ASHRAE Guideline 36 demonstration to show how using open-source supervisory control can be implemented in chilled water and hot water systems. The results were compared to baseline control strategies, such as variable primary flow, demand-based control, and outdoor reset control. The control strategy was demonstrated at two sites. One site had ASHRAE Guideline 36 implemented in both hot water and chilled water systems, and the other site only had ASHRAE Guideline 36 implemented in the hot water plant. Both buildings are located in Berkeley, California, and the project team also built normalized energy savings models to account for changing conditions, such as weather conditions.

## *Saturdja Dai Hall*

This 141,000-square-foot, seven-story campus building is on the University of California, Berkeley campus. It is a mixed-use building with laboratories, classrooms, offices, and a cleanroom space for fabrication. The building's chilled water system has two 600-ton chillers, one being an absorption chiller and the other a centrifugal chiller, along with modular chillers for server rooms and as backup chilling capacity. The chilled water system feeds six AHUs of various sizes, computer air conditioning systems, a fan coil unit, and process loads for the cleanroom. The hot water system has a heat exchanger connected to the campus steam system and distributes the hot water to 130 heating coils across the building.

Saturdja Dai Hall achieved energy savings on both the chilled water and hot water systems using ASHRAE Guideline 36. The chilled water system had a 14 percent energy savings, with normalized savings of 19 percent. The hot water system had 10 percent savings, with normalized savings of 9.8 percent.

## *David Brower Center Building*

This 38,600-square-foot LEED Platinum building is located in downtown Berkeley, California. It is a four-story mixed-use building with office and meeting spaces, an auditorium, and a restaurant. The hot water system used two condensing natural gas boilers, which fed two AHUs for heating, and a thermal radiant system.

The David Brower Center Building achieved energy savings using ASHRAE Guideline 36. The hot water system had 10.5 percent savings, with normalized savings of 4 percent.

## **Market opportunities and potential challenges**

### *Opportunities for growth*

There is significant potential for expansion in applying ASHRAE Guideline 36 through the ASO approach. While the traditional implementation method faces both technical and non-technical barriers—such as high costs, system complexity, and programming challenges—the ASO approach presents a more cost-effective and scalable solution. For comparative details, refer to the “Business Case” section for associated economic analyses.

Another major growth avenue for ASO lies in the large number of existing buildings whose obsolete BAS hardware and software cannot directly support ASHRAE Guideline 36 sequences without full system replacement. The ASO method offers an attractive alternative, enabling Guideline 36 compliance at a substantially lower cost and without discarding functioning BAS components.

Beyond affordability and faster deployment, ASO solutions could appeal to building owners seeking no upfront capital investment. Through energy performance contracting-style models, clients can partner with ASO providers to share future verified energy savings rather than pay full costs upfront. For

example, the ASO company BTune currently offers flexible pricing arrangements, allowing customers to choose between fixed-fee and variable performance-based payment options<sup>13</sup>.

## *Potential Challenges*

Over a three-month outreach period, the project team engaged with building owners across Minnesota to explore interest in conducting field tests that use the ASO approach to implement ASHRAE Guideline 36 for improved energy efficiency. Four facility managers overseeing large building portfolios were interviewed, and several key challenges were identified.

- **BAS warranty concerns:** Some owners expressed uncertainty about whether introducing ASO could void their existing BAS warranties, since ASO interacts directly with BAS setpoints rather than operating in a purely passive, data-reading mode.
- **Third-party control concerns:** Facility teams were hesitant to allow a third-party platform to exert supervisory control over their BAS, fearing potential complications if operators could not clearly understand or override ASO-generated commands.
- **IT department resistance:** IT teams may be reluctant to authorize external software to communicate with their BAS networks due to cybersecurity risks and strict internal network policies.
- **Protocol integration issues:** Compatibility challenges may arise when integrating ASO with older BAS technologies that use LON (LonTalk/LonWorks) or proprietary communication protocols like N1 (Johnson Controls) instead of modern BACnet systems.
- **Limited scalability in smaller or older buildings:** A significant portion of Minnesota's building stock comprises older facilities under 100,000 square feet with legacy control systems and limited network infrastructure, reducing the cost-effectiveness of ASO deployment.
- **Low occupancy post-COVID:** Some commercial buildings are still operating at low occupancy levels, where facilities are run in a minimal mode for preservation and energy conservation, leaving little opportunity for real-time optimization or measurable savings.

## **MN utility ECO programs**

Utilizing ASO to implement ASHRAE Guideline 36 aligns with Xcel Energy's custom energy efficiency program, specifically in the areas of building controls, retro-commissioning (RCx), and energy management systems (EMS). It provides an alternative, potentially more cost-effective option to building owners who do not have the budget to conduct building controls retrofits using the traditional approach, as no existing BAS hardware and software need to be replaced. It may also be much easier to meet Xcel Energy's cost-effectiveness / simple payback threshold to be approved to get rebates under their custom energy efficiency program.

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<sup>13</sup> <https://www.btune.com/pricing>

### Field Demonstration Key Takeaways

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#### ASHRAE Guideline 36 is Complex

ASHRAE Guideline 36 can make building operations more energy efficient. However, there is no denying that it increases the complexity compared to typical building control sequences. Most of the energy-saving measure concepts in ASHRAE Guideline 36 are not new and are known to the building HVAC system designers and controls contractors. But the real energy-saving impact comes from the complexity - the detailed implementation steps and recommended initial and optimal control parameters in ASHRAE Guideline 36. Without understanding the nuances of these implementation details, successful control retrofit projects implementing ASHRAE Guideline 36 could be difficult.

It was the ASHRAE Guideline 36 committee's original intention to wrap the complexity of ASHRAE Guideline 36 into design tools to help specify control sequences more easily, and into BAS manufacturers' libraries to enable control contractors to program and test control sequences quickly. Through this project's field demonstration experience, at least in Minnesota, for building controls retrofit projects, many challenges remain for successful field implementations of ASHRAE Guideline 36.

#### Challenges to Adopt ASHRAE Guideline 36 in Minnesota

- Slow industry adaptation despite growing awareness; many building owners and engineers have heard about it, but have not applied it in projects.
- High technical complexity: sequences are more detailed than typical BAS controls and require advanced knowledge and tools for both building design engineers, energy consultants, controls contractors, and commissioning agents. Some hesitate to adopt it because of its complexity.
- Need for better tools to simplify sequence design, programming, tuning, and commissioning.
- Implementation challenges due to often missing mechanical engineering input and old HVAC system configurations that need custom design and modification of the existing HVAC control parameters and control sequences.
- Controls contractors may lack sufficient training and understanding of new programming libraries aligned with Guideline 36.
- Varied quality and attention to detail among controls contractors; project success depends on skilled contractor selection beyond just price. Time and cost of ASHRAE Guideline 36 implementation may be increased due to its complexity and lack of training on how to use BAS manufacturers' Guideline 36 libraries.
- Projects implementing ASHRAE Guideline 36 may not pass the utility ECO program's cost-effectiveness threshold to qualify for rebates/incentives, due to its complexity and the need to replace existing hardware and software.
- Building owners may not fully appreciate the value, due to mixed energy savings results and high project complexity.

- Commissioning requires standardized, focused protocols because complexity can lead to overlooked issues without proper documentation and functional testing.

These challenges highlight the need for ongoing education, tool development, coordinated engineering and contractor collaboration, and a clear demonstration of value to promote wider acceptance and successful projects using ASHRAE Guideline 36.

## Market Research Key Takeaways

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ASHRAE Guideline 36 standardizes HVAC control sequences to improve energy efficiency, comfort, and system performance. There are two implementation paths: the traditional approach and the Automated System Optimization (ASO) approach.

### The Traditional Approach

#### *Major benefits and intentions*

Intended simplification: ASHRAE Guideline 36 was designed to standardize best-in-class building control sequences and simplify design, implementation, and commissioning processes. BAS manufacturers have developed programming libraries with pre-programmed ASHRAE Guideline 36 logic to reduce control sequence programming time and effort. California field demonstrations showed significant results with 26-35% whole-building electricity savings for full retrofits and 11-17% for software-only retrofits. From California demonstrations, the average cost for ASHRAE Guideline 36 implementation is \$6.40 per square foot for hardware/software retrofits and \$0.65 per square foot for software-only retrofits. This is in the same range as traditional controls upgrades without implementing ASHRAE Guideline 36.

#### *Key challenges and barriers*

However, field demonstration results from California may not translate to other states, like Minnesota, due to the differences in ASHARE Guideline 36 awareness, understanding of the technical details by building professionals, building code requirements, climates, and training.

Despite growing awareness since 2018, many building professionals are familiar with the guideline but have not applied it in projects. The guideline's technical complexity makes it challenging for engineers, contractors, and commissioning agents to understand and implement. Successful implementation requires mechanical engineering input, which is often absent in small to medium-sized building retrofits. There is a missing connection between BAS manufacturers' libraries and contractors' ability to properly implement them in real projects. Minnesota demonstrations showed minimal energy savings due to a lack of engineering oversight and improper implementation of technical details. Controls contractor work quality varies significantly, with many prioritizing speed over technical accuracy.

# The ASO Approach

## *Core advantage*

The core advantage of the ASO approach is its potential cost-effectiveness: \$0.15-\$0.20 per square foot initial cost (ASO) compared to \$0.65-\$1.00 per square foot (Traditional) for medium to large commercial buildings. There is no need to replace the existing building control hardware or software. ASO reads existing BAS data and sends optimized setpoints back. ASO focuses only on key energy efficiency measures that can be implemented at the supervisory control level. California field demonstration preliminary results show 12% whole-building energy reduction and 12% total energy bill reduction. Some ASO providers also provide multiple pricing models - options for fixed versus variable fee structures, including energy savings sharing arrangements.

## *Implementation process*

ASO uses a cloud-based architecture: a networking gateway will be installed and connected to the existing BAS network to read BAS data, process it through cloud algorithms, and send optimized setpoints back to BAS for execution. ASO can employ rule-based algorithms, including ASHRAE Guideline 36 control sequences, machine learning, or model predictive control approaches. It can provide real-time optimization, continuously adjust HVAC parameters based on occupancy, building load, and weather.

## *Market opportunities*

ASO provides an alternative for older building control systems that cannot implement ASHRAE Guideline 36 sequences to execute key energy savings measures in the guideline. It reduces the project risk, eliminates many traditional implementation challenges, while maintains energy savings potential. There is a growing market presence for ASO: multiple commercial providers, including CopperTree Analytics, BTune, BrainBox AI, and Nantum AI are currently offering ASO solutions.

## *Current challenges*

There are challenges and concerns regarding ASO implementation by building owners in Minnesota. Building owners worry about voiding existing HVAC and BAS system warranties. They also expressed cybersecurity concerns about third-party software communicating with BAS networks. ASO integration with existing BAS may be difficult for legacy systems using LON or proprietary protocols. The cost-effectiveness of implementing ASO for buildings under 100,000 square feet may be reduced.

Implementing ASHRAE Guideline 36 using ASO could be a more cost-effective alternative to the traditional approach, and it may be easier to pass the MN utilities' custom energy-efficiency program cost test. However, there are no ASO field demonstrations in Minnesota to comprehensively evaluate the ASO implementation process, energy savings potential, cost-effectiveness, and challenges to wide adoption by stakeholders.

# Conclusions and Recommendations

## General conclusions

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Successful ASHRAE Guideline 36 implementation in building control upgrade/retrofit projects requires a comprehensive mechanical engineering review, experienced controls contractors, and thorough commissioning - elements often missing in typical building controls retrofit projects in Minnesota. ASHRAE Guideline 36's complexity makes it impractical for small buildings with outdated HVAC systems that deviate from their standard configurations. The Automated System Optimization (ASO) approach offers a potentially more cost-effective path to implementing key Guideline 36 energy efficiency measures, particularly for existing buildings with legacy control systems. If implemented properly, ASHRAE Guideline 36 can save significant energy, as evidenced by multiple studies in California. Without proper design and attention to detail, a retrofit may fail to actually implement ASHRAE Guideline 36 and therefore not realize the anticipated energy savings. Awareness of ASHRAE Guideline 36 has grown in recent years and will increase considerably with a new California Energy Code requirement to follow ASHRAE Guideline 36 for select sequences of operation. There are various tools and guidance available to support identifying ASHRAE Guideline 36 retrofit opportunities and the design and implementation of ASHRAE Guideline 36. Wider use of these tools will certainly improve ASHRAE Guideline 36 market adoption and realized savings.

Both the traditional and ASO approaches could fit within Minnesota utility ECO programs, with ASO potentially offering broader market applicability due to lower costs and reduced implementation barriers. However, concerns and challenges remain for ASO implementation as it is an emerging technology and requires connecting existing BAS networks and providing supervisory-level optimization and control.

The study demonstrates that while ASHRAE Guideline 36 has significant energy-saving potential, successful implementation requires careful project planning, appropriate building selection, and sufficient technical expertise throughout the process.

## Recommendations

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The following recommendations are for building owners, facility managers, controls manufacturers, design engineers, and contractors. They emphasize that successful ASHRAE Guideline 36 implementation requires comprehensive planning, qualified contractors, enhanced commissioning, and ongoing support to achieve the documented energy savings potential:

- **Stakeholder Education:** Building owners and facility managers need to be knowledgeable about key energy-savings concepts in ASHRAE Guideline 36. Mechanical engineers, controls contractors, and commissioning agents should receive training on detailed ASHRAE Guideline 36 implementation before project initiation. Live and recorded trainings exist through various BAS manufacturers, the U.S. Department of Energy (DOE), the U.S. Department of Defense (DoD), Slipstream, Pacific Energy Center, and the BEST Center. Engineers, contractors, and

commissioning agents should also reference the Advanced Building Automation System Best Practices Guide, which serves as a key resource to highlight and explain key concepts in ASHRAE Guideline 36.

- **Mechanical Engineering Review:** Ensure mechanical engineering involvement from the beginning, especially for retrofit projects. The existing HVAC system must be thoroughly evaluated to determine compatibility with Guideline 36 sequences, and calculations may need to be revised to adapt control sequences effectively based on the latest building code requirements.
- **Building Selection Criteria:** Focus on buildings larger than 100,000 square feet with standard HVAC configurations or designs available in ASHRAE Guideline 36, as these buildings are more likely to need minimal control sequence customizations.
- **Use Standardized Tools:** Designers should leverage available control sequence specifying tools like ctrl-flow for generating plain language sequences, in addition to the zone ventilation airflow calculation tool. Controls contractors should use BAS manufacturer programming libraries that comply with ASHRAE Guideline 36.
- **Contractor Qualification:** Select controls contractors based on technical expertise and ASHRAE Guideline 36 experience, not just price. Require training and certification for Guideline 36 implementation.
- **BAS Manufacturer Support:** Work with BAS manufacturers who have developed and validated ASHRAE Guideline 36 programming libraries, ensuring proper training is provided to local contractors.
- **Programming libraries:** Require the use of a certified or third-party validated programming library.
- **Documentation Requirements:** Maintain detailed documentation throughout implementation, including as-built drawings, control sequence descriptions, and commissioning reports.
- **Enhanced Commissioning:** Implement standardized functional performance tests specifically designed for ASHRAE Guideline 36 sequences. Engage commissioning agents throughout the project, not just at the end.
- **Trend Data Analysis:** Conduct a thorough analysis of trending data to confirm system performance meets Guideline 36 requirements before project acceptance.
- **Consider Automated System Optimization:** For buildings with budget constraints or older control systems, evaluate ASO solutions that implement key Guideline 36 measures at the supervisory level without hardware replacement.

The following recommendations are for the industry more broadly to facilitate effective ASHRAE Guideline 36 adoption:

- **Develop guidance on applying the key energy savings measures of ASHRAE Guideline 36 to existing buildings, including how to screen buildings for applicability and practicality for a Guideline 36 retrofit and how to adapt ASHRAE Guideline 36 to existing conditions and limitations. This effort is currently in progress as part of a CalNext-funded project.**

- Develop a test method to validate that control programming is consistent with the control sequences in ASHRAE Guideline 36. This effort is currently in progress as part of a CalNext-funded project.
- Develop ASHRAE Guideline 36 energy efficiency measure savings calculation tools and make them publicly available for design engineers and controls contractors.
- Centralize and streamline various tools and guidance that support ASHRAE Guideline 36 to make them more accessible and easier to use.
- Continue to offer training opportunities through a variety of platforms.

To successfully integrate ASHRAE Guideline 36 into utility programs, several key strategies should be implemented. The utility should incorporate some of the key energy-saving measures from ASHRAE Guideline 36 as standard options in their program materials, emphasizing detailed implementation steps and recommended optimal parameters to ensure proper compliance with the guideline. They can require participating customers to partner with a controls contractor who has completed ASHRAE Guideline 36 training or obtained certification in ASHRAE Guideline 36. This training or certification could serve as a prerequisite for inclusion on the utility's approved contractor list or within its trade ally network to ensure quality ASHRAE Guideline 36 project delivery. The program should initially limit offerings to low-hanging measures such as VAV minimums and supply air temperature reset to reduce complexity and increase success rates. Utilities can leverage data analytics of customer utility data to identify buildings with the greatest potential for these measures. Additionally, ASHRAE Guideline 36 energy efficiency measure savings calculation tools should be developed and made publicly available for design engineers and controls contractors to streamline project development. Clear verification requirements should be defined by measure type and building size, while reporting requirements should be simplified to reduce administrative burden and encourage participation.

## Future Research Topics

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Several research priorities could enhance the design and evaluation of custom energy efficiency programs incorporating ASHRAE Guideline 36. Research should focus on identifying which specific energy-saving measures within ASHRAE Guideline 36 result in the greatest energy savings, enabling utilities to make more targeted recommendations to customers. Additionally, improving energy modeling techniques would allow for more accurate estimation of savings from ASHRAE Guideline 36 measures, supporting better program design and customer business cases. Expanding the scope of available control sequences through developing and implementing new sequences for additional HVAC equipment types, such as heat pumps, along with practical guidance for controls contractors on these implementations, would broaden program applicability. EMIS should be leveraged to validate existing control strategies and demonstrate performance outcomes. Market analysis research is needed to estimate the size of the potential market, including determining the number of buildings and total square footage that could benefit from these energy-saving measures. Establishing standardized methods to identify and manage rogue zones—zones that consistently operate improperly and cause system inefficiencies or disruptions—would improve overall program effectiveness and energy savings persistence. Finally, a field demonstration of implementing ASHRAE Guideline 36 using ASO could inform stakeholders on the energy-savings potential, cost-effectiveness, applicability to utility ECO programs,

and challenges and barriers to potential wide adoption by building owners, design engineers, and controls contractors / ASO providers.

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## Appendix A: Demonstration Site Selection Criteria

# MEMORANDUM

To: Laura Silver

From: Rupam Singla, Gwelen Paliaga (TRC)

Joe Zhou (Slipstream)

Re: MN CARD Field Demo of ASHRAE Guideline 36 Demonstration Site Selection Criteria

### Background

The Minnesota Department of Commerce is funding a research project led by Slipstream, TRC, and the University of Minnesota which aims to field demonstrate control retrofit process improvements by implementing ASHRAE Guideline 36 High-Performance Sequences of Operation for HVAC Systems. Participating in this research project brings several benefits to a building owner including providing 20-40 percent energy savings & reduced operations costs, improved occupant comfort, improved operational efficiency, building staff training on these new technologies, and the opportunity to participate in a research project with industry leaders.

The team is seeking buildings to serve as demonstration sites for this research project. In order to assist with selecting and finalizing demonstration sites, below is a summary of the site selection criteria. Two types of sites are desired for the study: (1) Sites slated to have a full building control system hardware retrofit; and (2) Sites with modern direct digital controls (DDC) (pre-existing DDC for the entire HVAC system), which are willing to participate in project for a building control system software-only upgrade.

### Selection Criteria

#### Criteria for Sites Slated for a Full Building Controls Hardware Retrofit

- An owner whose building is within the state of Minnesota with a planned owner-funded full controls retrofit scheduled to happen between April 2021 and August 2022.
- Planned retrofit scope and schedule
  - Full retrofit that includes DDC to the zone level and controllers capable of custom programming of ASHRAE Guideline 36 sequences.
  - Ideally very limited HVAC equipment upgrade scope other than the full DDC controls upgrade, unless it allows isolation of the savings from the controls upgrade (such as a like-for-like AHU replacement).
  - If the team has access to at least 6 months of whole-building electricity interval data, then construction can begin immediately. Construction expected to be completed by no

## Appendix A: Demonstration Site Selection Criteria

later than July 2023 to allow time for post-retrofit M&V and reporting prior to the expected contract end date of December 2023.

- No other significant retrofits or renovations or changes in occupancy planned between now and July 2023.
- **Building**
  - All or most of the building is served by single-zone VAV AHUs and/or multi-zone VAV AHUs. Systems are either packaged DX or have chilled water for cooling.
  - Existing controls are pneumatic or very old electronic standalone controls (limited existing DDC on central equipment is acceptable).
  - Building is a non-residential occupancy.
  - Preference for building owners with a portfolio of buildings or that are part of a campus.
  - Building does not have any significant process loads (such as data centers). Or, if process loads are present, then their associated electrical loads can be easily disaggregated from the rest of the building.
  - Existing energy data and metering: Preferably at least 1 year of historical utility data available, ideally 3-5 years. Ideally existing whole-building interval energy metering in place for electricity, gas, and chilled and hot water BTUs (if there are central utility plants),
    - Strong preference for buildings with at least a year of existing whole-building electricity interval data, or fan power trends from VFDs if there is central chilled water and hot water, which allows an earlier construction start date (see above).
  - Ideally, the new building control system vendor has developed and release partial or full ASRHAE Guideline 36 libraries. Following vendors may have satisfied this criterion based on project team's knowledge by February 2021:
    - Automate Logic
    - Trane
    - Distech Controls
    - Honeywell/Alerton
    - Siemens
    - Johnson Controls
    - Schneider Electric

### Criteria for Building Controls Software-only Retrofit Sites

- An owner whose building is within the state of Minnesota and is interested in participating in a research project by hosting a building control software-only retrofit in their building. Willing to complete the retrofit between April 2021 and August 2022.
- Retrofit scope and schedule

## Appendix A: Demonstration Site Selection Criteria

- If the team has access to at least 6 months of whole-building electricity interval data then retrofit can begin immediately. Software-only retrofit expected to be completed by no later than August 2022 to allow time for post-retrofit M&V and reporting prior to the expected contract end date of December 2023.
- No other significant retrofits or renovations or changes in occupancy planned between now and July 2023.
- Building
  - Existing Building Automation System (BAS) with DDC to the zone level and controllers capable of ASHRAE Guideline 36 sequences. Newer BASs (less than 5 years old) more likely to meet this criteria, but it is very manufacturer-specific.
  - All or most of the building is served by single-zone VAV AHUs and/or multi-zone VAV AHUs. Systems are either packaged DX or have chilled water for cooling.
  - Building is a non-residential occupancy.
  - Preference for building owners with a portfolio of buildings or that are part of a campus.
  - Building does not have any significant process loads (such as data centers). Or, if process loads are present, then their associated electrical loads can be easily disaggregated from the rest of the building.
  - Existing energy data and metering: Preferably at least 1 year of historical utility data available, ideally 3-5 years. Ideally existing whole-building interval energy metering in place for electricity, gas, and chilled and hot water BTUs (if there are central utility plants),
    - Strong preference for buildings with at least a year of existing whole-building electricity interval data, or fan power trends from VFDs if there is central chilled water and hot water, which allows an earlier construction start date (see above).
  - Ideally, the new building control system vendor has developed and release partial or full ASHRAE Guideline 36 libraries. Following vendors may have satisfied this criterion based on project team's knowledge by February 2021:
    - Automate Logic
    - Trane
    - Distech Controls
    - Honeywell/Alerton
    - Siemens
    - Johnson Controls
    - Schneider Electric

### Consider Secondary Criteria

The following is 'soft' criteria, where there are no right or wrong responses, but favorable responses can help distinguish between sites.

## Appendix A: Demonstration Site Selection Criteria

- Owner enthusiasm for project research goals
- Same building owner for all sites for ease of the demonstration
- Variety of building or occupancy types
- Variety of building sizes
- Different control system manufacturers represented
- Systems in good working condition? Lack of deferred maintenance issues?
- Representativeness of building
- BAS manufacturer and local dealer/distributor/contractor support
- Full hardware sites only: Engineer of record

Software only: Existing sequences of operation

# Appendix B: Demonstration Site Recruitment Flyers

Figure 32. Appendix B - Demo Site Recruitment Flyer



## Field demonstration sites needed

The Minnesota Department of Commerce is funding a field demonstration project led by Slipstream, which aims to improve commercial building control retrofit process, energy savings, and building operation and maintenance by implementing ASHRAE Guideline 36 High-Performance Sequences of Operation for HVAC Systems. Team partners include the University of Minnesota and TRC.

### We are looking for three demonstration sites in the state of Minnesota

Your building may be a good candidate if:

1. It is slated to have a full building control system hardware retrofit, OR
2. It has modern direct digital controls and you are willing to participate in a building control system software-only upgrade

### Benefits of participating

- 20 to 40 percent energy savings
- Reduced operations costs
- Improved occupant comfort and occupant engagement
- Improved operational efficiency via smart HVAC controls sequencing
- Marketing opportunity
- Financial incentives

### Ideal building candidates will...

- Be served by single-zone VAV AHUs and/or multi-zone VAV AHUs
- Have one of the following building control systems: Automated Logic, Trane, Distech Controls, Honeywell/Alerton, Siemens, Schneider Electric, Johnson Controls
- Not have significant process loads, or have process loads that can be disaggregated from other loads
- Have non-residential occupancy

**ASHRAE**  
GUIDELINE  
ASHRAE Guideline 36-2018  
**High-Performance Sequences of Operation for HVAC Systems**

**Want to participate?**  
If you are interested in becoming a demonstration site, please contact Slipstream:

**Dr. Joe Zhou**  
608.210.7155 | jzhou@slipstreaminc.org

**Maddie Koolbeck**  
608.210.7128 | mkoolbeck@slipstreaminc.org

"This project is supported by a grant from the Minnesota Department of Commerce, Division of Energy Resources, through the Conservation Applied Research and Development (CARD) program, which is funded by Minnesota ratepayers."

SPONSOR



PARTNERS



Figure 33. Appendix B - Demo Site Recruitment Flyer - ASO



## Improve Building Operations Using Automated System Optimization

The Minnesota Department of Commerce is funding a field demonstration project led by Slipstream, which aims to improve commercial building control sequences, energy savings, and building operation and maintenance by implementing ASHRAE Guideline 36 High-Performance Sequences of Operation for HVAC Systems. Team partners include the University of Minnesota and TRC.

### One demonstration site opening remains!

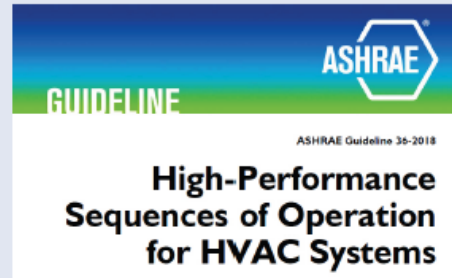
1. Incentive up to \$15,000 and payback under 1 year.
2. With options for no up-front cost.

### Benefits of participating

- Financial incentives
- Significant energy savings
- Reduced operations costs
- No existing building control hardware or software changes
- Best-in-class HVAC controls sequencing
- Marketing opportunity

### Ideal commercial building candidate

- Over 100,000 sq.ft. space served by single-zone VAV AHUs and/or multi-zone VAV AHUs.
- The existing Building Automation System (BAS) communicates using BACnet protocol.
- Does not have significant process loads, or has process loads that can be disaggregated from other loads.
- Has non-residential occupancy.



### Want to participate?

If you are interested in becoming a demonstration site, please contact Slipstream:

**Dr. Joe Zhou**  
608.210.7155 | [jzhou@slipstreaminc.org](mailto:jzhou@slipstreaminc.org)

**Josh Peterson**  
608.210.7103 | [jpetersen@slipstreaminc.org](mailto:jpetersen@slipstreaminc.org)

"This project is supported by a grant from the Minnesota Department of Commerce, Division of Energy Resources, through the Conservation Applied Research and Development (CARD) program, which is funded by Minnesota ratepayers."

#### SPONSOR



#### PARTNERS



## Appendix C: Questionnaire for Stakeholder Interviews

### Questions for facility operators (before and after the controls retrofit)

#### *Questions related to building info/characteristics (before the retrofit)*

1. Building gross area?
2. Utilities (electric, natural gas, district heating, district cooling)? One monthly utility bill sample.
3. Utility meter data collection method and data sampling rate
4. Building history
5. Engineering drawings available - Mechanical, Controls, Electrical?
6. Briefly describe the HVAC system
7. Briefly describe the building controls

#### *Questions related to O&M (before the retrofit)*

1. Can you describe the general O&M process?
2. How often are external contractors involved?
3. What is the process for resolving mechanical issues that occur at the building? How often do you experience mechanical issues? What types of issues are most common? Is the work done internally? Or do you utilize external contractors?
4. Generally, how satisfied are you with the current sequencing of the BAS system at your facility? Are there any common problems that you experience?
5. Are the current alarm features of the BAS system helpful?
  - a. If no, what changes could be made to make them more helpful?
  - b. If yes, how do they help with current O&M processes?
6. How often do you receive occupant complaints about comfort in the building?
7. What are the most common complaints you currently receive?
8. What is the general process to resolve these complaints?
9. What are you looking forward to regarding the new ASHRAE GL36 sequences at the building? What concerns do you have with the new ASHRAE GL36 sequences?
10. What would help alleviate your concerns?

## Appendix C: Questionnaire for Stakeholder Interviews

*Questions related to O&M (several months after the retrofit). Instruct the facility operator to only consider the time since the retrofit was completed. We are particularly interested in any changes from the pre-retrofit case.*

1. Has the general O&M process changed?
2. Have any external contractors been involved?
3. What is the process now for resolving mechanical issues that occur at the building? Has the process been altered and/or revised? How often do you experience mechanical issues? Have you experienced any new mechanical issues? What types of issues are most common? Is the work done internally? Or do you utilize external contractors?
4. Generally, how satisfied are you with the new ASHRAE Guideline 36 sequencing of the BAS system at your facility? Are there any common problems that you have experienced so far?
5. How has troubleshooting differed from before the retrofit?
6. Are the new FDD alarm features of the BAS system helpful?
  - a. If no, what changes could be made to make them more helpful?
  - b. If yes, how do they help with current O&M processes?
  - c. Has there been any change in how you handle alarms in the BAS?
7. Has there been any change in how you handle AHU demand-based resets and requests from rogue zones?
8. How often have you received occupant complaints about comfort in the building after the retrofit was completed?
9. What are the most common complaints you have received?
10. What is the general process to resolve these complaints?
11. Do you have any feedback on the new ASHRAE G36 sequences or their operation?

**Questions for building controls contractor (shortly after the controls retrofit is complete)**

Current practices and prior experience with G36

1. Prior to this project, had you heard of ASHRAE G36? What proportion of your company was aware of G36? For example, has it been talked about in staff meetings or team emails?
2. Aside from this project, on how many projects has your team implemented ASHRAE Guideline 36? How would you rate the success of those projects?
3. How do you most often start programming for a new job (examples: copy a previous job, from a manufacturer library, from own dealer library, from a library for a particular customer, program from scratch to match specified sequences of operation)? Do you use factory application libraries?
4. If you were doing a controls retrofit for this building and it wasn't following the ASHRAE GL36 process, what would you have recommended (how to do it)?

Experience with this G36 retrofit

5. What has been different with the GL36 process?
6. How did starting from the ALC GDL36 library impact your process and change the overall costs of the project – design, programming, implementation?
7. Has the overall implementation time been reduced because of the GDL36 process - design, programming, implementation? Or are there other major factors that influence the project timeline?
8. Was there any new hardware required for the GL36 implementation?
9. Who is responsible for modifying, revising, and customizing the pre-programmed GDL 36 control sequences?
10. How did the implementation of G36 go?
11. We want to spend a while discussing the GDL-36 implementation. We are interested in successes, challenges, lessons learned, and how you might do it differently next. *Interviewer to prompt for details as appropriate. For each challenge, consider the following aspects that we are interested in:*
  - a. How was the issue highlighted?
  - b. How was the issue resolved?
  - c. How much extra time/effort was required due to the issue?
  - d. Would this have also been an issue in a business-as-usual job?
  - e. After you've gone through this issue once, do you think it will be an issue again? (will you be able to prevent the same issue on future jobs?)
  - f. How could this issue be addressed systematically in the market?
12. Is there anything else that has come up that would be different in a business-as-usual job?
13. Is there anything that could have made the job any easier?
14. How did you verify that the GDL36 control sequences were implemented correctly before handing over to the commissioning agent?

Potential improvements to G36

1. What do you think of the G36 sequences and specifications overall?
2. About the Trim & Respond (G36-2021 Section 5.1.14):
  - a. Is the Trim & Respond in G36 the same as how you implemented it previously?
  - b. How do you tune T&R parameters to make sure the setpoint does not “cycle” too quickly, and also does not stick at one end of the setpoint range or the other?
  - c. How do you identify “rogue zones” and correct them?
3. How did you implement and test AHU hierarchical alarm suppression (G36-2021 Section 5.1.19) algorithms? Did you have to program the “source” and “load” specifically or is it part of the program library/template?
4. The AHU SAT setpoint reset in G36 incorporates both zone cooling requests (comparing zone temp. vs. setpoint) AND OAT (see G36-2021 Section 5.16.2.2). Is this clear and easy to implement?
5. Are the control charts that describe the AHU sequences (e.g., heating coil, economizer dampers and cooling coil - G36-2021 Section 5.16.2.3) clear and helpful? Is there a way to make their meaning more obvious/transparent?
6. Are the control charts that describe the VAV terminal unit sequences clear and helpful? What is the difference between implementing dual max vs. traditional single-max control?
7. Is it difficult to implement the AHU AFDD (G36-2021 Section 5.16.14) algorithm? Did you find it effective in reducing the number of alarms?

**Questions for the commissioning agent (if applicable, shortly after the controls retrofit commissioning is completed).**

Current practices and prior experience with G36

1. Prior to this project, had you heard of ASHRAE G36? What proportion of your company was aware of G36? For example, has it been talked about in staff meetings or team emails?
2. Aside from this project, on how many projects has your team commissioned ASHRAE Guideline 36?

Experience with this G36 retrofit

3. Can you please describe the general process of commissioning the ASHRAE Guideline 36 project? Do you feel there is a significant difference in the commissioning process compared to a non-ASHRAE Guideline 36 project?
4. Did you use your own functional test template for the commissioning process? Did you need to create new ones specifically for ASHRAE Guideline 36?
5. How did the commissioning of G36 go?
6. We want to spend a while discussing the GDL-36 commissioning. We are interested in successes, challenges, lessons learned, and how you might do it differently next. *Interviewer to prompt for details as appropriate. For each challenge, consider the following aspects that we are interested in:*
  - a. How was the issue highlighted?
  - b. How was the issue resolved?
  - c. How much extra time/effort was required due to the issue?
  - d. Would this have also been an issue in a business-as-usual job?
  - e. After you've gone through this issue once, do you think it will be an issue again? (will you be able to prevent the same issue on future jobs?)
  - f. How could this issue be addressed systematically in the market?
7. Is there anything else that has come up that would be different in a business-as-usual job?
8. Is there anything that could have made the job any easier?

Testing process for specific G36 sections

9. Please describe your testing process relative to point-to-point testing vs functional testing:
  - a. Did you perform p2p tests on all hardware points, or just a sampling?
  - b. How did you test that the relationships between equipment are properly represented in the BAS? For example, zone schedules cascade upward to AHUs, which then trigger plant equipment. Did you test these control cascades specifically?
10. How did you test the generic logic that applies to all zones (i.e., G36-2021 Section 5.2 "Generic ventilation zones" and Section 5.3 "Generic thermal zones")?
11. A few questions about the Trim & Respond method (G36-2021 Section 5.1.14):

## Appendix C: Questionnaire for Stakeholder Interviews

- d. Were you previously familiar with Trim & Respond?
  - e. Did you observe in testing that T&R loop resulted in a setpoint that cycles *slowly* around the ideal setpoint, rather than the hunting behavior (which is characterized by rapid cycles)?
  - f. Did you observe that the setpoints get “stuck” at one end of the setpoint range or the other? This probably indicates programming errors, or due to a “rogue zone”.
12. How did you test the hierarchical alarm suppression (G36-2021 Section 5.1.19) algorithm?
  13. How did you test the demand-controlled ventilation (DCV) algorithm implemented in the project?
  14. When testing the AHU outdoor airflow, what method did you use?
  15. How did you test the AHU SAT setpoint reset, which incorporates both zone cooling requests (based on zone temperature vs. setpoint) and OAT (see G36-2021 Section 5.16.2.2)?
  16. How did you test the control charts that describe the AHU control sequences (e.g., heating coil, economizer dampers and cooling coil, G36-2021 Section 5.16.2.3)?
  17. How did you test the control charts that describe the VAV control sequences?
  18. How did you test the AHU AFDD (G36-2021 Section 5.16.14), which is a new fault detection strategy based on earlier research?
  19. If applicable, can you describe the method of testing equipment staging and rotation (Section 5.1.15) sequences used?

## Appendix D: Literature Review and Savings Potential

# MEMORANDUM

To: Laura Silver

From: Rupam Singla, Gwelen Paliaga (TRC)

Joe Zhou (Slipstream)

**Re: MN CARD Field Demo of ASHRAE Guideline 36 Demonstration – Literature Review and Savings Potential**

The energy savings potential with a full building automation system (BAS) retrofit that uses control logic from ASHRAE Guideline 36 – High Performance Sequences of Operation for HVAC Systems (G36) may vary based on several important factors. Nevertheless, there are a few key data points that indicate significant energy-saving opportunities. In addition to the improved sequences of operation, control retrofits provide a synergistic opportunity to address deferred maintenance and other measures that may deliver additional energy savings. A large study of hundreds of buildings found RCx resulted in 16 percent whole-building energy savings in existing buildings (Mills 2011).

An end-of-life replacement for an obsolete BAS in a large office building in San Mateo, California, that utilized sequences of operation similar to G36 resulted in measured savings of 15 percent of whole-building electricity and over 50 percent natural gas, with an overall simple payback of seven years (Taylor Engineering 2020). The existing BAS already had direct digital controls (DDC) down to the zone level, highlighting the role that the optimized control sequences had in the savings.

TRC, along with Taylor Engineering, Lawrence Berkeley National Laboratory, and Integral Group, is currently conducting a California Energy Commission-funded research project where they have implemented BAS retrofits with G36 sequences of operation in four buildings and G36 with existing BAS hardware in three buildings in California. NYSERDA is funding a similar demonstration in four buildings in New York State. The first completed full BAS retrofit is from a medical office building in Vallejo, California. The retrofit included replacing existing pneumatic zone control hardware with DDC controls. The retrofit used control logic from the G36 site and showed savings of 22 percent of whole-building electricity, 40 percent of chilled water use, and 61 percent of heating hot water use, with an estimated simple payback of eight years. We anticipate that results from the additional sites will further corroborate the significant energy savings, while also showing a diversity of results that will help the industry better understand the range in potential outcomes and the contributing factors.

Two other existing building demonstrations implemented a portion of the zone sequences of operation from G36 using the existing modern BAS. In one of these studies, researchers at the University of California, Berkeley implemented time-averaged ventilation sequences of operation and found average heating, cooling, and fan power savings to be 41 percent, 23 percent, and 15 percent, respectively, over

a baseline of single-maximum VAV logic (Kaam 2018). In the other study, researchers reduced VAV box minimum airflow setpoints to around 10 percent. This results in 10 - 30 percent HVAC energy savings and improved occupant thermal comfort (Arens 2015). Simulation studies of similar control strategies show significant energy savings potential compared to conventional practice, which corroborates the scale of the field measured energy savings mentioned above (Wetter, 2018; Pang et al., 2017).

The research team anticipates that the G36 demonstrations in Minnesota will show 15 to 30 percent whole-building energy savings, though actual savings will depend on specific site conditions.

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## Appendix D: Literature Review and Savings Potential

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Wetter, e. a. (2018). OpenBuildingControl: Modeling feedback control as a step towards formal design, specification, deployment and verification of building control sequences. Proc. of Building Performance Modeling Conference and SimBuild, 775-782. Retrieved from lbl.gov:  
<https://simulationresearch.lbl.gov/wetter/download/2018-simBuild-OpenBuildingControl.pdf>

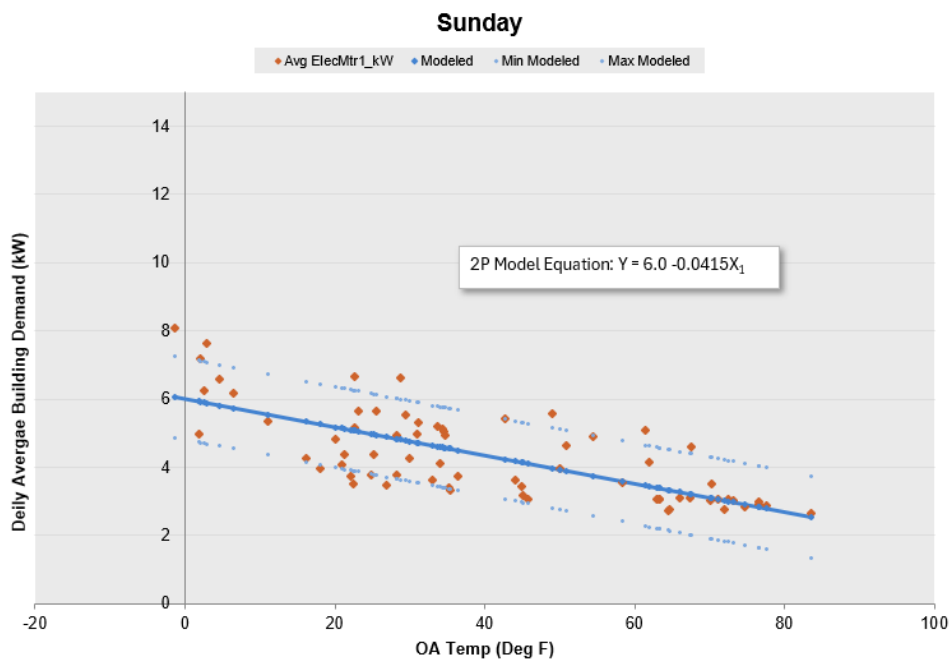
## Appendix E: Champlin Library Energy Models

### Whole-building Electric Demand Models

For both the baseline and post-retrofit periods, whole-building electric demand models were created by three different “Daytypes”: Monday/Wednesday/Friday/Saturday, Tuesday/Thursday, and Sunday, using daily average electric demand. For working days (Monday to Saturday), the ASHRAE four-point (4P) change point model was used. For non-working days (Sunday), the ASHRAE two-point (2P) change point model was used.

Baseline models are shown in the following figures.

Figure 34. Appendix E – Baseline Electric Demand Model - Sunday



## Appendix E: Champlin Library Energy Models

Figure 35. Appendix E – Baseline Electric Demand Model – Mon/Wed/Fri/Sat

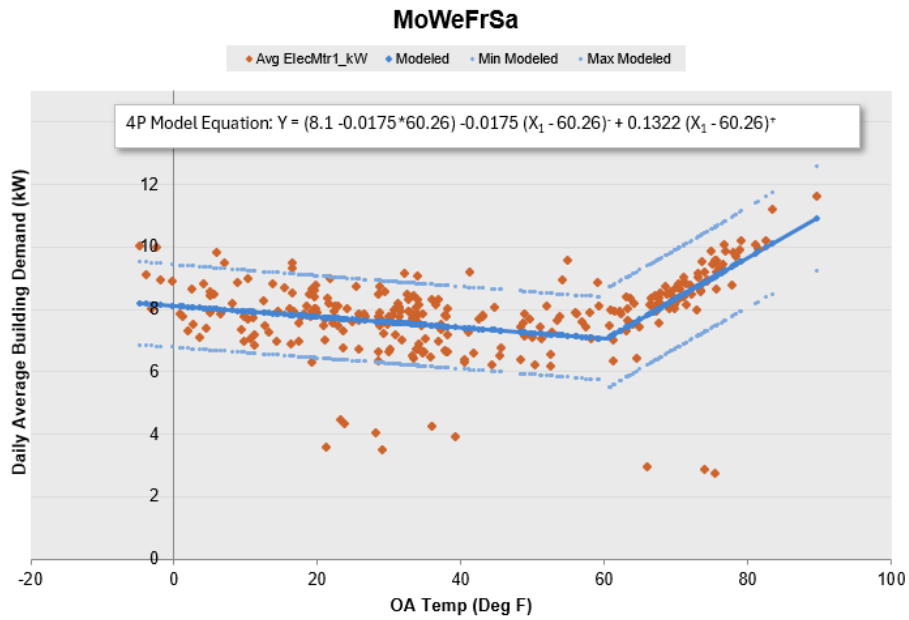
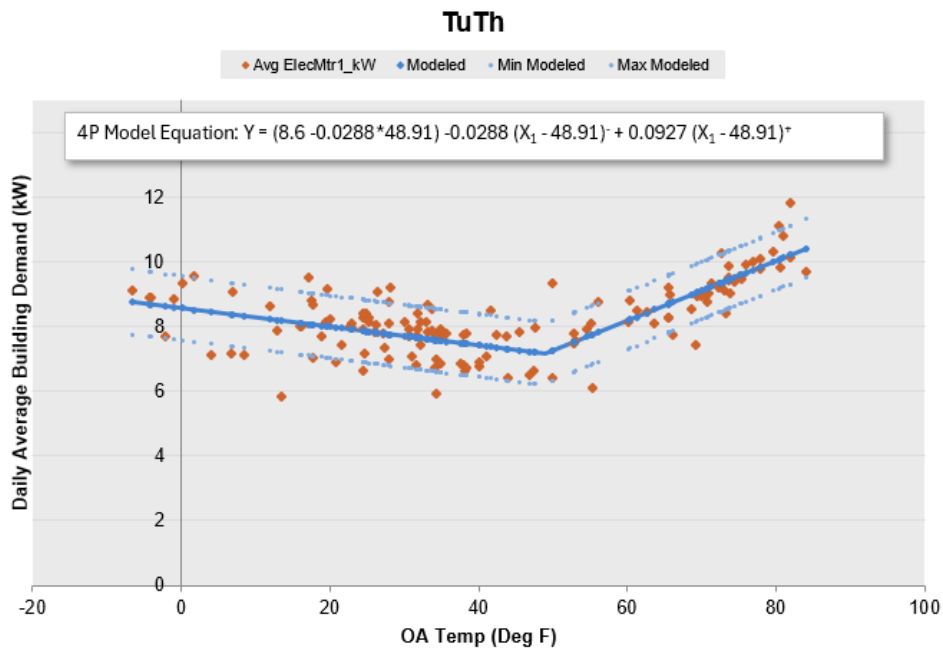


Figure 36. Appendix E – Baseline Electric Demand Model – Tue/Thu



## Appendix E: Champlin Library Energy Models

Post-retrofit models are shown in the following figures.

Figure 37. Appendix E – Post-Retrofit Electric Demand Model - Sunday

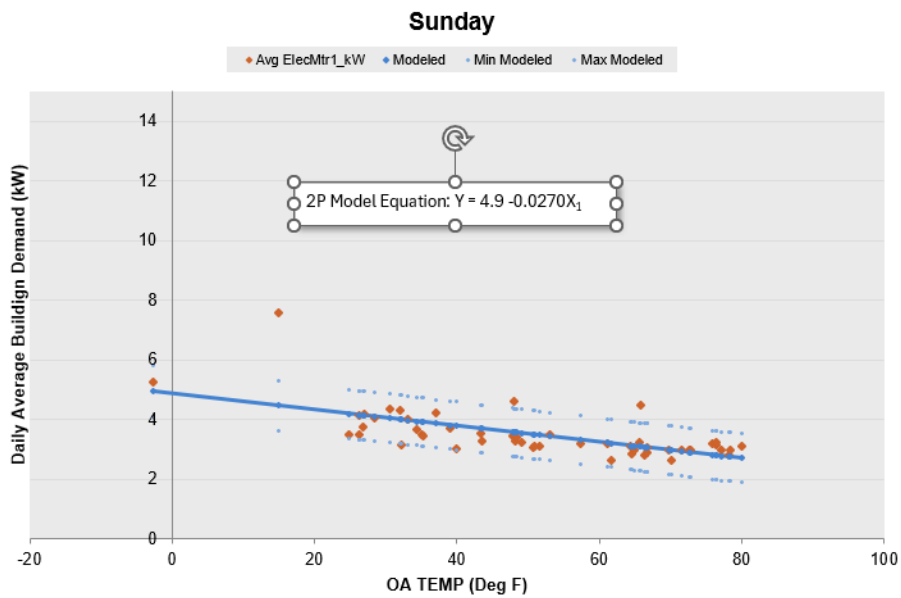
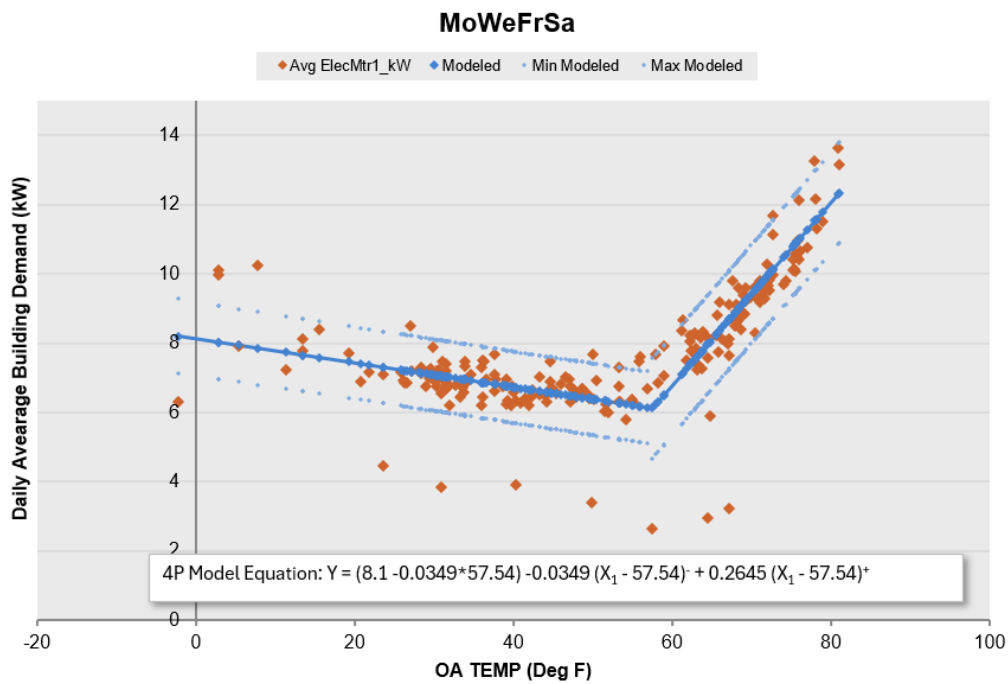
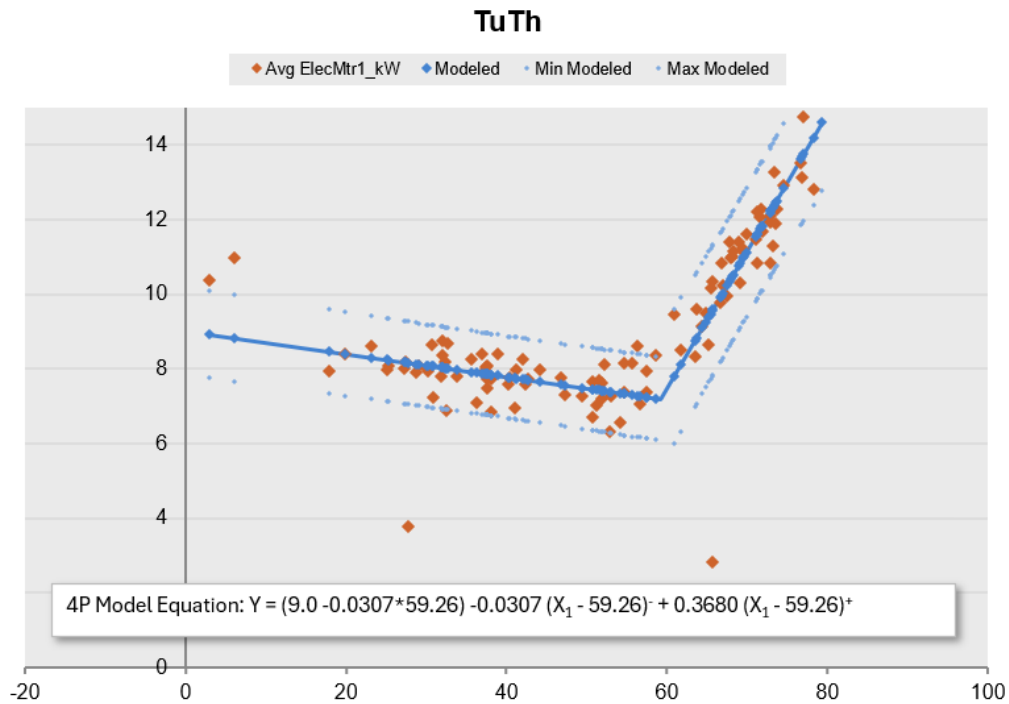


Figure 38. Appendix E – Post-Retrofit Electric Demand Model – Mon/Wed/Fri/Sat



## Appendix E: Champlin Library Energy Models

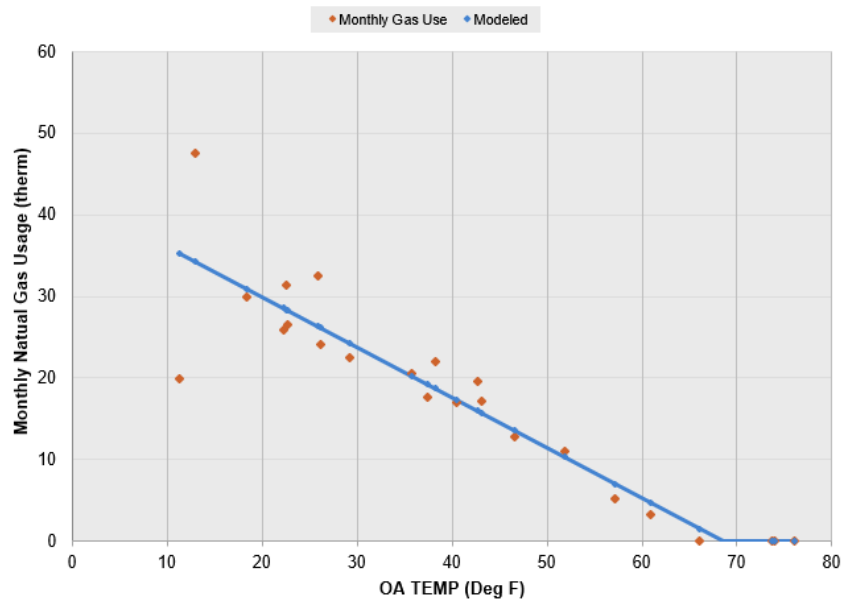
Figure 39. Appendix E – Post-Retrofit Electric Demand Model – Tue/Thu



### Whole-building Natural Gas Models

The baseline and post-retrofit natural gas monthly energy use models are shown in the following two figures. These models were used for normalized pre- and post-retrofit natural gas energy use comparisons.

Figure 40. Appendix E – Baseline Monthly Natural Gas Use Model



## Appendix E: Champlin Library Energy Models

Figure 41. Appendix E – Post-Retrofit Monthly Natural Gas Use Model

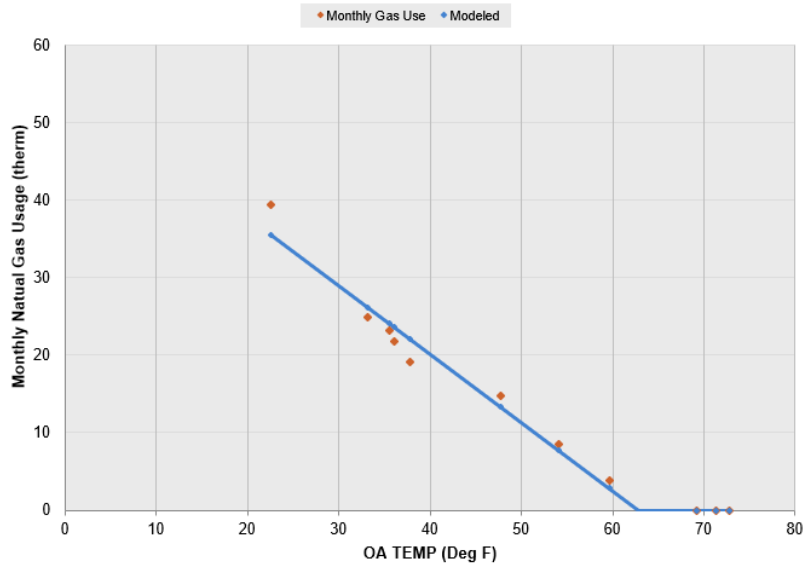
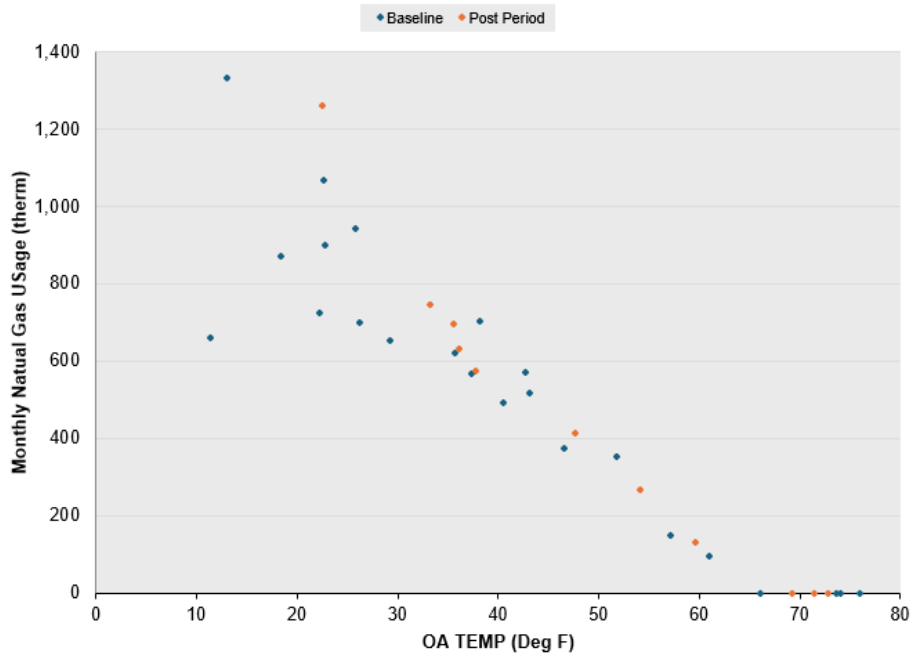


Figure 42. Appendix E – Monthly Natural Gas Use vs. Outside Air Temperature Scatter Plot



Slipstream collected post-retrofit hourly natural gas use data. Additional charts and models based on the post-retrofit hourly data are shown below.

## Appendix E: Champlin Library Energy Models

Figure 43. Appendix E – Post-Retrofit Hourly Natural Gas Use vs. Outside Air Temperature Scatter Plot

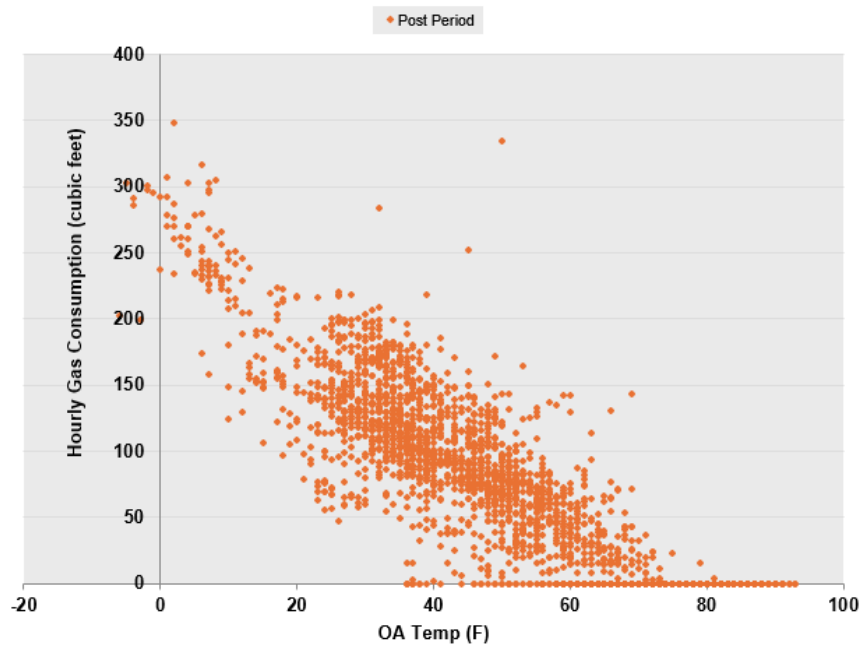
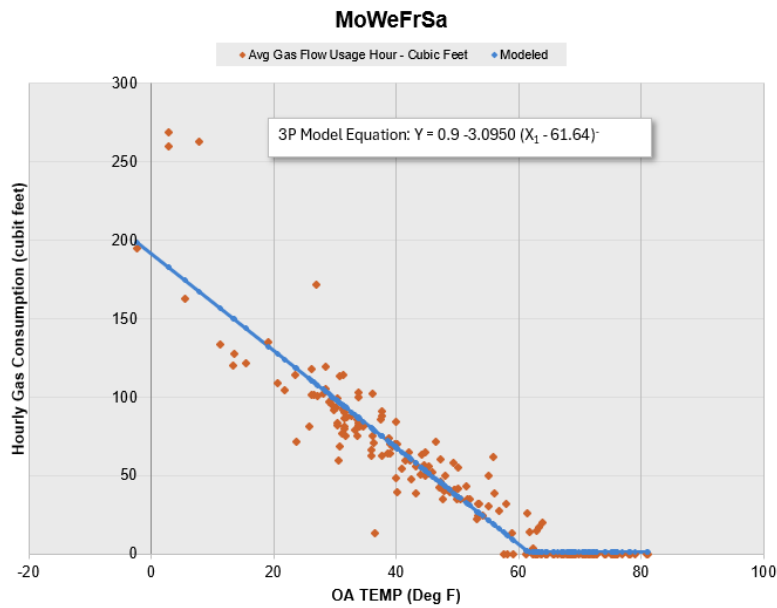


Figure 44. Appendix E – Post-Retrofit Hourly Natural Gas Use Model - Mon/Wed/Fri/Sat



## Appendix E: Champlin Library Energy Models

Figure 45. Appendix E – Post-Retrofit Hourly Natural Gas Use Model - Tue/Thu

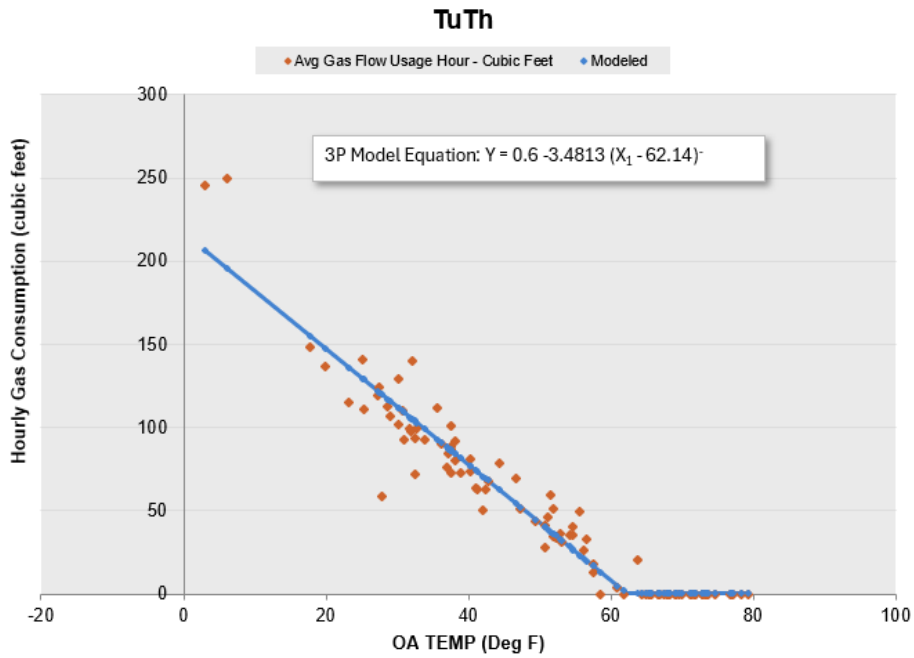
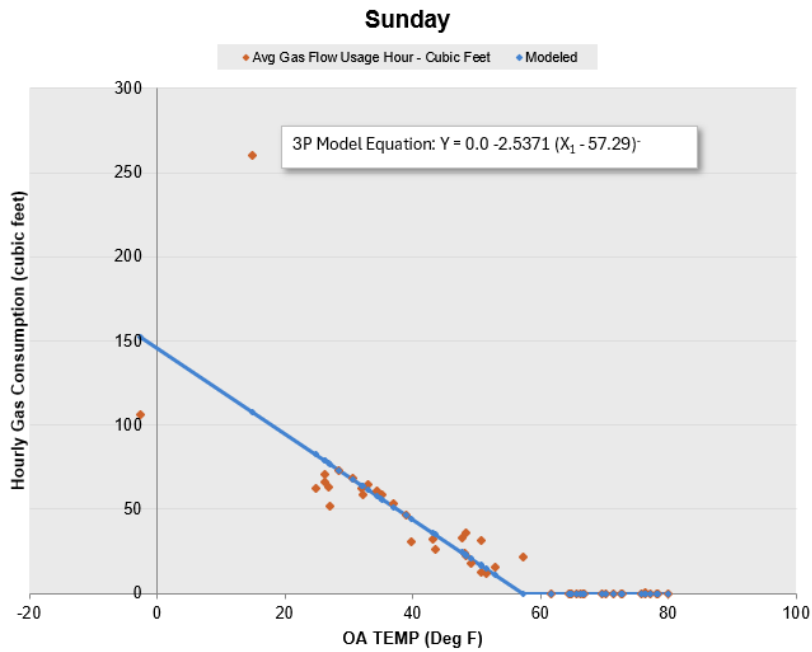
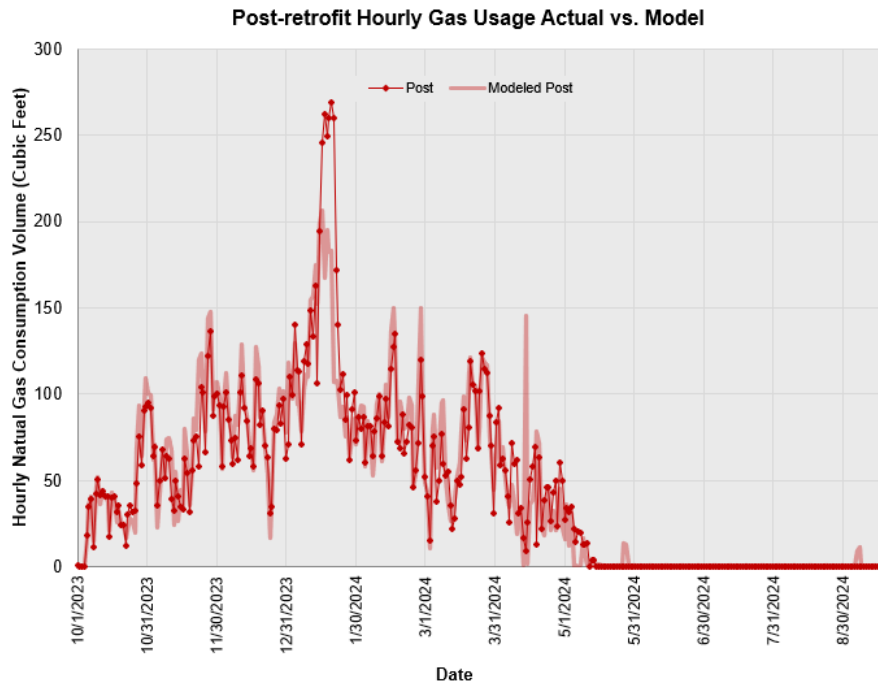


Figure 46. Appendix E – Post-Retrofit Hourly Natural Gas Use Model - Sun



## Appendix E: Champlin Library Energy Models

Figure 47. Appendix E – Post-Retrofit Hourly Natural Gas Actual Use vs. Model



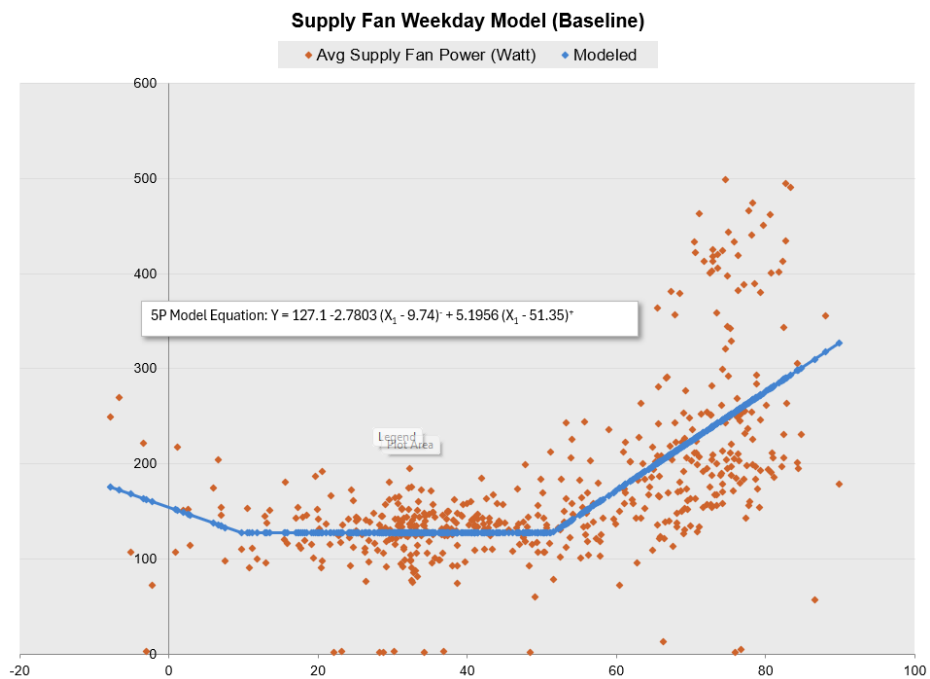
## Appendix F: Central Library Energy Models

To compare baseline and post-retrofit supply and return fan energy use, supply and return fan models were created by three different “Daytypes”: Weekdays, Saturday, and Sunday, using daily average supply and return fan powers. The ASHRAE five-point (5P) change point model was used.

### AHU Supply Fan Models

Baseline models for supply fan power are shown in the following figures.

Figure 48. Appendix F – Baseline Daily AHU Supply Fan Power Model - Weekdays



## Appendix F: Central Library Energy Models

Figure 49. Appendix F – Baseline Daily AHU Supply Fan Power Model – Saturday

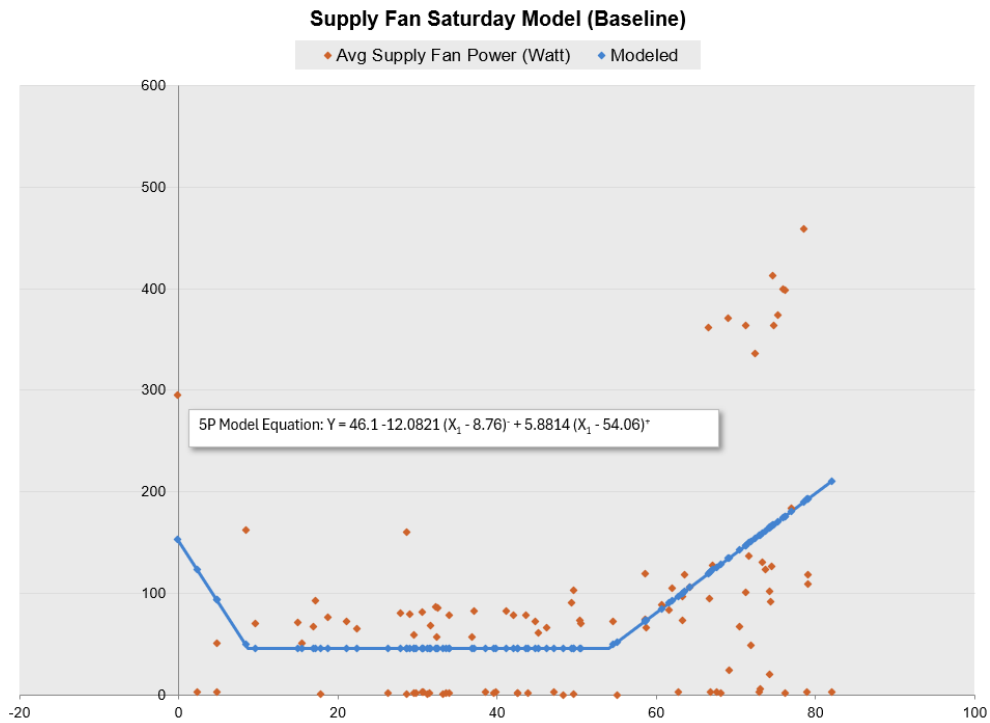
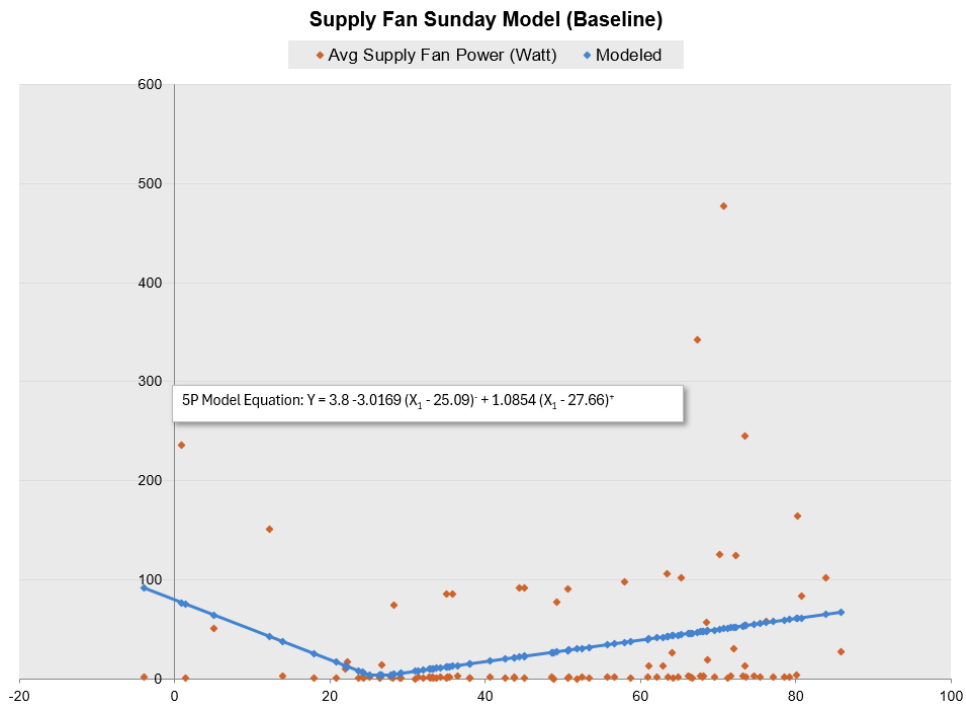


Figure 50. Appendix F – Baseline Daily AHU Supply Fan Power Model – Sunday



Post-retrofit models for supply fan power are shown in the following figures.

## Appendix F: Central Library Energy Models

Figure 51. Appendix F – Post-Retrofit Daily AHU Supply Fan Power Model - Weekday

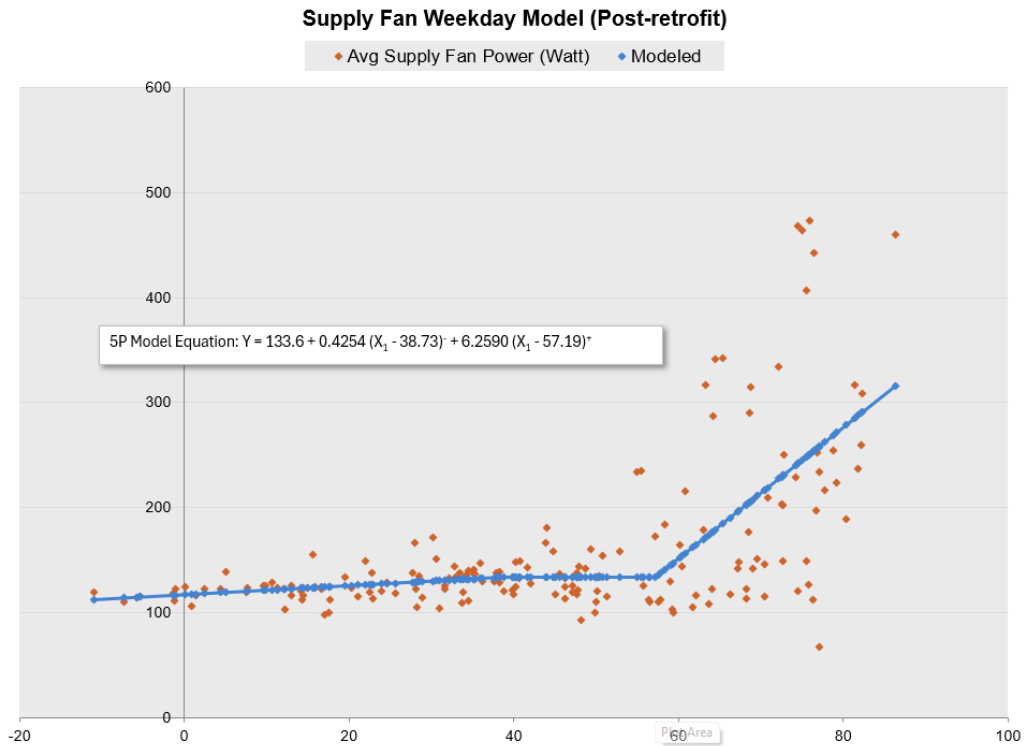
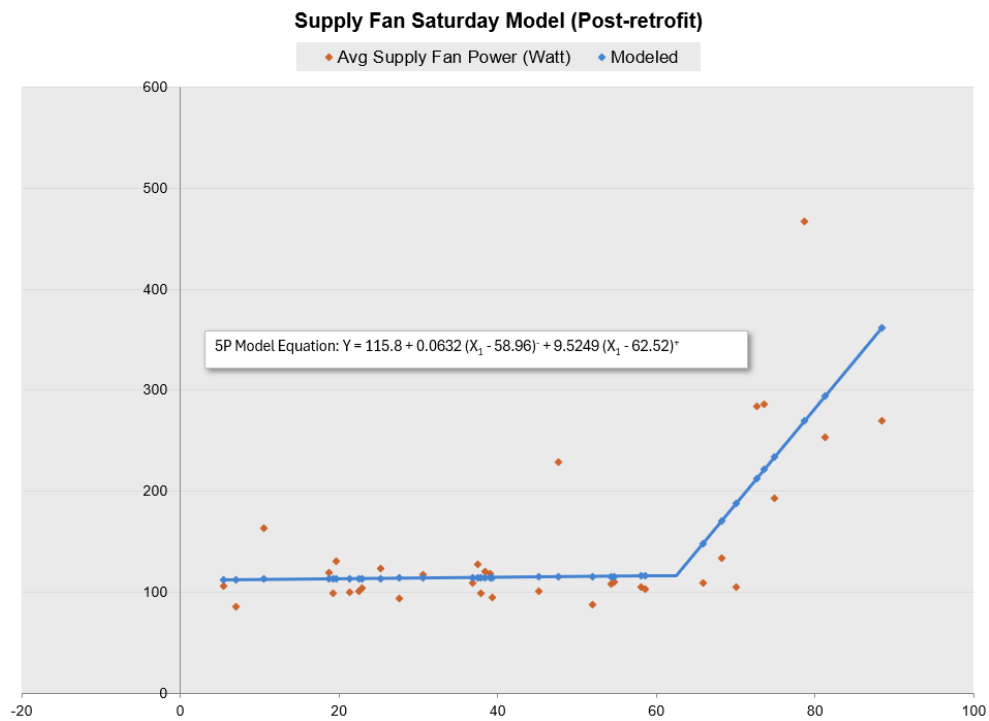


Figure 52. Appendix F – Post-Retrofit Daily AHU Supply Fan Power Model - Saturday



## Appendix F: Central Library Energy Models

Figure 53. Appendix F – Post-Retrofit Daily AHU Supply Fan Power Model - Sunday

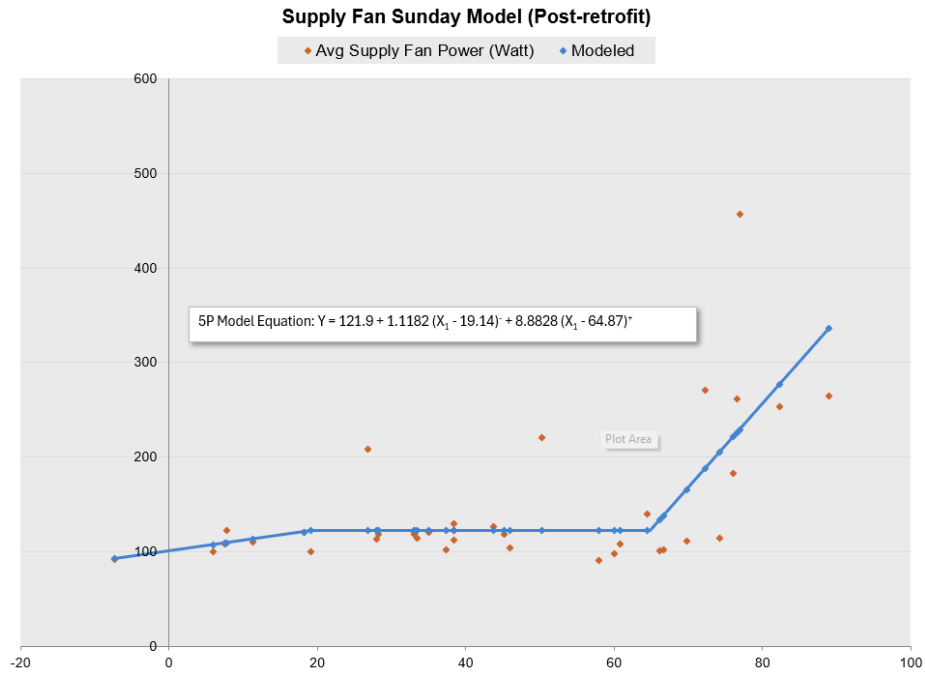
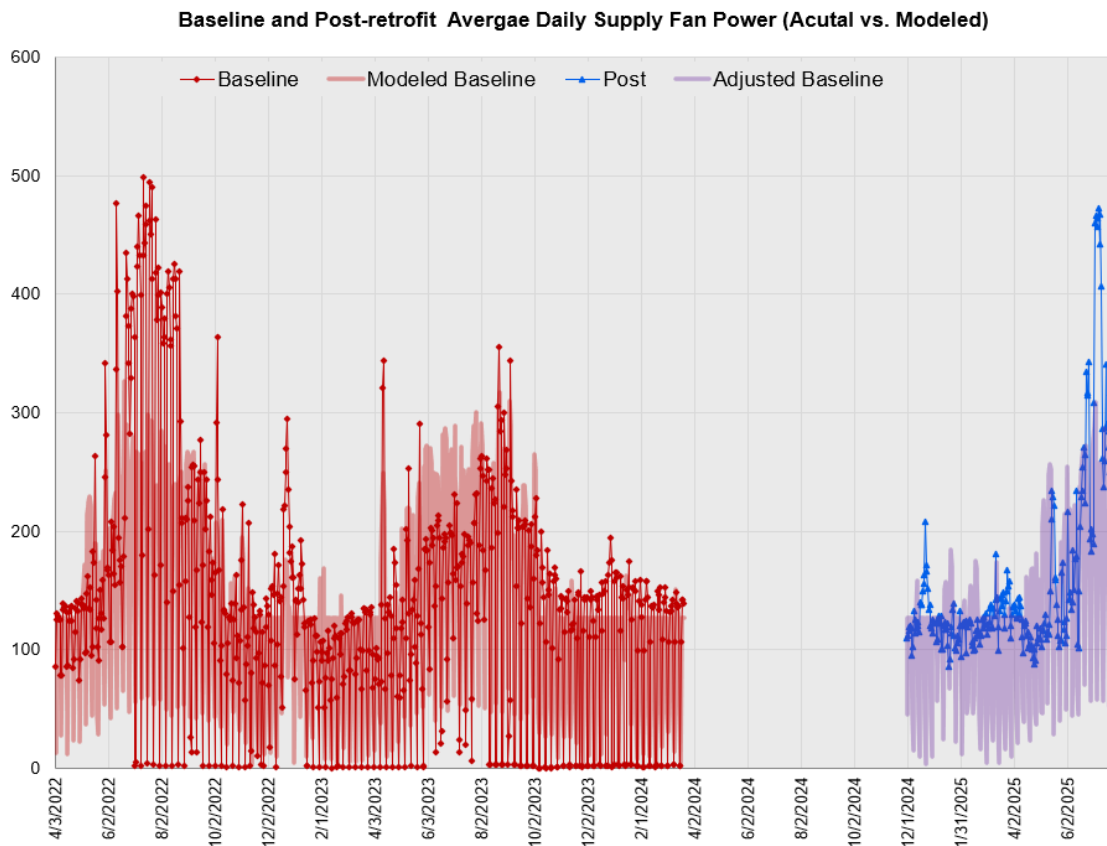


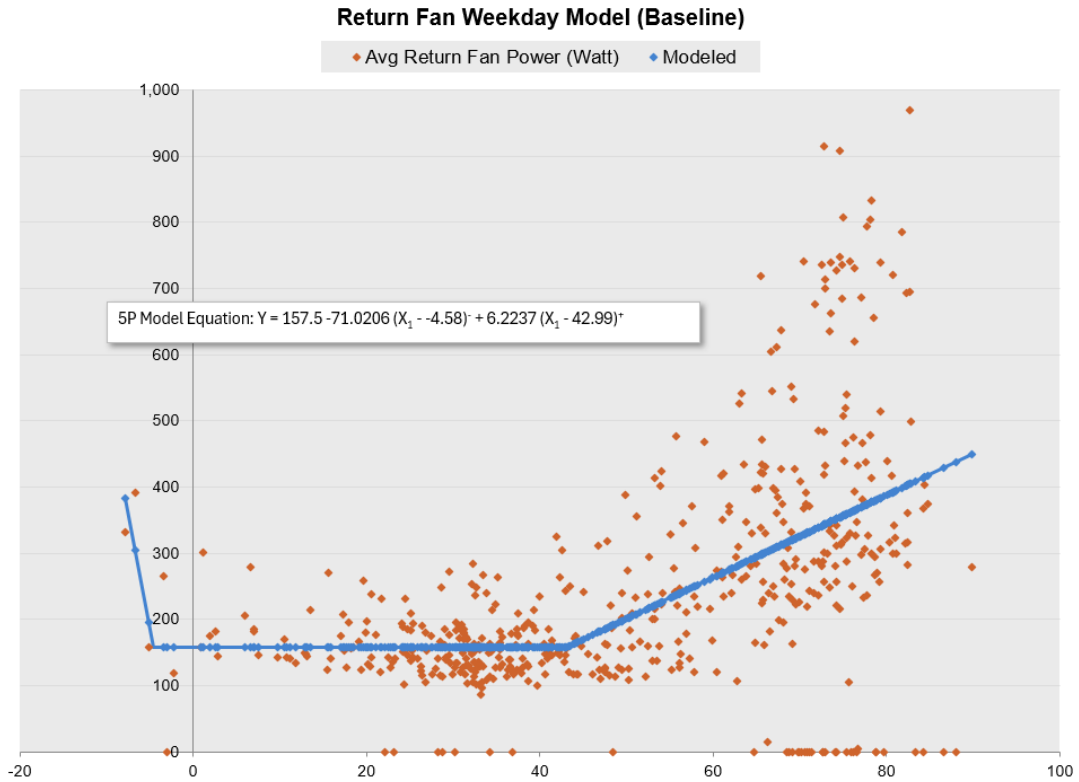
Figure 54. Appendix F – Daily AHU Supply Fan Power Actual vs. Model



### AHU Return Fan Models

Baseline models for return fan power are shown in the following figures.

Figure 55. Appendix F – Baseline Daily AHU Return Fan Power Model - Weekdays



## Appendix F: Central Library Energy Models

Figure 56. Appendix F – Baseline Daily AHU Return Fan Power Model - Saturday

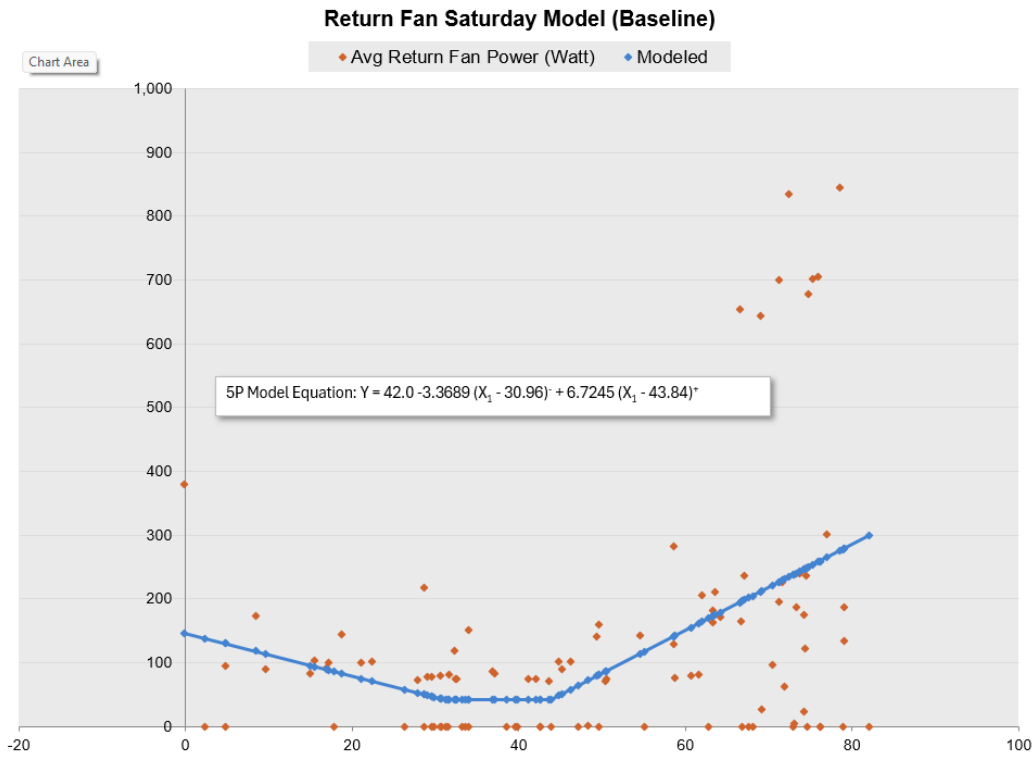
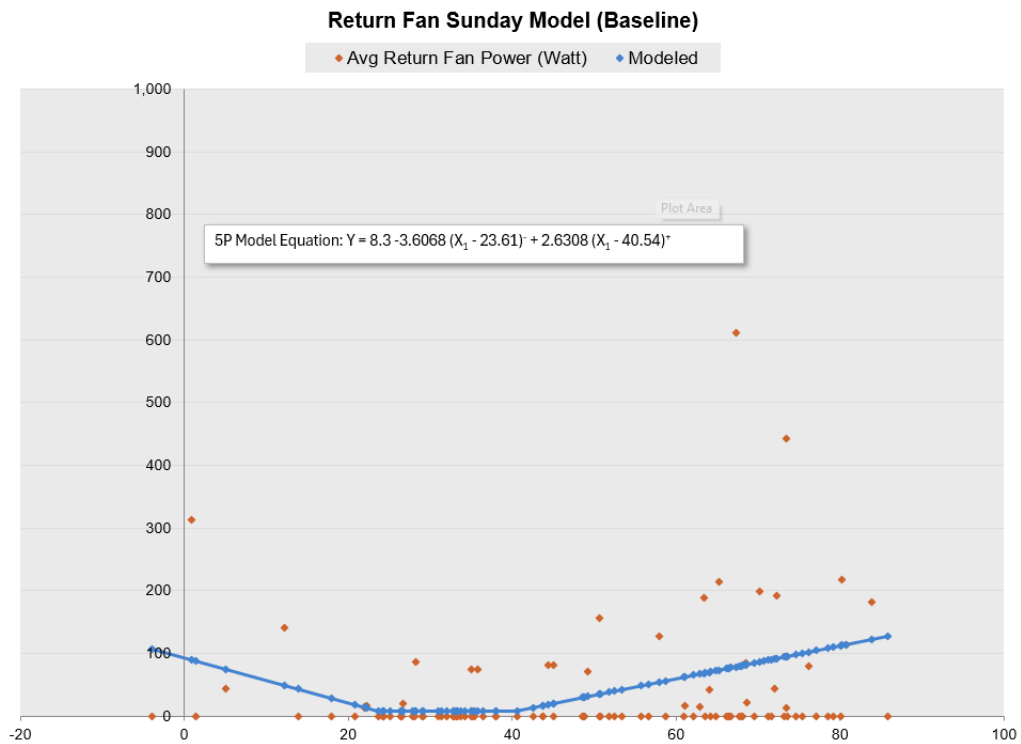


Figure 57. Appendix F – Baseline Daily AHU Return Fan Power Model - Sunday



Post-refit period supply fan models are shown below.

## Appendix F: Central Library Energy Models

Figure 58. Appendix F – Post-Retrofit Daily AHU Return Fan Power Model - Weekdays

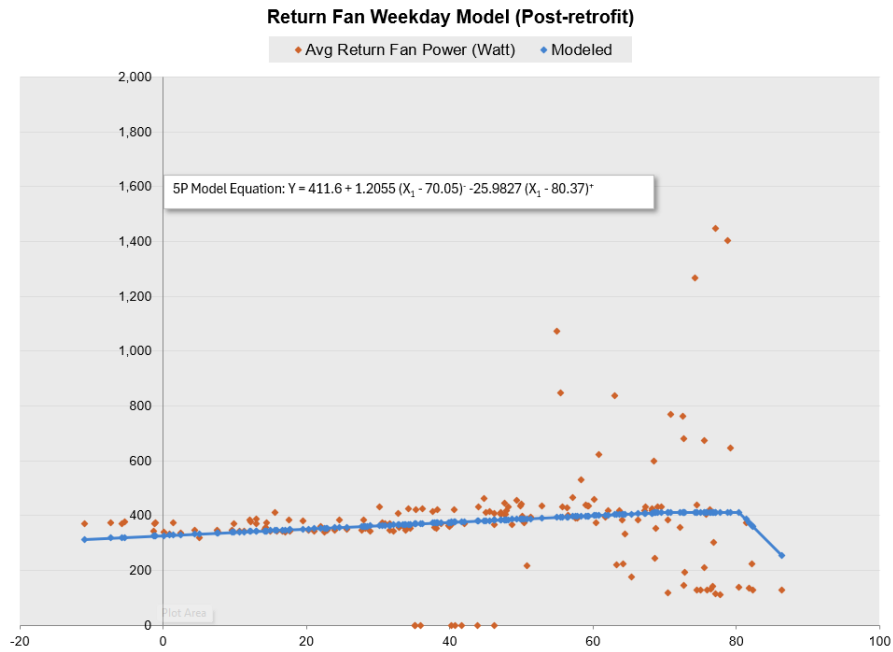
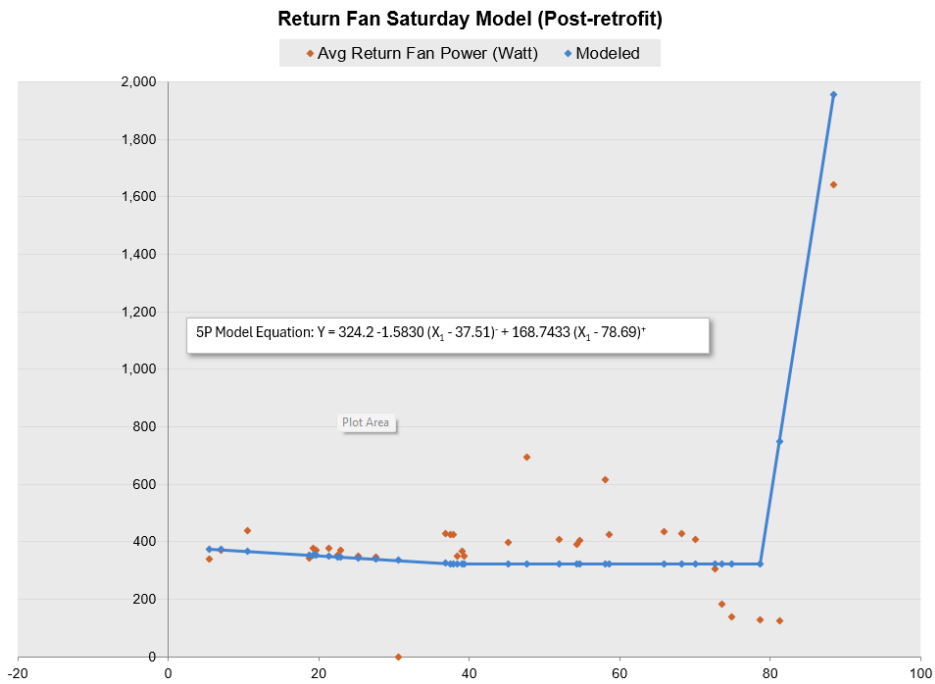


Figure 59. Appendix F – Post-Retrofit Daily AHU Return Fan Power Model - Saturday



## Appendix F: Central Library Energy Models

Figure 60. Appendix F – Post-Retrofit Daily AHU Return Fan Power Model - Sunday

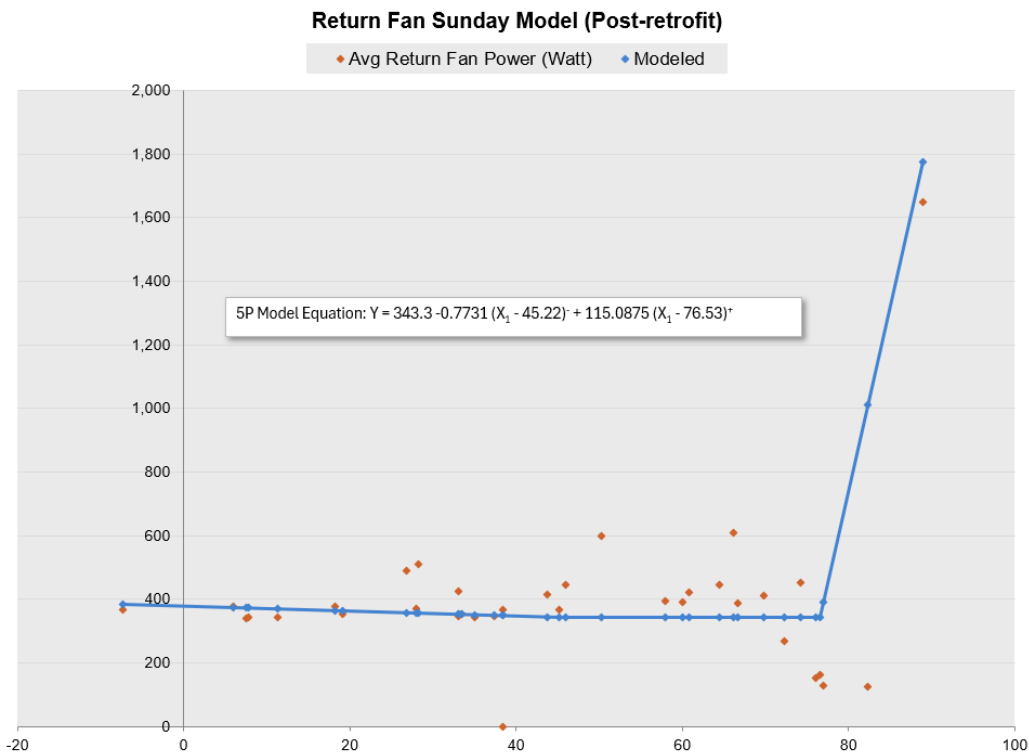


Figure 61. Appendix F – Daily AHU Return Fan Power Actual vs. Model  
**Baseline and Pos-retrofit Average Daily Return Fan Power (Actual vs. Modeled)**

