Title

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Journal

ASHRAE Winter Conference Proceedings

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Publication Date

2026

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ABSTRACT

ASHRAE Guideline 36 defines standardized high-performance control sequences for heating, ventilation, and air conditioning (HVAC) systems, yet limited field evidence exists on its plant-level applications. In this project, the team implemented Guideline 36 supply water temperature reset sequences for two hot water plants and a chilled water plant using a layered architecture of supervisory control, Building Automation and Control Networks (BACnet) communication, Control Description Language (CDL) based programming developed by ASHRAE Standard 231p, and Brick ontology to ensure scalability and interoperability. Measurement and verification (M&V) with weather normalization showed savings of 3.28 kBTU/ft²-year (10.38 kWh/m²-year)(7.5%) and 10.15 kBTU/ft²-year(32 kWh/m²-year) (11.5%) for the hot water plants, and 6.61 kWh/m² (2,097 BTU/ft²) (14.6%) for the chilled water plant, translating to cost reductions of \$0.095/ft²-year (\$1.02/m²-year), \$0.17/ft²-year (\$1.82/m²-year), and \$0.12/ft² (\$1.29/m²), respectively. These results provide empirical evidence of Guideline 36's effectiveness in plant applications and highlight its potential for broader adoption. Additionally, retro-commissioning efforts in one building reduced chilled water energy use by 16%, demonstrating the importance of addressing existing operational inefficiencies to fully realize the benefits of advanced control strategies.

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INTRODUCTION

ASHRAE Guideline 36 (G36) titled "High-Performance Sequences of Operation for HVAC Systems," (ASHRAE, 2024), was first published in 2018 and establishes industry best-practice standardized sequence of operations (SOOs) for heating, ventilation, and air conditioning (HVAC) systems. These include airside control sequences introduced with the original Guideline 36 in 2018, and chilled water and hot water control sequences introduced in the 2021 update. Standardization of control sequences allows HVAC system manufacturers to centrally program the control logic and then distribute to installers. This approach reduces cost and the risk of errors inherent in current practice. Designers can specify Guideline 36 rather than writing their own SOOs and installers can draw from a library of Guideline 36 control logic options rather than programming their own logic.

Previous field demonstration research studies have implemented airside sequences of operations of Guideline 36 and estimated energy savings. One study conducted in 2022 (Taylor Engineering, TRC, Integral Group, 2022) implemented the airside SOOs of Guideline 36 for variable air volume (VAV) systems in seven non-residential buildings and estimated electricity savings of 11-35%. We did not find similar studies that demonstrate the SOOs for hydronic systems such as the chilled water plant and hot water plant. In this project, we implemented Guideline 36 SOOs in one chilled water system and two hot water systems in two buildings and evaluated the energy savings of G36 against the existing control strategy.

We also demonstrated a streamlined implementation methodology (Duarte Roa et al., 2023) where we utilized a supervisory control layer to perform the advanced controls calculations using standardized Control Description Language (CDL) and used Brick ontology for mapping between the control logic and BAS points that streamlines the deployment in a manufacturer-agnostic manner. This methodology avoids the need to program Guideline 36 in each unique system and thereby increases the adotion of high-performance control sequences such as Guideline 36 across the building stock. It also provides options if the existing system is not able to accommodate control algorithm intensity or controllability of equipment. This methodology brings together multiple ASHRAE standardization efforts, from current standards and guidelines such as ASHRAE Guideline 36, Bacnet (ASHRAE Standard 135), to those currently under development such as Controls Description Language (ASHRAE Standard 231P) and methods for representing building metadata (ASHRAE 223P).

EXISTING CONTROL STRATEGIES AND ASHRAE GUIDELINE 36

Conventional control methods for chilled water plants and hot water plants involve regulating temperatures and flowrates using feedback from thermostats, pressure sensors and flow meters but can vary between fixed values to resets. *ASHRAE Handbook: HVAC Systems and Equipment* (ASHRAE, 2020) discusses control strategies used in chilled water and hot water plants that include temperature and flow rate reset based on cooling and heating demand. Some of these strategies, such as chiller and boiler staging, are part of the standardized sequences presented in Guideline 36.

These control strategies represent a range of possible approaches to managing chilled water and hot water plants in existing buildings. Some of them are often combined (e.g., variable primary flow and chiller staging) for optimization. However, many buildings use sub-optimal controls like fixed supply water temperature setpoints. Guideline 36 provides standardized sequences of control and uses combinations of control strategies including some that are presented in the Handbook to minimize energy use while meeting heating and cooling demand.

ASHRAE Guideline 36

ASHRAE G36 establishes current industry best-practice SOOs for HVAC systems, including chilled water plant and hot water plant control, which is the focus of this study. The aim of G36 is to maximize the energy efficiency and overall performance of HVAC systems, provide control stability, and allow for real-time fault detection and diagnostics. The sequences provided in this guideline complement other ASHRAE standards and help maintain occupant comfort and acceptable indoor air quality.

Chilled and hot water plant control sequences in ASHRAE G36 include standardized control sequences for the entire plant including chiller control, waterside economizer control, pump control, and pressure control on the chilled water side, and boiler staging and control, hot water supply temperature reset, and hot water pump control on the hot water side. The primary energy measure from G36 considered for the chilled and hot water plants as part of this demonstration is chilled water and hot water supply temperature setpoint reset. This strategy uses trim and respond (T&R) reset logic based on demand from associated chilled water and hot water valves to reset the supply temperature and differential pressure setpoints.

RESEARCH OBJECTIVES OF THE FIELD DEMONSTRATION

The main research objectives of this project are to implement ASHRAE Guideline 36 hydronics SOOs and quantify energy and cost savings in real world scenarios, document challenges encountered, highlight lessons learned for future implementations, and demonstrateusing supervisory controls and semantic interoperability tools. These include the Brick ontology that standardizes building and HVAC system descriptions, and CDL that standardizes the control logic programming language to provide advanced HVAC controls logic. This paper focuses on the implementation and identification of challenges and lessons learned. Duarte Roa et al. (2023) discusses in detail, the implementation methodology and how it can be used to scale up implementation of advanced control sequences.

DEMONSTRATION SITES AND IMPLEMENTATION OVERVIEW

The team selected two commercial buildings for this demonstration. Building-1 is a seven-floor, 141,000 ft^2 (13,000 m^2) University of California, Berkeley (UC Berkeley) campus building that primarily contains open-plan and private offices. There is also a multi-level cleanroom facility , classrooms, laboratory and workshop areas, a 149-seat auditorium, and a cyber cafe within the building. Building-1 has a building-wide HVAC system with two parallel 600-ton (2.1 MW) chillers to provide chilled water to the air handling units (AHU) and process loads. One chiller (CH1) is an absorption chiller that runs on excess steam from campus's cogeneration plant during summer conditions. The other chiller (CH2) is a centrifugal chiller that mostly operates during winter conditions when the steam resource is less abundant. The chillers do not run in parallel. The chilled water plant serves thirty-eight cooling coils in four large AHUs, two small AHUs, several computer air conditioning systems (CAC), and a fan coil unit. The chilled water plant also serves a heat exchanger that supplies cooled water for process loads in the cleanroom facility. Two of the large AHUs (AH2A and AH2B) with air-side economizers distribute air to variable air volume (VAV) terminal units in floor areas of the building not associated with the cleanroom facility, e.g., office spaces, classrooms, and the auditorium. The two other large AHUs (AH1A and AH1B) serve as a dedicated outside air system (DOAS) that distributes 100 percent outside air to nine reheat coils that reheat the AHUs' discharge air to 68°F (20°C). The reheat coils in turn discharge air into plenums in which recirculating air handling units (RAHUs) recirculate and cool air to 70°F (21.1°C) for the cleanroom chambers. The fans in the large AHUs have variable-frequency drives. The two smaller AHUs supply conditioned air to electrical rooms and the CACs provide cooling for server rooms. The hot water plant of Building-1 uses a heat exchanger connected to the campus's steam resource to supply hot water to the building. The system distributes hot water to 130 heating coils in the four large AHUs, cleanroom reheating coils, and the office space VAV terminal units with reheat coils. Most of the VAV terminal units with reheat coils have a discharge air temperature sensor.

Building-2 is a LEED Platinum, four-story mixed-use building in downtown Berkeley, California consisting of private and open-plan offices, conference rooms, an auditorium, a restaurant, and a gallery with 38,600 ft^2 (3,590 m^2) and 3,300 ft^2 (307 m^2) of conditioned and unconditioned area, respectively. The restaurant's natural gas and electricity are metered separately from the office space and are not part of the energy savings analysis. The HVAC system includes two gas condensing boilers with rated input 1 million Btu/hr (293 kW) and output of 0.85 million btu/hr (249 kW) each for hot water, a cooling tower with a heat exchanger for cooled water, and two AHUs with underfloor air distribution system. A dedicated outdoor air system (DOAS) combine with natural ventilation through operable windows provide ventilation. Each AHU contains a single coil with three-way valves that switch to either provide heating or cooling. Eight water-to-air heat pumps connected to the hot water loop condition the gallery, conference rooms on the first and second floors, and the auditorium. A two-pipe thermally activated building (TABS) radiant system supplies heating or cooling to floors two through four. Hot water production is available 24 hours a day and each of the boilers has an input capacity of 26 BTU/hr-ft^2 (82 W/m^2). The boilers have a lead-lag operation and nominal efficiency range between 85% and 95%, depending on the operating mode and return water temperature when operating at or above the minimum turndown capability of the boilers.

Existing System Evaluation

Prior to the implementation, the team conducted a thorough evaluation of the existing systems of the two buildings to identify operational requirements, limitations, and barriers to implementing Guideline 36 SOOs. We identified several challenges at this stage and with the support of the facilities staff, updated the existing controls to improve energy efficiency of the existing operation as well as facilitate effective operation of Guideline 36 SOOs. Building-1 has cleanrooms in the nano-fabrication facility which had strict environmental control requirements, 68°F (20°C) space temperature and 55% (+/- 5%) relative humidity. This posed challenges in operating the Guideline 36 SOOs in their full range. After conducting a psychometric analysis and consulting with the facilities staff, we implemented the following updates to the system operating setpoints. We raised the cleanroom space setpoint from 68°F (20°C) to 72°F (22.2°C) where we kept the reheat coils' discharge setpoint at 68°F (20°C) and raised the RAHU's discharge setpoints from 68°F (20°C) to 72°F (22.2°C). We lowered the preheat coil leaving air temperature setpoints of the AHUs from 55°F (12.7°C) to 50°F (10°C) and increased the dew point setpoint from 45°F (7.2°C) to 55°F (12.7°C). These changes aimed at maintaining the cleanroom conditions at 72°F +/- 2°F (22.2°C +/- 1.1°C) space temperature and 55% +/-5% relative humidity. Although lowering the AHU discharge setpoint helped, the increased dewpoint setpoints caused unstable relative humidity. To address the humidity instability, the team identified and corrected unstable discharge air temperatures in the cleanrooms' recirculated AHUs' by retuning their reheating coils' PID controls using methods outlined by Lin, et al., (2023). This resulted in a more moderate dew point increase to 50°F (10°C) to balance relative himdity stability and energy saving potential, yielding a 16.4% savings in the chilled water plant thermal energy consumption.

Implementation of ASHRAE Guideline 36 Sequences

To implement Guideline 36 using supervisory controls, the team combined standardized communication, semantic modeling, and vendor-independent programming. We established BACnet communication with the building automation system, then built Brick data models to represent equipment, points, and relationships in a machine-readable form. These Brick models allowed us to query HVAC system design and operating information, which was then used to configure and deploy ASHRAE Guideline 36 temperature reset sequences. For programming, we leveraged the OpenBuildingControl project (Wetter, Grahovac, & Hu, 2019), which provides pre-tested Guideline 36 sequences expressed in control description language (CDL) and packaged as functional mockup units (FMUs) (Blochwitz, et al., 2012). These CDL-based sequences calculated new supply water setpoints based on real-time valve positions and returned them to the plant equipment via BACnet. This workflow created a repeatable process where implementing the same SOOs in a new building only required substituting its Brick model, while the rest of the control application remained unchanged. A more detailed description of the Brick modeling and deployment process has been published previously (Duarte Roa et al., 2023), and prior studies have also emphasized the practical challenges in constructing accurate Brick models for real buildings (Duarte Roa et al., 2022).

MEASUREMENT AND VERIFICATION APPROACH

To evaluate the energy consumption and energy cost performance of Guideline 36, the team conducted a detailed measurement and verification (M&V) analysis. We collected relevant data to calculate thermal energy consumption using existing metering in the buildings and where necessary, installed additional metering to capture data. To compare with Guideline 36, we used the existing control strategy in each plant as the baseline

Data Collection and Quality Checks

Energy consumption calculation at the chilled water plant at Building-1 required two types of energy uses: cooling energy through a water-side calculation and power use of the chiller and plant equipment(chilled water pumps, condenser water pumps, and cooling tower fans). The team separately evaluated energy use for water cooling energy and plant equipment energy by using the standard International Performance Measurement and Verification Protocol (IPMVP) Option B retrofit isolation procedure (Efficiency Valuation Organization, 2025). The chilled water cooling energy included process loads for the laboratory equipment, as well as space cooling. We assumed that these process loads stayed constant over the total M&V period. Chilled water cooling energy consumption (power) was calculated using the water-side data of calculated total flow rate ($Q_{CHW,Tot}$), and temperature differences using Equation 1 below. Power was integrated over time to calculate the total energy consumption for a given timeframe.

$$P_{cooling} = Q_{CHW,Tot} \times \rho \times (T_{CHW,ret} - T_{CHW,sup}) \quad (1)$$

The team used cooling energy consumption and outside air temperature to develop regression models that accounted for weather changes and the day of the week for both the intervention and baseline and used them to estimate and compare annual energy consumption for the two strategies.

Plant equipment power was the sum of power of the chiller, chilled water pumps, condenser water pumps, and cooling tower fans as shown in Equation 2 below. We developed regression models to similarly compare total plant energy using the plant equipment energy.

$$\dot{P}_{Equip.} = P_{CHILLER} + P_{CHWP1} + P_{CWP1,2} + P_{CT1,2} \quad (2)$$

The hot water plant at Building-1 uses campus steam, which is supplied to a heat exchanger to produce hot water. The team calculated the heating energy use in the building through hot water temperatures and flow rates. We separately evaluated energy use for water heating energy and pump energy as the pump energy is expected to increase due to higher hot water flow rate. The team calculated hot water heating energy consumption (power) using the water flow rate and the temperature difference using the Equation 3 below. This result and the measured pump energy were then used to develop a regression model to estimate annual energy consumption and compare Guideline 36 and baseline.

$$\dot{P}_{heating} = Q_{HW} \times \rho \times (T_{HW,sup} - T_{HW,ret}) \quad (3)$$

For Building-2, the team collected natural gas consumption using a pulse meter attached to the natural gas meter on site. Natural gas consumption was converted to thermal energy by using standard energy density of natural gas. For days where the heating hot water generation boiler was shut off, the natural gas consumption represent domestic hot water (DHW) natural gas use. This usage was consistent between days and small compared to space heating natural gas usage. To develop regression models, we used IPMVP Option C: whole facility method (Efficiency Valuation Organization, 2025). The hot water pump in the plant has a 0.5HP (0.37 kW) motor and the energy use is very small compared to the thermal energy, and it ran at 100% speed almost all the time. Therefore we ignored the energy use of the pump for the energy comparison.

Rapid M&V Procedure

For measurement and verification (M&V), we employed a novel randomized switching method that alternates between the baseline control sequence and Guildeine 36 sequences, enabling faster and more reliable estimation of retrofit savings compared to conventional year-long baseline and intervention measurements (Raftery et al., 2023). This approach, based on a randomized block experimental design, balances sampling across days of the week and allows analysts to detect intervention effects through statistical testing with controlled uncertainty. The team excluded days with boiler shutdowns but otherwise relied on unadjusted natural gas data that include DHW usage accounting to about 10% of the total usage. To address differences in system dynamics, the sampling interval was set to one day for Building-1 and three days for Building-2 with the first day after each switch between strategies discarded to mitigate carryover effects from the thermal mass of the radiant system. This approach demonstrated that randomized switching can provide faster, more robust M&V results for evaluating control retrofits.

Energy Savings Analysis

To evaluate performance under the baseline and G36 intervention strategies, the team developed regression models using the Time-of-Week and Temperature (TOWT) approach (Granderson and Lin, 2016), with data collected through the randomized M&V procedure. A one-tailed hypothesis test (Montgomery and Runger, 2018) was applied to compare daily energy use distributions, testing whether the intervention reduced consumption relative to the baseline. Statistically significant results ($p < 0.05$) provided evidence that G36 achieved measurable savings. To estimate normalized annual energy use, the TOWT regression models were combined with Typical Meterological Year, version 3 (TMY3) weather data (Wilcox and Marion, 2008) to predict building energy consumption across a full year. While some extrapolation was necessary for temperature conditions not observed during the demonstration period, the TOWT framework captured key time-of-week and temperature-response effects, enabling consistent comparison of baseline and intervention performance under standardized weather conditions.

RESULTS AND DISCUSSION

To compare energy consumption and savings between the baseline and Guideline 36, we evaluate two sets of energy usage results: 1) measured energy use difference and 2) normalized annual energy use estimation. Measured energy use compares the daily energy consumption using measured data during the data collection period. This period does not cover the entire annual weather conditions. However, due to the use of rapid M&V procedure which ensure a similar distribution of weather and building conditions between strategies, the comparison is still valid. Normalized annual energy use is estimated for both baseline and Guideline 36 using the developed regression models and compared to estimate normalized annual energy savings.

Building-1 Chilled Water Plant

Figure 1 shows the measured daily electrical energy consumption comparison between baseline and G36 for Building-1 chilled water plant. Figure 1(left) shows the total daily electrical energy consumption that include chiller, pumps, and cooling towers, where as Figure 1(right) shows the electrical energy consumption for the chiller. This shows that G36, on average, saves 332 kWh (1,133 kBTU) (11.6%) most of which 330 kWh (1,126 kBTU) is attributable to chiller energy consumption. The low p-value also indicate the statistical significance of the conclusion that G36 saved energy. We also evaluated the thermal energy consumption using the chilled water flow rates and supply and return temperatures and found 9.8% energy savings for G36. Chiller peak power consumption was similar between the two strategies. Peak chiller power typically occurred during periods of highest cooling demand, often in the early afternoon when outside air temperatures reached their daily maximum. The similarity in peak power across both strategies indicates that each was capable of meeting these peak cooling demands with comparable power input. Consequently, the energy savings observed with G36 were primarily realized during partial load conditions, when cooling demand was lower and the system operated more efficiently through temperature reset and demand-based control.

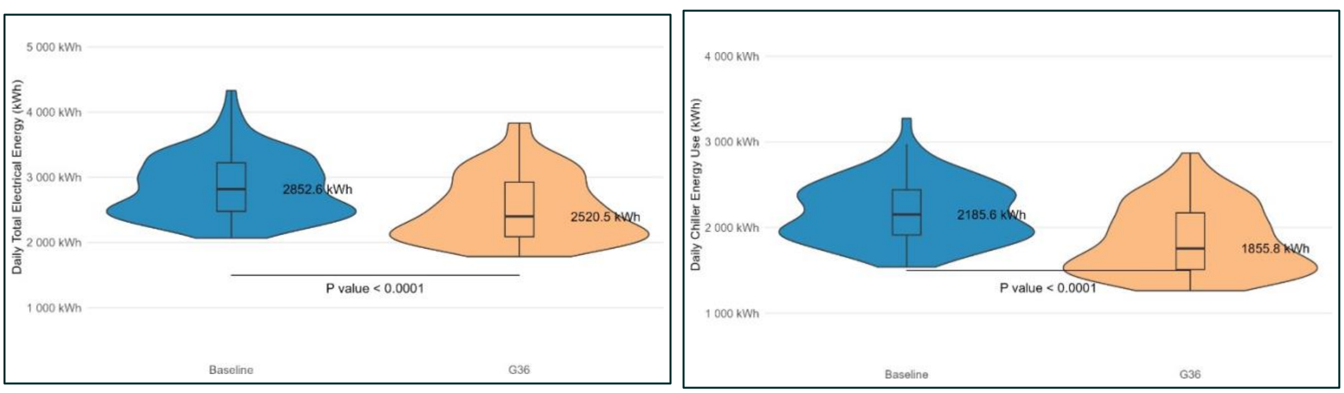

Figure 1. Daily energy consumption distribution for total electrical energy (left) and chiller electrical energy (right) between Baseline and Guideline 36 – Building-1 Chilled water plant

The team collected limited summer time (Jun-Aug) data and observed different chiller plant operation setpoints during this time than the rest of the year. Therefore, we excluded the summer months from normalized annual energy consumption estimation. Using TMY3 weather data and energy consumption calculations during non-summer months for both strategies compared in Figure 2, we estimated a total electrical energy saving of 6.61 kWh/m^2 (2,097 BTU/ft^2) (14.6%) highlighting the long term energy savings potential of implementing Guideline 36 SOOs. Using an estimated average commercial electricity rate of \$0.20 per kWh in California, the cost savings would be approximately \$0.12/ft^2 (\$1.29/m^2) .

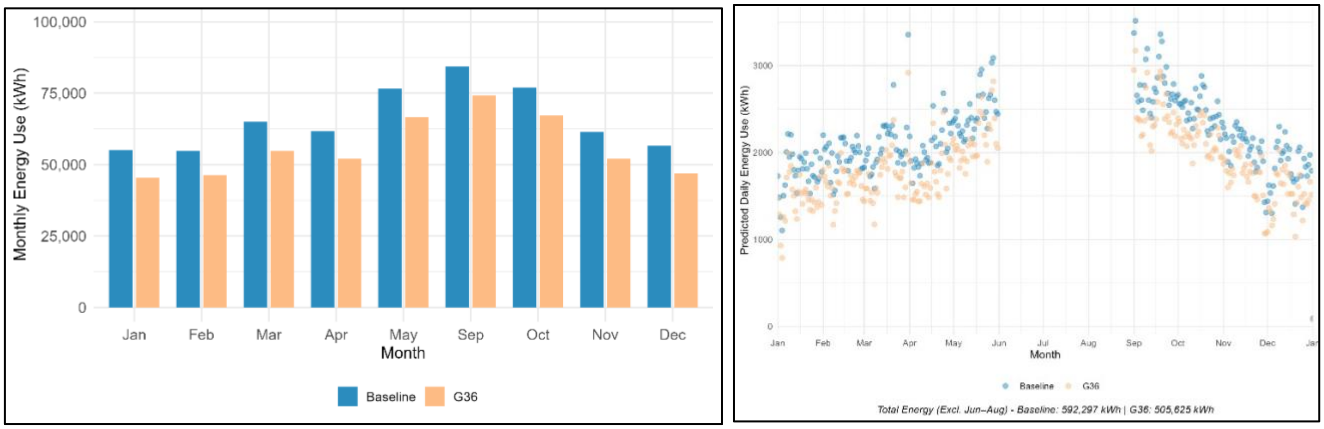

Figure 2. TOWT model predicted monthly chiller plant electrical energy consumption (left) and daily chiller plant electrical energy consumption (right) between baseline and Guideline 36 excluding summer months (Jun-Aug).

Building-1 and Building-2 Hot Water Plants

We conducted similar analysis of measured energy and normalized annual energy consumption comparisons to estimate energy savings of Guideline 36 compared to the baseline in the Building-1 hot water plant. Measured energy comparison showed 23.4 BTU/ft^2-day (0.073 kWh/m^2-day) (10.2%) thermal energy savings. We used the TOWT regression models to estimate the annual energy consumption for a typical year using TMY3 weather data which showed 10.15 kBTU/ft^2-year (32 kWh/m^2-year) (11.5%) reduction in heating thermal energy consumption. Assuming typical equipment efficiency, and a natural gas utility rate of $15/MMBTU, this will save $23,860 per year ($0.17/ft^2-year or $1.82/m^2-year) for this building.

Measured energy use comparison for Building-2 hot water plant showed 15.1 BTU/ft^2-day (0.048 kWh/m^2-day) (9.4%) energy saving. Annual TOWT model predicted energy savings were 3.29 kBTU/ft^2-year (10.38 kWh/m^2-year) (7.5%). Based on an average natural gas utility rate of $2.885/therm, this leads to a normalized annual cost savings of $0.095/ft^2-year ($1.02/m^2-year).

Table 1 Summarizes the avoided energy savings and annual normalized energy savings as well as annual cost savings for implementing Guideline 36 against the existing baseline control strategy for the three plants. Energy and cost savings estimates for Bldg-1 CHW plant electricity does not include the summer months (Jun – Aug).

Table 1: Summary of Energy and Cost Savings

Energy Type	Normalized Energy Savings		Cost Savings	
Bldg-1 CHW plant electricity	6.61 kWh/m^2 (2,097 BTU/ft^2)	14.6%	$17,334	$0.12/ft^2 ($1.29/m^2)
Bldg-1 HW plant	10.15 kBTU/ft^2-year (32 kWh/m^2-year)	11.5%	$23,860/yr	$0.17/ft^2-yr ($1.82/m^2-yr)
Bldg-2 HW plant Natural gas	3.28 kBTU/ft^2-year (10.38 kWh/m^2-year)	7.5%	$3,662/yr	$0.095/ft^2-yr ($1.02/m^2-yr)

These savings are reductions in heating load solely due to the decreased water temperatures. These savings are in addition to any further savings from improved efficiency of the heating equipment serving that hot water system (e.g. a condensing boiler). The mechanism is likely due to reduced piping distribution losses, recently quantified as a median of 0.37 BTU/hr.ft^2 (1.2 W/m^2) across seven buildings (Raftery et al. 2023).

Implementation Challenges and Market Scalability

The field demonstrations highlighted several challenges in deploying Guideline 36 in existing buildings, particularly in facilities with strict operational constraints. In cleanrooms in Building-1 with constant thermal loads and tight humidity requirements, Guideline 36 temperature reset strategies provided limited flexibility and may be further constrained by practical issues such as sensor drift, aging controls, and actuator reliability, which can undermine setpoint stability. Similarly, in

Building-2, unreliable boiler operation prevented the hot water plant from reliably achieving setpoints commanded by the Guideline 36 logic, introducing additional uncertainty in performance measurement. These suggest that successful Guideline 36 implementation requires thorough system review and retro-commissioning to address hardware limitations, ensure sensor and actuator reliability, and confirm system readiness before deploying advanced sequences—particularly in sensitive environments.

Despite these challenges, the project demonstrated a promising pathway for scaling Guideline 36 deployment through a modular and standards-based architecture. By separating tasks across domain experts, control engineers developing CDL-based vendor-agnostic sequences, ontology specialists creating Brick models, and software developers integrating applications on BACnet edge devices, the approach enabled automated system integration, streamlined configuration, and consistent performance across BAS platforms. Broader market adoption can be accelerated through several mechanisms including manufacturer-level pre-programming of Guideline 36 sequences to reduce project complexity, design-phase tools such as Lawrence Berkeley National Lab's ctrl-flow (Wetter et al., 2022) to generate standardized specifications, and inclusion in utility incentive programs supported by rapid M&V methods for cost-effective savings verification. Finally, integration of Guideline 36 into codes and standards, already underway through California's Title 24–2025 (California Energy Commission, 2025), will be pivotal in transforming Guideline 36 from a high performance option to a baseline expectation in HVAC design.

CONCLUSION

This study demonstrated that ASHRAE Guideline 36 hydronic sequences can be effectively deployed using a scalable framework that integrates a supervisory control layer, CDL programming, and Brick ontology for standardized tagging and configuration. The approach streamlined adoption across multiple plant systems and provided a replicable model for broader deployment. Field results showed consistent energy and cost savings: 14.6% ($0.12/ft^2 or $1.29/m^2) in the Building-1 chilled water plant, 11.5% ($0.17/ft^2-yr or $1.82/m^2-yr)) in the Building-1 hot water plant, and 7.5% ($0.095/ft^2-yr or $1.02/m^2-yr) in the Building-2 hot water plant, confirming Guideline 36's efficiency potential in real-world settings. At the same time, deployment challenges were observed in sensitive environments (e.g., cleanroom constraints at Building-1) and where equipment reliability was limited (e.g., Building-2 boiler hardware), highlighting the importance of thorough system review and retro-commissioning prior to implementation. Overall, these findings highlight both the significant benefits and the practical considerations for scaling Guideline 36 adoption.

ACKNOWLEDGMENTS

The authors would like to thank Domenico Caramagno, Danny Pestal, Maria Hassid, and Chris Ellis for the support at the demonstration sites, subject matter experts and other stakeholders for their valuable inputs. This research was funded by the CalNEXT program (contract 9212) and by The Center for the Built Environment at University of California Berkeley.

NOMENCLATURE

P = Power
Q = Flow rate
ρ = Density
T = Temperature

Subscripts

chw = Chilled water
hw = Hot water
chwp = Chilled water pump
cwp = Condenser water pump

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