Energy Research and Development Division

COMMERCIALIZATION REPORT

OpenBuildingControl

Commercialization and Market Transformation Plan

California Energy Commission

Gavin Newsom, Governor

December 2019 | CEC EPC-16-056

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CEC Contract Number: EPC-16-056
DOE Contract Number: DE-AC02-05CH11231
CEC Grant Number: 14-308

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ACKNOWLEDGEMENTS

This research was supported by:

The Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technologies of the U.S. Department of Energy, under Contract No. DE-AC02-05CH11231

The California Energy Commission's Electric Program Investment Charge (EPIC) Program

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PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution, and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation, and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities — Pacific Gas and Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company — were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

This *OpenBuildingControl: Commercialization and Market Transformation Plan* is an interim report for the OpenBuildingControl Project (Grant Number 14-308) conducted by the Lawrence Berkeley National Laboratory. The information from this project contributes to Energy Research and Development Division's EPIC Program.

All figures and tables are the work of the author(s) for this project unless otherwise cited or credited.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website C:\Users\eluk\Desktop\www.energy.ca.gov\research\or contact the Energy Commission at 916-327-1551.

ABSTRACT

This report is part of the OpenBuildingControl Project, which is intended to improve the development and implementation of the building control strategies (typically called “sequences of operation”) that are used to control the comfort, safety, energy efficiency, and demand response capabilities for commercial buildings. The project involves the development of a set of tools to resolve many of the existing process challenges related to building controls or "building automation systems" (BAS). This document provides a strategy for the project team to engage the industry and promote the adoption of the process and tools developed in the project as a means of market transformation.

Keywords: *OpenBuildingControl, Open Building Control, commercial buildings, energy efficiency, automation, high-performance controls, description language, Department of Energy, Lawrence Berkeley National Laboratory, sequences of operation, BACnet, ASHRAE*

Please use the following citation for this report:

Switenki, Paul. 2019. Arup North America, Ltd. *OpenBuildingControl: Commercialization and Market Transformation Plan.* California Energy Commission. Publication Number: CEC EPC-16-056.

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Introduction

Well-designed and properly implemented control sequences have the potential to reduce building energy use by 10 to 30%. However, most buildings do not implement industry best practice sequences. Many existing buildings predate current energy codes, standards and guidelines. New construction projects that are designed to implement such strategies frequently struggle due to the inherently complicated process of traditional development, documentation, interpretation, implementation and owner operation that offers many opportunities for failure.

The first phase of the OpenBuildingControl project is a three-year effort focused on improving the process and tools necessary for the design, cost-effective implementation, and validation of the operating sequences used for control of commercial buildings.

This project will provide the capability to avoid the current ambiguous and error-prone process of verbally describing control system sequences, then requiring a project technician to interpret the intent and write the necessary code to deploy the sequence.

This project will provide tools for systems designers to select, model the performance of, and then specify, tested control sequences. The designer will be able to express the desired sequence in an electronic format, which can be readily translated to programming code without the need for manual interpretation. The project will also provide tools to automatically document the sequences of operation implemented in a building and compare them to the original design intent.

Used together, this set of tools has the potential to substantially reduce energy use in both new and existing commercial buildings. However, to be effective, these tools need to be widely adopted and used by industry, including system engineers, designers, controls manufacturers, controls subcontractors, owners, and other interested parties, including state energy agencies and utilities. This *Commercialization and Market Transformation Plan* outlines what is needed for the project work to be adopted and used by the industry.

This project complements work by ASHRAE's Standing Guideline Project Committee 36 (G36), which collects, develops and publishes control sequences considered to be industry best-in-class in improving system stability, energy performance, indoor air quality and comfort. Modern versions of energy standards and codes like ASHRAE 90.1 and the California Energy Code require specific G36 algorithms and are expected to adopt or reference G36 sequences as awareness of the Standard grows.

Project Purpose

The purpose of the OpenBuildingControl project is to substantially reduce commercial building energy use by optimizing the design, implementation, and validation of building controls. The project team documented existing buildings controls practices and processes and developed tools and processes to remove impediments to effective design and correct implementation.

Project Process

The Department of Energy (DOE)'s Lawrence Berkeley National Laboratory is leading this project, with regular reviews from DOE and California Energy Commission program management. The process started with the establishment of a project team consisting of lab staff and industry experts in the design and implementation of control systems, along with an advisory panel that includes design engineers, general contractors, mechanical subcontractors, controls subcontractors, controls manufacturers, commissioning agents, and building owners and operators.

The advisory panel provides industry input and feedback while the core team is responsible for defining the new process and coding, testing, validating, and documenting the associated tools. Key elements of the development work include:

- Definition of use cases and processes related to controls design and implementation.
- Development of the new Controls Description Language used in the tools.
- Review of the semantics and syntax of the proposed Controls Description Language with controls suppliers.
- Development of tools to allow the Controls Description Language to be used within annual whole building energy simulation using Spawn of EnergyPlus.
- Tools to translate the Controls Description Language into common data formats (JSON and HTML).
- Case studies that compare the performance of new sequences developed for Guideline 36 to current typical sequences.
- Demonstration of translation of the Controls Description Language to a proprietary controller language and uploading of this code into a functioning control system.
- Coordination with other industry efforts including ASHRAE Guideline 36.
- Development of this commercialization plan.

Project Results

The project achievements to date have been very positively received by members of the ASHRAE SGPC 36 and others in the industry. The following items are expected to be completed at the end of this project phase (December 2019):

- Definition and documentation of the semantics and syntax of the Controls Description Language and of its JSON export format (Wetter, Grahovac and Hu, Jianjun, Control Description Language 2018a)

- A library of control sequences for chiller plants and variable-air-volume systems expressed in the Controls Description Language (link)). These sequences are based on ASHRAE's Research Project 1711 and ASHRAE's Guideline 36.

- Modeling tools that can simulate sequences expressed in the Controls Description Language coupled to heating, ventilation, and air-conditioning models from the Modelica Buildings library and linked to EnergyPlus envelope models (link)https://lbl-srg.github.io/soep/.

- A tool that verifies that the control response from a Controls Description Language–specified sequence and trended control outputs are within user-specified tolerances (link).
- Tools to translate the Controls Description Language into open formats such as JSON and HTML (link).
- Demonstration of sequences expressed in the Controls Description Language being translated to a proprietary language and uploaded into a working control system.
- Case studies (Wetter, Grahovac and Hu, et al. 2018b).
- This Commercialization Plan.

There is also a set of items that were not completed by the end of the initial phase of this project; follow-on funding to complete these items has now been secured. These items include:

- A systems design tool to allow an engineer to specify the type of system to control and to select control options. The tool will then select and generate the proper Controls Description Language and control sequence description. This tool would include a library of capabilities from sources such as ASHRAE Guideline 36 and the engineers' current library and will make use of the Spawn of EnergyPlus simulation tool.
- An expanded library of control sequences, expressed in the Controls Description Language, that can be used as input for the above design tool.
- Tools and documentation that can be used by control systems suppliers to develop translators from the Controls Description Language to their proprietary control system.
- Proposal to adopt the Controls Description Language as an ASHRAE/ANSI standard and, ultimately, an ISO standard.
- Provisions to add tagging to the Controls Description Language so that it can be used with Brick, Project Haystack and other similar semantic tagging and data modeling standardization efforts. Refer to APPENDIX A Target Audiences and Organizations.
- Programs for implementing market transformation.
- Tools for evaluating a current control system and developing documentation for both installed sequences and any variations from the original Controls Description Language.

Benefits to California

This project will benefit both the State of California and the rest of the US — and, ideally, the world. The key benefits are as follows:

- **Reduced cost to design and implement advanced controls**. This project will make the use of these advanced controls more cost effective for new construction and, even more importantly, for retrofit where costs and complexity are impediments to implementation.

- **Improved energy efficiency**. The project team has documented the potential to reduce heating, ventilation, and air-conditioning system energy use by 30% through the use of advanced controls for secondary systems. The team is confident that this approach can be extended to other building systems, including primary systems, lighting systems, and active façade systems. The ability to reduce building energy use is a significant benefit for the state and is essential to achieving California's goal of all new commercial buildings being net zero energy by 2030.

The adoption of OpenBuildingControl will result in improved design and implementation of building controls. An LBNL study identified 16% median actual savings from retro-commissioning (Evan Mills 2009) and a study of 481 operational issues identified in existing commercial buildings found that control problems accounted for >75% of the potential energy savings (Effinger, et al. 2009). Taken together, these studies indicate that current control practices are inadequate to meet the needs of even conventional buildings. Therefore, the energy savings from widespread adoption of OpenBuildingControl can be estimated by noting that 75% of the 16% primary energy savings associated with commissioning are related to controls. The primary energy consumption of US commercial buildings with floor area above 50,000 sf is 18 quads/yr. Assuming that the technologies to be developed in the proposed project can save 12% in 50% of these buildings, the potential savings are around 1.1 quads/yr nationally and around 0.05 quads/yr in California, saving IOU ratepayers a maximum of around $0.3B/yr.

CHAPTER 1
Overview

The current process of designing, implementing, and commissioning building automation systems (BAS) is suboptimal. The result is that controls systems are expensive and often do not deliver the necessary energy efficiency or comfort level.

Current State of the Industry

The current state of the BAS industry is segmented. Many parties with different roles and/or interests are involved, including:

- Design Engineers
- General Contractors
- Mechanical Subcontractors
- Controls Subcontractors and System Integrators
- Low Voltage Electrical Subcontractors
- Controls Manufacturers
- Commissioning Agents
- Owners and Landlords

These parties are rarely at the same table at the same time. A typical project might break down as follows:

The Design Process

The heating, ventilation, and air-conditioning (HVAC) system designer or engineer is typically tasked with selecting system type(s), calculating thermal loads, and sizing, configuring, and locating equipment and distribution systems in harmony with the architecture, structural, and other building systems. Deliverables typically consist of specifications, equipment schedules, code compliance forms, floor plans, sections, system diagrams, details, and BAS documentation.

In a perfect world, BAS documentation might consist of the following:

- Network architecture diagrams illustrating how the overall system of server, workstation and controllers is to be arranged, connected, and how/where it ties into a larger IT network.
- Diagrams illustrating instrumentation and wiring associated with each type of subsystem/equipment.
- Points lists summarizing controller, device and instrument types, quantities and associated inputs and outputs
- Specifications describing control hardware, software, controllers, instrumentation and cabling, and network and communication protocols.

- Narratives and/or logic diagrams clarifying intended sequences of operation, alarms, setpoints, etc. for each BAS component and system.

Design expertise varies from person-to-person, and BAS documentation databases and standards vary from firm-to-firm. BAS documentation varies greatly and is often reduced to a subset of the items above, perhaps to as little as major system/equipment diagrams and incomplete sequences of operation narrative.

The Bid and Construction Processes

For typical design-bid-build projects, general contractors formulate competitive bids for projects based on the designer's project documents. Typically, the general contractor subcontracts the HVAC portion of the project to a mechanical subcontractor, who might subcontract the BAS portion to a specialist controls subcontractor or systems integrator. (From this point on, we refer to both as “controls subcontractor”.) The controls subcontractor provides BAS products from a manufacturer or manufacturers and may further subcontract the associated low-voltage control wiring to another subcontractor. There are other permutations of contractual hierarchy, but all tend to involve the same mix of industry players.

The controls subcontractor reviews bid documents and generates a cost estimate for BAS materials, controllers, instrumentation, programming and commissioning. They add profit to their estimate, then pass the costs up to the mechanical subcontractor who, in turn, marks up the controls subcontractor's costs to account for time and effort they will expend managing the controls subcontractor. This type of markup might occur at each level of subcontract.

Ideally, the designer's documentation accurately quantifies and specifies systems, components, and materials so the BAS material and installation cost estimate can be similarly accurate. This minimizes the risk of changes and expensive construction-phase change orders.

Costs for controller programming depend on the types and quantities of control devices and systems and also their associated sequences of operation. Controls subcontractors might assume they will be able to use their own programming and/or programming options already embedded in controllers with minimal modifications, especially if the designer's sequences are incomplete or conflicting and/or confusing. However, doing so may lead to inconsistencies between design intent and the implemented sequence(s).

During construction, the controls subcontractor's first focus is on building the BAS network and fulfilling the contract documents' submittal requirements. At least one of those submittals includes sequences of operation. For this, the engineers' specifications may dictate that the controls subcontractor interpret, expand upon, and submit the engineer's narrative sequences. Sometimes the submitted sequences may do exactly that, but often they simply repeat verbatim the engineer's original narrative sequences, which can be incomplete and/or include errors.

Regardless of the state of the controls subcontractor's submitted sequences, controls subcontractors do not use plain English to program their controllers; they use their proprietary programming software, tools and languages that are specific to their family of controllers. The English narrative sequences in the engineers' documentation or expanded controls

subcontractor submittal version are only valuable insofar as they provide a basis of intent for programming. Even then, the controls subcontractor's programmer might not read those sequences before they commence work late in the construction phase. At that stage of the project, there is usually a big push for the general contractor to finish their work and hand the completed building to the Owner. The BAS programmer is under pressure to get the sequences implemented and the system up and running. If they discover holes or errors in the engineer's sequences at this point, there is little incentive to do anything than make their best (sometimes quickest) effort to fill the holes in their own programming language. They often do not bother to adjust or expand the sequence narratives to accurately reflect the final implemented sequences.

The Commissioning Process

Building owners or tenants sometimes hire commissioning agents to ensure the contractors implement the intended BAS system and sequences. This is particularly true where green building rating systems, codes or standards incentivize or require such a process. Depending on their project-specific scope, commissioning agents may be involved in design phase reviews; confirming completion of testing, adjusting and balancing efforts; witnessing equipment and system start-up; and generating and witnessing equipment and system pre-functional and functional tests. Ideally, the commissioning agent can rely on the engineer to deliver robust documentation, and the controls subcontractors to install and program accordingly. In some cases where gaps exist in the documentation, or where controls subcontractors do not meet design intent, the commissioning agent wastes time and part of their fee helping solve problems. In cases where construction delays occur without extending the project completion date, there can be a mad scramble to complete the commissioning effort and often pre-functional and functional tests are minimized, eliminated, or not witnessed by the commissioning agent.

Post Occupancy

Building maintenance is mostly a reactive practice. Prolonged wear on a system component begins to impact system performance, but the problem is not detected until either complete failure triggers and alarm or results in occupant discomfort. A complaint is lodged, and the owner's maintenance team is called. Systems are taken off-line. Costly repairs or replacements are made, and the equipment and systems are brought back online. The maintenance work order is closed, but the temporary reduction in productivity has negatively impacted the tenant's business and the failing system component had been eroding system energy efficiency for months if not years. If only the issue could have been detected earlier.

Streamlining the Process

There are currently no generic tools to determine or compare control strategies, to generate sequences, to ensure sequences are properly converted to control programming language, or to generate and/or implement commissioning tests. Other industries have developed such tools and depend on them. The building controls industry needs to catch up.

CHAPTER 2
Tool Workflow and Benefits

This chapter summarizes the proposed OpenBuildingControl (OBC) tools and their use cases.

Process Workflow

There are two possible process workflow cases envisaged for the use of OBC at the design stage:

- Case 1: Conventional buildings and systems for which suitable sequences are already available, either in a public library, such as Guideline 36, or in the designer's library, and the designer elects to use one of them essentially unaltered – this is expected to be the more common case.
- Case 2: Buildings and/or systems for which a suitable sequence is not available or for which there are alternative sequences that the designer wishes to compare.

In Case 1, where there is no need to compare or otherwise evaluate sequences, a simulation model is not required. In Case #2, where there is a need to validate modifications to the selected sequence or compare candidate sequences, simulation is required. Tools being developed as part of the project will gather inputs about the mechanical system selections and code requirements and output the required CDL and English language sequences.

In Case 2, the full OBC process workflow, illustrated in Figure 1, can be followed. Upon starting the controls design phase of a project, the designer identifies project requirements (1) and selects one or more control sequences from a preassembled sequence library (3). The designer then adjusts parameters of the sequence(s) to suit project constraints that have been established by the owner, codes, standards and industry practice. The designer then uses the OBC Toolset's simulation feature (2) to evaluate and compare sequence performance using a generic, reference building model (4). Depending on the simulation results, the designer may opt to use one of the sequences as-is or to modify it and then verify that requirements and performance targets are met.

Later in the project, when the specific building is more defined, the designer can adjust, evaluate and compare sequences using a more evolved, project-specific building model. Once satisfied with the chosen sequence and parameters, the designer exports a control specification, an executable sequence and functional tests (5) in the software's Controls Description Language (CDL). If the user wishes, they can save the sequence to the user library (6) for use on a future project.

The controls manufacturer/vendor can utilize the exported CDL specification to generate their detailed bid (7) and, during project development, can utilize a conversion tool they have developed to assist in programming the controllers (8). After control system installation and programming, the project commissioning agent verifies that the sequences have been

implemented properly by running functional tests against the digital, executable specification in the software's Commissioning and Functional Verification Tool (9).

A simplified version of the process workflow is used in Case 1, with no testing and performance assessment required in (2).

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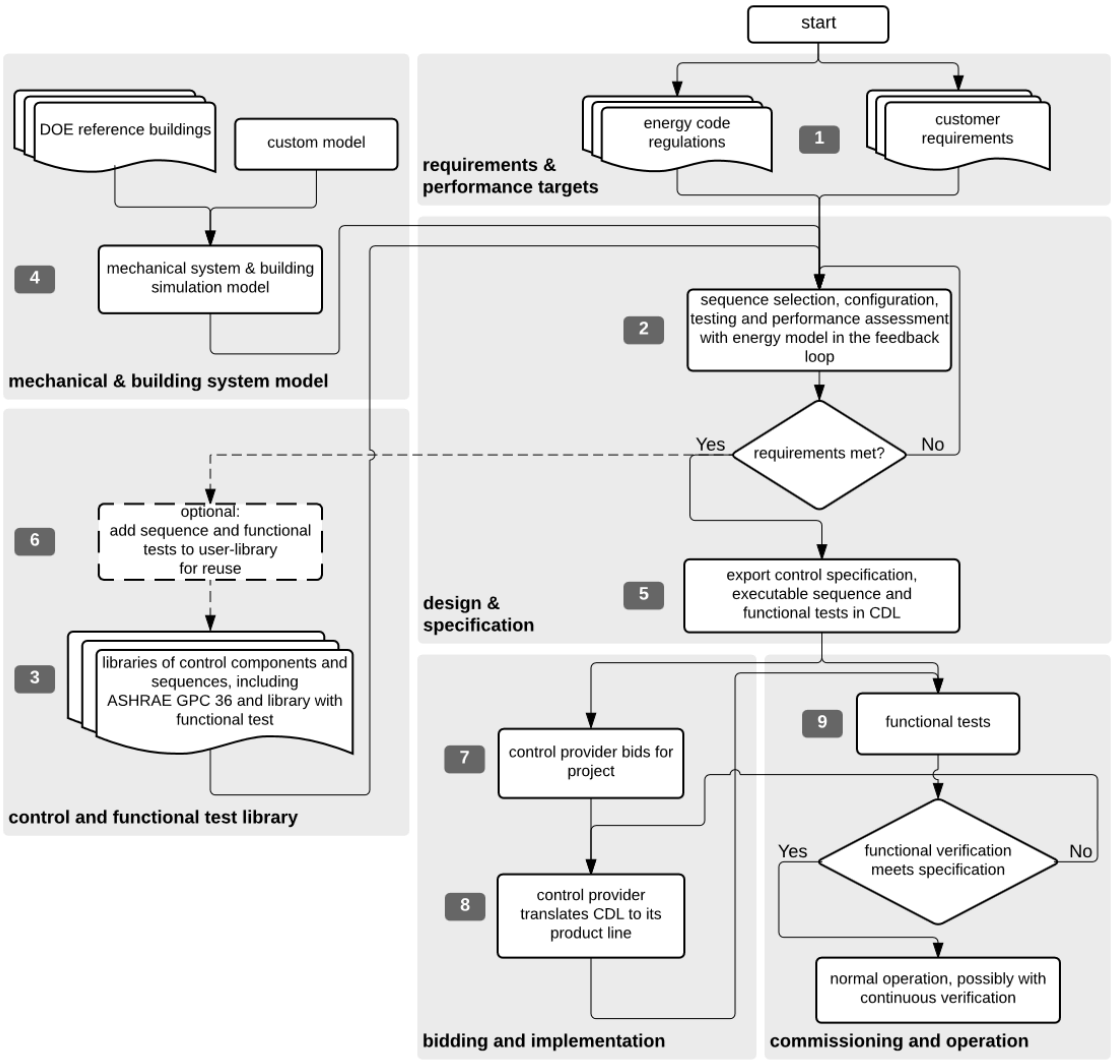
Figure 1: OpenBuildingControl Process Workflow



Industry Best Practice Control Sequence Library

The OBC Toolset's control sequence library incorporates sequences from the American Society of Heating, Refrigeration and Air-Conditioning Engineers' (ASHRAE) Guideline 36 (G36): High Performance Sequences of Operation for HVAC Systems. The Guideline provides sequences that incorporate a common set of sequence terms to facilitate communication between specifiers,

contractors, and operators throughout the building project. This reduces programming and commissioning time during construction, improves control stability, system energy efficiency and performance, improves indoor air quality and facilitates real-time fault detection and diagnostics. The best-in-class sequences also meet requirements of the California Energy Code and ASHRAE energy standards (Standard 90.1), Ventilation (Standard 62.1) and Comfort (Standard 55). Guideline 36, its Standing Guideline Project Committee (SGPC) and its associated Research Project (RP-1711) are sponsored by ASHRAE's Technical Committee (TC 1.4): Control Theory and Applications.

The OBC Toolset was used to demonstrate that the annual site energy of a particular variable-air-volume (VAV) system could be reduced by 30% by simply changing the control sequences from ASHRAE's (2006) Sequences of Operation for Common HVAC Systems to G36's best-in-class sequences (Wetter et al., 2018b).

Modeling Approach

For closed-loop performance assessment and verification, the Controls Design Tool and Commissioning and Functional Verification Tool use the control sequences, expressed in CDL linked to a Modelica systems model and an EnergyPlus or Modelica envelope model using the OBC Toolset’s external interface. If a project-specific model of the building and its systems for either Modelica or the Spawn of EnergyPlus simulation tools already exists, it can be imported into the Controls Design Tool.

Beneficiaries and Use Cases

The following summarizes the process improvements from the use of the digital process defined in OBC.

Designers

Designers range from mechanical design engineers to specialists who focus only on control system design to jacks-of-all-trades who may manage multidisciplinary design teams, design HVAC systems and/or design control systems. Designers generally want to assure their HVAC and systems meet code, are effective in keeping the building functioning and provide an acceptable level of comfort to occupants while minimizing energy use. During design, they want to efficiently produce complete, reliable documentation so they do not end up being responsible for contractor change orders during construction.

Many designers have developed libraries of plain English sequences that they copy, paste and modify for each project. With the Toolset, they will be able to convert their plain English sequences to the Toolset’s graphical format and continue to curate their sequence library. A bonus will be having access to the ASHRAE G36 sequence library, which are being developed as industry best-practice sequences.

Designers will be able to use the OBC Toolset’s energy modeling capabilities to analyze and troubleshoot novel HVAC system designs and sequences, and compare sequence options for specific project types, system configurations and geographical locations. Examples include:

- Comparing designers' libraries of sequences with ASHRAE G36 sequences
- Comparing ASHRAE G36 sequence sub-options, for example: determining what combination of a central AHU supply air temperature and pressure reset saves more energy and/or results in greater occupant comfort.
- Comparing other sequence sub-options

While other commercially available energy modeling software may be used to approximate comfort and/or energy effects of control sequences, most do not incorporate the same level of sequence options and/or detail as the Toolset.

The Toolset is being implemented as part of the DOE Spawn of EnergyPlus, which provides a direct coupling between HVAC and controls simulation in the Modelica Buildings Library and building envelope load modeling in EnergyPlus. This Toolset is developed to allow integration in OpenStudio.

Also, the designer will save time and have a higher quality deliverable by using OBC tools to generate output that can be used for documentation (sequences, diagrams, etc.) and input to controls subcontractor software that automatically and accurately translates specified sequences into their specific control programming language without requiring further interpretation or extrapolation.

The following designer use cases have been specified and tested by the OBC Toolset's developers:

- Loading, editing, and storing a sequence from the ASHRAE G36 sequence library.
- Connecting a VAV control sequence to a system model and customizing the control sequence.
- Customizing and configuring a sequence for a single-zone VAV air handling system.
- Performance assessment of a control sequence.

Bidding and BAS Implementation Use Cases

The OBC Toolset will generate control point schedules from sequences. Should they develop their own complementary tools, controls subcontractors will be able to tie points to associated devices and estimate associated material and labor costs. Owners and cost estimators would also benefit from accurate and efficient bidding and procurement.

Generating Control Point Schedule from Sequences

When the user adds a control point in the Controls Design Tool, the Toolset provides default values and allows the user to change the values for tagging/point name/point type/comments. The user clicks on a button to generate Points Schedule, and an Excel file is then generated listing all the points and their details. User clicks on a button to generate a tag list of unique control devices within the project in Excel, so that the associated specification section can be extracted and populated within third party software.

Commissioning Use Case

To facilitate the commissioning process and assist the contractor develop better estimates, third party pre-functional and functional test software programs could be created via an extension of CDL. OBC tools could help the contractor develop better estimates.

Conducting Verification Test of a VAV Cooling-Only Terminal Unit

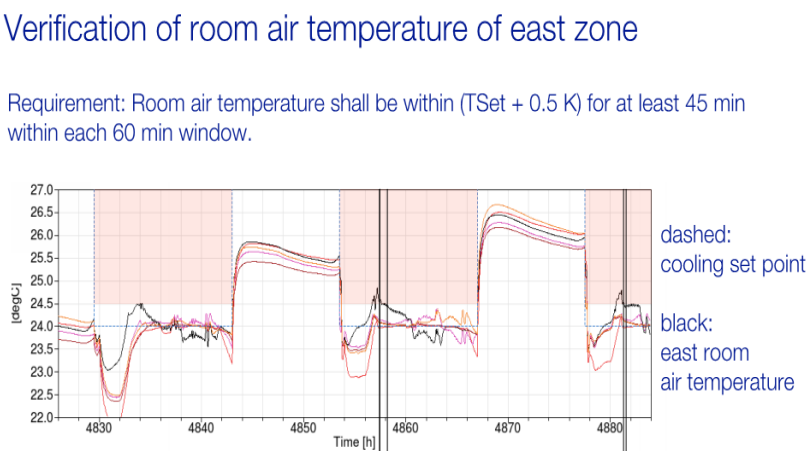
In the future, the commissioning agent might be able to import CDL-conformant control sequences and verification tests into the Verification Tool and connect it to the BAS. The Verification Tool might then perform automatic functionality tests (set VAV to unoccupied, set VAV to occupied, etc.) and commissioning override checks (force zone airflow to zero, force zone airflow to minimum, force damper full closed/full open, reset request-hours accumulator to zero (one point per reset type).

Operations and Maintenance Use Case

The OBC Toolset could be reversible, in that the controls subcontractors and/or manufacturers could make sequence and/or hardware adjustments and convert their controllers' parameters to as-built point lists, bills of materials, sequences and/or specifications. Owners would benefit from having accurate, as-built information for their operations and maintenance team.

Additionally, the OBC Toolset could incorporate logic that provides fault detection and diagnostics and continuous commissioning. For example, a high air temperature read downstream of a VAV box that should be in cooling mode might trigger an alarm that leads to discovery of a leaking hot water control valve for the reheat coil. Figure 2 illustrates a more general fault detection algorithm that quantifies the duration a zone is outside of its allowable temperature and alarms when there is a problem.

Figure 2: Commissioning Example



Alarm indicated when temperature falls outside of room temperature setpoint for more than 15 minutes per hour.

Documentation

When using CDL to implement a control sequence in a BAS, OBC Tools will be able to create control block diagrams and automatically produce points lists, plain language sequence of operation, and verification that the control diagram includes all instrumentation required to complete the control sequence.

Priorities and Benefits

The following is a summary of potential benefits to each of the major contributors to the building automation process.

Owners, Property Managers, and Landlords

Studies show that a comfortable occupant environment leads to productivity, and that productivity leads to profitability. With this in mind, it only makes sense that the highest priority for building owners and property managers (both called "owners" for simplicity) is keeping their building operational and their tenants comfortable. Reducing utility bills and maintenance costs are also important since they improve the bottom line, but they rank lower simply because the dollar spent on maintaining productivity reaps greater financial return than the dollar spent on saving energy.

Use of the OBC Toolset allows the owner to maximize productivity while minimizing costs associated with design, construction, operation and maintenance. The designer chooses from industry best-practice sequences that have been proven to both (a) meet Code and (b) maximize comfort and save energy. The designer might also incorporate optimal startup, demand reduction and/or fault detection and diagnostics strategies into the sequences. The controls subcontractor will use their own translator software to convert the CDL output into their own, proprietary programming and program controllers with the specified sequences and commissioning tests. The controls subcontractor issues proof-of-certification forms, runs point-to-point system validation tests and delivers pre-functional and functional test output reports (generated by the Tool) for each controlled device or system. The commissioning agent reviews the forms, runs a few in-field spot checks, and signs the final commissioning report.

Once the building is up and running, the owner knows that best-in-class, high-performance sequences have been correctly installed, will help maximize occupant comfort, productivity and energy efficiency, and will help the operator identify system, equipment and component issues before they result in system failure and/or excessive utility bills.

Owners can also use the OBC Toolset to produce record documents. Through its graphical user interface, the owner can see and understand how the systems operate and understand how to maintain them. This helps prevent implementation of rogue fixes like overriding setpoints, operating modes and/or alarms, etc. Even if such "band aid" fixes are made over the years, the Toolset and its associated outputs can be used to assist with future retro-commissioning efforts to bring the system back to its originally intended operation.

While this section focuses mostly on new control systems, the Toolset could potentially be used to re-program existing controls systems.

Controls Manufacturer and Controls Subcontractor Benefits

Controls manufacturers sell products by making them easy to implement and operate. Along with controls subcontractors, manufacturers would benefit by developing their own software tools to automate translation of the Toolset’s CDL into their system's native programming language.

Use of the Toolset would help assure the designer's sequences were accurate and complete and, since the ASHRAE G36 CDL blocks are pre-checked and pre-vetted, would allow the controls subcontractor to efficiently translate the sequences into programming language and program their controllers. This workflow could save the controls subcontractors’ programming (and programming revisions, as G36 is revised) labor and result in fewer post-occupancy issues, especially if a commissioning tool is used. One controls manufacturer’s representative estimated that warranty phase fixes account for 10 to 20% of their typical project budget.

A member of this project team offered this analogy: In the 1970s, when someone purchased a new car and was about to drive it off the lot, the dealer might have advised the buyer to make a list of the things they found that weren't working right, and bring the car back in later, so the

dealer could take care of those issues. Now, in the 21st century, buying a car comes with the expectation that everything will work when it's driven off the lot.

Despite this expectation, there is a relatively small cadre of skilled technicians trained in BAS. By minimizing programming and commissioning effort, the industry reduces dependence on these technicians, who are difficult to find and afford, given the draw to other technical industries.

Contractors

Contractors (including all subcontractors) are driven by project costs and schedules. Any construction-phase processes that can be expedited, and/or automated have the potential to reduce project costs and shorten schedules, thereby increasing profits and enhancing reputation.

In this sense, controls subcontractors can benefit from using the OBC Toolset in several important ways. By directly converting the sequences expressed in CDL to controller programming, they can give the general contractor confidence that they are not deviating from the designer's intent. Similarly, by using the Toolset for commissioning, the controls subcontractor can expect a shorter and less laborious and contentious commissioning effort. Finally, the controls subcontractor could also use the Toolset to automatically generate submittal and as-built documentation. All of these streamlined efforts add up to reduced costs, earlier owner handover dates and fewer issues to resolve after the building is occupied and after the contractors have de-mobilized.

Utilities

Utilities will benefit from reduced building energy consumption and peak draw. Buildings using ASHRAE Guideline 36 sequences implemented with the OBC Toolset are expected to consume less energy than others, and demand reduction sequences would be more likely to be properly implemented, thereby reducing peak energy draw. This would result in reduced capital, operations and maintenance, and energy costs for the utilities.

CHAPTER 3
Project Status

This project was started with an aggressive set of goals. Over the last three years the team has worked hard to gather requirements from industry, and to deliver on most of the anticipated results. At the end of the initial phase of the project in December 2019, the following items should be completed.

User and Market Documentation

Delivery will include a series of case studies that document the current processes used for design and delivery of controls and the challenges that this presents in terms of both cost and energy efficiency. Further studies include modeled impacts of using optimized controls versus the use of “business as usual” sequences. Other market documentation includes this commercialization plan, which describes the project team's recommendations for further action.

Tools and Process Improvement

Controls Description Language

A key deliverable for this project is the definition of an open source description for building control sequences called “Controls Description Language” or CDL. There are several benefits to the use of CDL.

Simplicity

Traditionally a designer develops a control sequence that is in a verbose English language format. For example, “Upon morning warm-up, when the outdoor air temperature is below 40 degrees F, the air handler shall start with the heating valve open and the outdoor air damper closed” might be used to express the designer's intent. In CDL this would be expressed with a representation that show the relevant control blocks and connections in a machine-readable file. This same file can also contain English language descriptions that are expressed as HTML that can be rendered in a web browser or converted to Microsoft Word format.

Energy Modeling

The CDL file can readily be used as an input for conducting energy simulation that allow for comparisons of alternative control sequences. This allows the designer to compare options for controlling a building and to select the best solution. Note that this process makes use of the modeling tools that are also deliverables from this project.

Automatic Controller Programming

Finally, the CDL file can be provided to the controls subcontractor for translation into their own programming language. Part of the OBC Toolset is a tool to express CDL in “Java Script Object

Notation" (JSON). The use of JSON provides the ability to readily parse and interpret the CDL file, facilitating the development of automated translation tools (developed by the controls supplier) to express the file in the format used for their controllers. This translation process removes the uncertainty and cost in the controls subcontractor having to interpret the designers' sequence noted in Chapter 2.

High-Performance Controls Sequence Library

The project team has used work developed by ASHRAE to define best practices for high-performance control sequences to develop an initial set of libraries expressed in CDL. The initial library will include high-performance airside control sequences (for single and multiple zone air handling systems) that have been published in ASHRAE G36. It also will include sequences for chiller plants and other "water side" systems that are currently defined by ASHRAE Research Project 1711 and are scheduled for addition to ASHRAE G36.

Modeling Tools

For this project, the team has developed a simulation solution that uses HVAC control models that are based on the Modelica Buildings Library that can use CDL as an input to define the controls sequence. This can be used concurrently with models in EnergyPlus that provide loads based on the envelope models. Ongoing work led by Lawrence Berkeley National Laboratory (called Spawn of EnergyPlus) brings these functions together.

Validation Tools

To validate that the designers' specified CDL-described sequence has been properly applied, a tool will be provided that will compare trended control outputs to those generated by a simulation of the sequence in the CDL file.

Demonstration System

The demonstration will show how the CDL file can be translated from its JSON format into the control programming language used by a commercial controls supplier. This will then be uploaded into an operable demonstration system to show the validity of the process.

Future Work

There are also a series of items that are not anticipated to be completed by the end of this project and will need follow on projects and funding to complete. These include:

Market Transformation

Implementation of the plan described in Chapter 4 to educate the industry about this project and to gain acceptance as a best practice for the design and implementation of control sequences for commercial buildings.

System Design Tool

The systems design tool will allow a designer to specify the type of system to be controlled, and to select control options. The tool will then select and generate the proper CDL and control sequence description. For innovative buildings, the tool will enable predefined sequences to be modified or completely new sequences defined. Comparison of the performance of different sequences will be able to be performed using a simulation tool based on Modelica and EnergyPlus.

Library Expansion

Provide an expanded library of control sequences, in CDL beyond those for airside and water side HVAC systems that can be used as input to the above design tool. Examples of expanded sequences would include systems such as active facades, lighting, integrated systems, variable refrigerant flow, unitary equipment, etc. Note that many of these sequences are required for both retrofit of older systems as well as for use on new systems using innovative and integrated systems.

The tools will access libraries of sequences from sources such as ASHRAE G36 and the designers' current library.

Controls Manufacturer Support Tools

Tools and documentation that can be used by control systems suppliers to develop translators from CDL to their proprietary control system will be produced. Note that the project team does not envision that the development of translators would be done by the project team, since a large portion of the needed work is related to the proprietary nature of most current control systems. What this would provide is support and tools to assist the manufacturers in the development and validation of these tools.

ANSI Standards

The project team has developed a definition for CDL that is available on an open source repository. The team did reach out to get industry review of the format and content of CDL. The next step is to make CDL an international standard. The process of standards development is quite involved and requires following a specific process defined by ANSI and ISO. Making CDL a standard will make long term support easier and will help controls manufacturers justify the effort needed to build and support translators. The process of establishing an ASHRAE Standards Project Committee has been initiated. ASHRAE is an ANSI sanctioned body.

Semantic Tagging

There are a number of projects underway in the building controls industry to establish standards for semantic tagging. This includes work started by Project Haystack and Brick and more recently with ASHRAE, which is seeking to integrate Haystack tagging and Brick data modeling in its proposed Standard 223. Semantic tagging is invaluable in allowing data to be extracted from control systems for functions such as fault detection and diagnostics. Semantic tags also can allow for improved efficiency in programming and setting up a new control

system. Ideally, CDL would include semantic tags from the earliest steps of design to assist in process improvements for the installation and operation of control systems.

CHAPTER 4
Deployment Plan

This chapter describes the deployment plan for the OBC processes and tools. It lists goals and objectives, summarizes activities necessary to achieve those goals, and defines target audiences and how the target audiences are best approached.

Goals, Objectives, and Supporting Activities

The overarching goal of the deployment plan is to improve substantially the efficiency, comfort, and safety of buildings through the broad adoption of the OBC process and tools as the control industry's standard for specifying, implementing, and commissioning BAS sequences of operation.

The medium-term (~5 year) objectives for the OBC Toolset include:

- Designers become competent in the use of the OBC Toolset and recommend to their clients that CDL implementation be an integral part of the controls specification.
- Controls manufacturers incorporate CDL in one or more of their major product lines, including the development of tools to translate CDL into their native programming languages.
- Controls subcontractors become competent in the use of the OBC Toolset and the implementation of sequences expressed in CDL.
- Major owners/clients experience the benefits of the OBC Toolset and CDL in the design and implementation of the control systems in their projects and require their use by default.
- The OBC Toolset becomes the preferred means of testing and comparing ASHRAE SGPC 36 best-in-class sequences, and those sequences are subsequently published in CDL.
- CDL becomes an ANSI/ASHRAE Standard, receiving continuous maintenance after initial publication.

The goals and objectives listed above are strongly coupled and must be pursued in parallel through closely coordinated activities. To that end, this Commercialization Plan should become a living document. Activities to support the achievement of these objectives should include:

- Actively working with interested controls manufacturers to maximize compatibility between CDL and their native programming languages.
- Demonstrations, at ASHRAE meeting and similar venues, of the use of the OBC Toolset and CDL in the design and implementation phases of real projects.
- Development of training materials for designers and controls subcontractors, including video documentation of demonstrations
- Workshops and seminars for managers, including owners, designers, controls subcontractors and controls manufacturers

- Active involvement in ASHRAE SGPC 36 to reinforce how CDL and the OBC toolset are critical to the success of the Guideline.
- Work within ASHRAE, and equivalent organizations, to promote the adoption of CDL as a standard; this will require regular attendance at ASHRAE and other professional societies' semi-annual meetings and conferences, active participation in relevant committees, and outreach at the Chapter and Region level.

Utilities and state energy agencies should be engaged with to secure financial and organizational support for these market transformation activities.

Active involvement in SGPC 36 is a critically important activity in that it is the starting point for credible engagement with designers, controls subcontractors and controls manufacturers. Corresponding avenues for engagement with owners and with controls subcontractors will need to be identified or developed as a matter of urgency.

ASHRAE Relationship

ASHRAE presents major opportunities to promote deployment of the OBC Toolset to designers through their guidelines and standards and biannual conferences. The latter will be discussed further below. The former is the subject of this section.

ASHRAE has over 85 active standards and guideline project committees, addressing such broad areas as indoor air quality, thermal comfort, energy conservation in buildings, reducing refrigerant emissions, and the designation and safety classification of refrigerants. These Standards and Guidelines are periodically reviewed and updated and are often referenced in building codes and adopted as best practice by designers, mechanical subcontractors, architects, and government agencies.

The project team’s short-term goal (1-3 years) is to reach the target market for the tools by embedding them within Guideline 36. The longer-term goal (5-10 years) is to have OBC’s Control Description Language become the standard industry control sequence programming language

Guideline 36

Chapter 2 introduced ASHRAE's Guideline 36, which was created to publish and maintain best-in-class sequences for HVAC systems. If the OBC Toolset can become directly associated with Guideline 36, it will be adopted by OBC’s target audience at a much faster rate than otherwise. Therefore, the team and project need to maintain active involvement with SGPC 36 to demonstrate that CDL and the OBC Toolset are critical to OBC’s success. This can be accomplished by using the Toolset to develop, test and publish new Guideline 36 sequences and by demonstrating that use of the Toolset helps users manage the increased complexity of advanced, high-performance sequences. This is a critically important activity in that is the starting point for credible engagement with designers, controls subcontractors and controls manufacturers.

The path to active collaboration with G36 has already been largely cleared. The project team and technical advisory group include several TC 1.4 and SGPC 36 committee members who have been involved in project's industry charrette and technical advisory group reviews and have graciously provided guidance. The project team has been sharing Toolset development updates at recent TC 1.4 and SGPC 36 meetings.

As mentioned in Chapter 1, the OBC tools were used to demonstrate the energy saving potential of key Guideline 36 sequences compared ASHRAE's previously published typical sequences. That demonstration also raised, and resolved, issues regarding ambiguities and misinterpretations of the Guideline. The Guideline 36 committee was impressed and understands the potential of the Toolset to assist with Guideline 36 development and with its potential to transform the industry.

The project team has proposed that Guideline 36 include CDL versions of the sequences and references to the OBC Toolset in future revisions. SGPC 36 has expressed strong interest in this approach to delivering their sequences and in using the OBC Toolset in the development of additional sequences. They are also awaiting the final versions of the CDL sequences currently being developed in the OBC project. Critical to the adoption of OBC is the availability of an English language expression of the sequence to accompany the CDL representation. The current OBC Toolset generates an English language expression in HTML format and a generator for MS Word format is currently under development.

Further relationship opportunities exist with SGPC 36 due to the current format of the Guideline. The Guideline is truly a guide - a manual that describes the sequences, subsequences and the related options from which the designer to choose. It does not represent what designers have been used to delivering for so long: a plain English narrative. The SGPC leadership acknowledges this and notes that designers need to either generate their own narratives or simply refer to a specific G36 sequence and list desired subsequence options and setpoints. In the project team's local industry charrette and in the 2019 ASHRAE Winter Conference SGPC meeting, it was evident that the engineering community craves English language narratives. If future Toolset development include conversion of CDL to English, designers will happily adopt the tool, even if only for this feature and the Guideline 36 sequence library.

CDL as a Standard

Standardizing the CDL will facilitate its acceptance industry-wide by this project's target audience: the many bodies who touch building controls throughout projects. There are two ASHRAE Standards that provide examples of how control related protocols can be developed into standards and accepted by industry, ANSI/ASHRAE Standard 135 (BACnet) and ASHRAE Standard 223 (Semantic Tagging). These Standards are described further in Appendix A.

ASHRAE Conferences

ASHRAE's winter and summer conferences host technical committee meetings and provide forums for HVAC and refrigeration industry information exchange. The 2019 winter conference,

in Atlanta had more than 3,200 registrants and the co-sponsored American Heating and Refrigeration (AHR) Exposition attracted over 65,000 visitors. The 2019 summer conference in Kansas City attracted 1,600 attendees. ASHRAE also has many regional chapters that hold regular meetings and offer opportunities to present industry work and research.

Industry Outreach

A template presentation should be generated and customized for each target audience. Presentations to target audiences should be made. This should be through industry conferences and through personal appointments. The project team has relationships with many of these organizations, which increases the chances of gaining those opportunities.

A successful outreach campaign should result in presentations at many major conferences throughout the US and generation of a contact list that summarizes BAS/energy efficiency influencers within each organization identified as part of the target audience. Eventually, these contacts should lead to presentation opportunities within those organizations. Refer to Appendix A for descriptions of the Toolset's target audience and their related professional societies, who often host industry conferences.

Designers and Energy Modelers

The design side of the industry consists of mechanical/HVAC engineers, technicians and building energy modelers. For brevity, we label all of these as "designers".

Designers would be the most likely to adopt the OBC Toolset, primarily because they are driven by codes, standards, and guidelines and because they like to have access to modern, energy-efficient sequences of operations for the systems they design.

As ASHRAE's Guideline 36 becomes better known, designers will become more familiar with it. It is already referenced by ASHRAE Standard 90.1 (Energy Standard for Buildings Except Low-Rise Residential Buildings), which through state codes' adoption processes means it may soon be codified in many states. If Guideline 36 sequences come with the OBC Toolset, which includes a tool that converts CDL to Boolean English sequence narratives, designers will embrace it for project documentation purposes, and might even learn to modify the Guideline 36 sequences for their own advanced control designs.

Those who use EnergyPlus or who will use the Spawn of EnergyPlus to model building energy consumption would be most likely to use the OBC Toolset to compare sequence and/or set-point options.

Conferences

The design community is best reached through industry conferences. As discussed earlier, ASHRAE offers semi-annual conferences that draw many designs and other industry target audiences. There are others that target designers, architects, and energy modelers. Contractors and controls subcontractors may also attend. Many of the following listed events are further detailed in APPENDIX A Target Audiences and Organizations

- ASHRAE summer and winter conferences
- ASHRAE/IBPSA-USA biennial Building Performance Analysis Conference and SimBuild
- US Green Building Council (USGBC) annual Greenbuild conference
- AEE annual East Coast Energy Management Conference
- AEE annual West Coast Energy Management Conference
- AEE annual World Energy Engineering Congress
- Biennial Haystack Connect conference
- Tridium's biennial Niagara Summit

Owners

Large governmental agencies, institutions, campuses, corporations, and commercial real estate professionals form the major owner target audience.

Owners who adopt the Tools for their building projects will do so for at least one of the following reasons: (1) the design team needs to use them to test sequences that have been adapted for non-standard systems; (2) the design team already uses them to assure ASHRAE Guideline 36's best-in-class sequences are implemented; (3) the owner requires their use for the same reasons; (4) the owner and/or design team is incentivized to do so by utilities; and/or (5) the general contractor insists on them to facilitate the controls subcontractors' delivery process. This section focuses on case (3), which involves convincing the owner of the benefits of the OBC Toolset's.

An earlier section discussed how ASHRAE G36 and standardization might convince designers to adopt and use the OBC process and tools. The same would be true of owners, since many of their facility managers, energy managers, and operations and maintenance team members are familiar with ASHRAE Standards and Guidelines.

All of the owners listed below (especially the governmental agencies) tend to be hierarchical and have many moving parts, so it is important to find the branches and groups who have most concern and influence over buildings, control systems and energy efficiency. The target audiences are described below.

Governmental Agencies

The main governmental target audiences are the US Department of Defense, the General Services Administration, the DOE, and the Federal Energy Management Program.

US Department of Defense (DoD)

The DoD includes the Army Corps of Engineers and the Naval Facilities Engineering Command (NAVFAC), who are responsible for establishing building standards and adopting technology and solutions for military bases and other buildings that house some of the DoD's 2.8 million active servicemembers.

General Services Administration (GSA)

The GSA is a US government agency. Among its many other duties, it provides workplaces by constructing, managing, and preserving government buildings and by leasing and managing commercial real estate. The GSA has a complex hierarchy, of which certain branches and projects might be interested in the OBC process and tools. These include the Public Buildings Service (PBS) and its offices of Design and Construction, and Facilities Management and Services Programs; the Office of Government-wide Policy Overview and its Office of Federal High Performance Building (OFHPB), along with its Green Building Advisory Committee; and two programs falling under "Emerging Building Technologies": the GSA Proving Ground (GPG) and the Pilot to Portfolio (P2P).

US Department of Energy (DOE)

DOE is a cabinet-level department of the US government concerned with US policies regarding energy and safety in handling nuclear material. Amongst its responsibilities are energy conservation and energy-related research. DOE sponsors more research in the physical sciences than any other US federal agency. The majority of this research is conducted through its system of National Laboratories.

US Federal Energy Management Program (FEMP)

With more than 350,000 energy-using buildings, the federal government is the largest energy consumer in the United States. Mandated by law, FEMP promotes energy efficiency and the use of renewable energy resources at federal sites. FEMP's Facility and Fleet Optimization and Strategic Programming and Integration Planning focus areas are closely tied to building construction, renovation, and energy efficiency. FEMP offers many free online training courses and design guides.

There are also targets at the regional, state, or local level. One example is the California Department of General Services, which operates state building in California. There are many other state agencies and local government organizations.

Institutions, Campuses, and Corporations

Many colleges and universities have offices of architecture and construction. Along with healthcare providers and large corporations, colleges and universities often have large facility management teams who sometimes generate and maintain automation standards, specifications, and control sequences.

Commercial Real Estate Developers and Managers

Commercial real estate developers renovate and re-lease existing buildings and/or purchase land upon which they develop new buildings. Commercial real estate management companies oversee the day-to-day operations of buildings and may collect rent, negotiate leases, supervise building cleaning and maintenance activities. According to the Commercial Property Executive, the top five commercial development firms of 2018 included the Trammell Crow Company, Hines, Related Companies, Tishman Speyer and Duke Realty, and the top five commercial

property management firms of 2018 included Jones Lang LaSalle, Cushman & Wakefield, Colliers International, CBRE Group Inc. and Hines. Some companies perform both development and management services.

Conferences

The previous section on designer adoption recommended various industry conferences that might serve as the best vehicles to educate designers on both ASHRAE G36 and the Tool. These conferences would also attract various owner representatives.

Additionally, the following conferences draw attendees from the building owner's side and would be good opportunities to promote the Toolset and network.

- US DOE's annual Energy Exchange conference
- US DOE's Better Building Summit
- International District Energy Association (IDEA) conference
- International District Energy Association (CampusEnergy) conference
- Realcomm/Intelligent Buildings Conference
- Realcomm's CoRETECH
- International Facility Managers Association (IFMA) Facility Fusion
- IFMA's World Workplace
- Building Owner and Managers Association (BOMA) International Conference & Expo
- BOMA's Medical Office Buildings + Healthcare Real Estate Conference

Controls Manufacturers and Controls Subcontractors

A BusinessWire.com article (Technavio 2017) describes the global Integrated Building Management Systems (IBMS) market as "highly fragmented with the presence of several global and local vendors. Global vendors mostly operate as original equipment manufacturers (OEMs), catering to the requirements of the end-user through distributors/dealers or system integrators." There are many controls manufacturers in the US market, including Alerton, Automated Logic, Delta, Distech, Honeywell, Johnson Controls, Schneider Electric, Siemens and Tridium.

Activities with this group need to focus on educational outreach and convincing manufacturers to incorporate CDL translators into their product lines. This might be facilitated should a smaller vendor prove this is possible with a reasonable effort.

Continental Automated Buildings Association (CABA)

CABA is an international not-for-profit industry association dedicated to the advancement of intelligent home and building technologies. Their Intelligent Buildings Council works to strengthen the large building automation industry through technology-driven research projects.

International Society of Automation (ISA)

ISA is a global, nonprofit organization that develops automation standards, certifies industry professionals, provides education and training, and publishes books and technical articles. ISA

has a Building Automation Systems Division and an Automation Federation that works with CABA to provide education, training, and certifications for building automation professionals.

Conferences

Beyond the conferences listed for designers and owners, there are very few that target building controls manufacturers and controls subcontractors. ISA hosts a few conferences, but none of the 2019 conferences is dedicated to BAS. CABA's annual Smart Buildings Summit is a "by invitation only" event that limits attendance to 100-120 executives from leading North American Building Industry companies, based on customer base, market influence and breadth of service. Their call for papers appears to be open to non-invitees.

Commissioning Agents

Commissioning (Cx) is the process of verifying building subsystems for mechanical (HVAC), plumbing, electrical, fire/life safety building envelopes, process systems (example: laboratory hoods) co-generation, utility plants, sustainable systems, lighting, wastewater, controls and building security to achieve the owner's project requirements as intended by the building owner and as designed by the building architects and designers. Commissioning agents come many varieties, ranging for those who work for large firms that also provide design services, to sole proprietorships, specializing in commissioning only, and many variations in between.

A commissioning agent's job is typically to verify proper installation, operating and performance of these systems through commissioning processes. A great deal of a building Commissioning Agent's time is spent commissioning the HVAC and central plant control system. The Toolset can ultimately incorporate automated functional testing that can save the agent's time, effort and fees associated with this effort.

Building Commissioning Association (BCxA)

The BCxA is an international non-profit organization made up of professionals from the commercial building industry. Their mission is to advance best practices and education throughout the building industry, and to promote the benefits of building commissioning. The BCxA supports certification programs for commissioning professionals who manage the total building commissioning process.

Conferences

The BCxA hosts the annual National Conference on Building Commissioning (NCBC).

Utilities and Other Energy Organizations

In the US, most public utility rates and services are regulated by utilities commissions, utility regulatory commissions (URCs), public utilities commissions (PUCs), or public service commissions (PSCs). These state government agencies mandate energy incentive programs. Incentive programs are typically funded by ratepayers through a systems benefits charge that accrues into a Public Benefits Funds (PBF). The PBF supports energy efficiency investments and

research. State governments can also access PBFs to offer financial incentives. A few states charge a third-party with PBF administration.

In addition to using their own resources, utilities and their state government agencies (like the California Public Utilities Commission) typically work closely with Regional Energy Efficiency Organizations (REEOs) and other agencies like the Electric Power Research Institute (EPRI), the Gas Technology Institute (GTI), the Consortium for Energy Efficiency (CEE) and Design Lights Consortium (DLC) to select technology and building energy efficiency programs.

Generally, states and utilities like dependable, reliable, simple energy efficiency incentives, such as replacing old inefficient equipment with new, efficient equipment, or replacing incandescent or fluorescent lights with LED lights. Since building controls present layers of variability, an incentive program based on controls might be difficult to develop and/or administer.

In the immediate future, the developers of the Toolset should reach out to Regional Energy Efficiency Organizations (REEOs) and EPRI to discuss the best way to incorporate the Toolset and/or Guideline 36 sequences into energy efficiency incentives. This means knocking on doors, making phone calls pursuing representatives of these group. Other, lower priority utility-related groups would be the GTI, CEE, CEEP, NBI, E Source, ACEEE, ASE and ANSI.

Descriptions and definitions of these organizations are included in Appendix A. Below is an abbreviated summary of the major target organizations.

Regional Energy Efficiency Organizations (REEOs)

REEOs are a national network of organizations working through funded partnerships with the US DOE, as well as utilities, third-party program administrators, public officials, various advocacy groups, businesses, and foundations. REEOs actively contribute to and reference materials and initiatives of the US DOE and the US EPA's SEE Action Network to help states and local governments take energy efficiency to scale and achieve all cost-effective energy efficiency by 2020.

The project team aims to establish relationships with REEOs and educate them on Guideline 36 and the Toolset's potential to impact energy consumption (both overall and peak demand). The template presentation mentioned in the "Industry Outreach" section of this report would be developed to this audience. Success would mean the project team has made in-roads with the largest, most influential, and well-funded REEOs or a few of the smaller ones. The list of REEOs and is as listed below by priority. Descriptions of each can be found in Appendix A.

- Northwest Energy Efficiency Alliance (NEEA)
- Northeast Energy Efficiency Partnerships (NEEP)
- Midwest Energy Efficiency Alliance (MEEA)
- Southeast Energy Efficiency Alliance (SEEA)
- Southwest Energy Efficiency Alliance (SWEEP)
- South Central Program for Energy as a Resource (SPEER)

Electric Power Research Institute (EPRI)

EPRI is an independent, non-profit organization that conducts research and development related to the generation, delivery and use of electricity to help address challenges with reliability, efficiency, affordability, health, safety, and the environment. Its members represent ~90% of the electric utility revenue generated in the US.

Others

- The Gas Technology Institute (GTI) is a non-profit research and development organization focusing on the natural gas industry.
- The Consortium for Energy Efficiency (CEE) is a utility-funded group of US and Canadian gas and electric efficiency program administrators who accelerate the development and availability of energy efficient products and services.
- The New Buildings Institute (NBI) is a non-profit driving better energy performance in commercial buildings.
- E Source is a company providing energy efficiency program planning, design, execution and benchmarking research and consulting for utilities and customers.
- The American Council for an Energy Efficient Economy (ACEEE) is a non-profit catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviors.
- The Alliance to Save Energy (ASE) is a non-profit, bipartisan alliance of business, government, environmental, and consumer leaders advocating for enhanced energy productivity to achieve economic growth, a cleaner environment, and greater energy security, affordability, and reliability.
- The American National Standards Institute's Energy Efficiency Standardization Coordination Collaborative (ANSI-EESCC) established and maintains a strategic roadmap detailing the standards and conformity assessment programs needed to enable a more energy- and water-efficient built environment.

GLOSSARY

Term	Definition
ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers)	Refer to Appendix A.
ASHRAE Guideline Project Committees (GPC)	ASHRAE project committees (PCs) are established and supervised by the ASHRAE Standards Committee to develop new guidelines and revise current ones so that they reflect technical advances in the areas they cover. Standing committees are those that maintain existing guidelines. (link)
ASHRAE Technical Committees (TC)	ASHRAE Technical Committees (TCs) consist of people who have a recognized proficiency in a specific field of interest. In conjunction with ASHRAE Task Groups, Technical Research Groups and Multidisciplinary Task Groups, TCs are responsible for: • preparing the text of ASHRAE Handbook chapters • originating, coordinating, and supervising Society-sponsored research projects • presenting programs at ASHRAE meetings • reviewing technical papers • evaluating the need for standards • advising the Society on all aspects of the technology it embraces (link)
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- originating, coordinating, and supervising Society-sponsored research projects
- presenting programs at ASHRAE meetings
- reviewing technical papers
- evaluating the need for standards
- advising the Society on all aspects of the technology it embraces

(link)

Brick

Brick (or BrickSchema) is an open-source effort to standardize semantic descriptions of the physical, logical and virtual assets in buildings and the relationships between them. Brick consists of an extensible dictionary of terms and concepts in and around buildings, a set of relationships for linking and composing concepts together, and a flexible data model permitting seamless integration of Brick with existing tools and databases. Through the use of powerful Semantic Web technology, Brick can describe the broad set of idiosyncratic and custom features, assets and subsystems found across the building stock in a consistent matter. Adopting Brick as the canonical description of a building enables the following:

- Lowers the cost of deploying analytics, energy efficiency measures and intelligent controls across buildings
- Presents an integrated, cross-vendor representation of the multitude of subsystems in modern buildings: HVAC, lighting, fire, security and so on
- Simplifies the development of smart analytics and control applications
- Reduces the reliance upon the non-standard, unstructured labels endemic to building management systems

Brick is free and open-sourced under the BSD 3-Clause license. The source code for Brick and related tools developed by the Brick team are available on GitHub.

Building automation

Building automation is the automatic centralized control of a building's heating, ventilation and air conditioning, lighting and other systems through a building management system or building automation system (BAS). The objectives of building automation are improved occupant comfort, efficient operation of building systems, reduction in energy consumption and operating costs, and improved life cycle of utilities. BAS core functionality keeps building climate

	within a specified range, provides light to rooms based on an occupancy schedule (in the absence of overt switches to the contrary), monitors performance and device failures in all systems, and provides malfunction alarms to building maintenance staff.
Commissioning (Cx)	Building commissioning is the process of verifying, in new construction, all (or some, depending on scope) building and technical installations to achieve the owner's project requirements as intended by the building owner and as designed by the building architects and engineers. (Adapted from Wikipedia.)

CDL (Control Description Language)	The language used to express control sequences and requirements. It is a declarative language based on a subset of the Modelica language. It consists of the following elements:
	- A list of elementary control blocks, such as a block that adds two signals and outputs the sum, or a block that represents a PID controller.
	- Connectors through which these blocks receive values and output values.
	- Permissible data types.
	- Syntax to specify:
	  o How to instantiate these blocks and assign values of parameters, such as a proportional gain.
	  o How to document blocks.
	  o How to add annotations such as for graphical rendering of blocks and their connections.
	  o How to specify composite blocks.
	- A model of computation that describes when blocks are executed and when outputs are assigned to inputs.

DDC (Direct Digital Control)	Direct Digital Control is the automated control of a condition or process by a digital device (computer). DDC takes a centralized network-oriented approach. All instrumentation is gathered by various analog and digital converters which use the network to transport these signals to the central controller. The centralized computer then follows all of its production rules (which may incorporate sense points anywhere in the structure) and causes actions to be sent via the same network to valves, actuators, and other HVAC components that can be adjusted.
DOE (Department of Energy)	The United States Department of Energy
EnergyPlus	EnergyPlus is the US Department of Energy's whole building energy simulation program that engineers, architects, and researchers use

	to model both energy consumption—for heating, cooling, ventilation, lighting and plug and process loads—and water use in buildings. (link)
EPIC (Electric Program Investment Charge)	The Electric Program Investment Charge, created by the California Public Utilities Commission in December 2011, supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
HVAC (heating, ventilation, and air-conditioning)	The technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality. HVAC system design is a subdiscipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics and heat transfer. "Refrigeration" is sometimes added to the field's abbreviation, as HVAC&R or HVACR or "ventilation" is dropped, as in HACR (as in the designation of HACR-rated circuit breakers). (Wikipedia)
ISO (International Organization for Standardization)	This is an international standard-setting body composed of representatives from various national standards organization. It promotes worldwide proprietary, industrial, and commercial standards.
Modelica	A non-proprietary, object-oriented, equation-based language to conveniently model complex physical systems containing, e.g., mechanical, electrical, electronic, hydraulic, thermal, control, electric power, or process-oriented subcomponents. According to Modelica's website, "Industry is increasingly using Modelica for model-based development. Especially, many automotive companies, such as Audi, BMW, Daimler, Ford, Toyota and Volkswagen use Modelica to design energy efficient vehicles and/or improved air conditioning systems. Also power plant providers, such as ABB, EDF and Siemens use Modelica." An object-oriented, declarative, multi-domain modeling language for component-oriented modeling of complex systems, e.g., systems containing mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents. The free Modelica language is developed by the non-profit Modelica Association. The Modelica Association also develops the free Modelica Standard Library that contains about 1360 generic model components and 1280 functions in various domains, as of version 3.2.1. (link)

OBC (OpenBuildingControl)	A project led by the Department of Energy's Lawrence Berkeley National Laboratory focused on improving the process and tools necessary for the design, cost-effective implementation, and validation of the operating sequences used for control of commercial buildings.
Project Haystack	Project Haystack is an open source initiative to streamline working with data from the Internet of Things. The initiative standardizes semantic data models and web services with the goal of making it easier to unlock value from the vast quantity of data being generated by the smart devices that permeate homes, buildings, factories, and cities. Applications include automation, control, energy, HVAC, lighting, and other environmental systems.
Spawn of EnergyPlus	Spawn-of-EnergyPlus (Spawn) is a next generation building energy modeling engine that leverages open standards for equation-based modeling (Modelica) and co-simulation (FMI). Equation-based models can be repurposed, allowing Spawn to unify BEM with control workflows - Amir Roth, BTO. (link)
VAV (variable air volume)	A HVAC system that conditions building areas via modulating air flow.

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APPENDIX A Target Audiences and Organizations

This appendix describes some of the target audiences mentioned in the Plan.

Designers and Energy Modelers

The following are descriptions and definitions of the various architectural, engineering, and energy-modeling related professional organizations mentioned in the main body of this report.

American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)

ASHRAE's Membership demographics include more than 56,000 members from over 132 nations, consisting mostly of designers, but also including manufacturers, mechanical subcontractors, controls subcontractors commissioning agents, facility operators, utilities, and other parties interested in design, operation and/or maintenance of HVAC&R systems.

Conferences

ASHRAE's summer and winter conferences host technical committee meetings and provide forums for HVAC and refrigeration industry information exchange. The 2019 winter conference technical programs included tracks on "Construction, Operating and Maintenance of High Performance Systems", "Common System Issues and Misapplications" and "The Convergence of Comfort, Indoor Air Quality, and Energy Efficiency". The annual (summer) 2019 conference in Kansas City included tracks on "Optimization in HVC&R", "Commissioning New and Existing Buildings" and "Modeling Throughout the Building Life Cycle". The 2018 winter conference in Chicago had more than 3,200 registrants and the co-sponsored American Heating and Refrigeration (AHR) Exposition attracted over 70,000 visitors. The 2016 summer conference in St. Louis attracted 1,800 attendees. ASHRAE also has many regional chapters that hold regular meetings and offer opportunities to present industry work and research. See Table 1 for a schedule of upcoming conferences.

Table 1: Upcoming ASHRAE Conferences

Future Winter Conferences	Future AHR Expos	Future Annual Conferences
Feb 1–5, 2020 – Orlando, FL	Feb 3–5, 2020 – Orlando, FL	Jun 27–Jul 1, 2020 – Austin, TX
Jan 23–27, 2021 – Chicago, IL	Jan 25–27, 2021 – Chicago, IL	Jun 26–30, 2021 – Phoenix, AZ
Jan 29–Feb 2, 2022 – Las Vegas, NV	Jan 31–Feb 2, 2022 – Las Vegas, NV	Jun 25–29, 2022 – Toronto, ON

Standards and Guidelines

ASHRAE has over 85 active standards and guideline project committees, addressing such broad areas as indoor air quality, thermal comfort, energy conservation in buildings, reducing

refrigerant emissions, and the designation and safety classification of refrigerants. These Standards and Guidelines are periodically reviewed and updated and are often referenced in building codes and adopted as best practice by consulting engineers, mechanical subcontractors, architects, and government agencies.

ASHRAE Guideline 36 - High Performance Sequences of Operation for HVAC Systems, provides uniform, sequences that incorporate a common set of sequence terms to facilitate communication between specifiers, general contractors, subcontractors, commissioning agents and operators throughout the building project; reduces programming and commissioning time during construction: provides control stability; maximizes system energy efficiency and performance; improves indoor air quality; and allows for real-time fault detection and diagnostics. The best-in-class sequences also meet requirements of the California Energy Code and ASHRAE published standards for Energy (Standard 90.1), Ventilation (Standard 62.1) and Comfort (Standard 55). Guideline 36, its Standing Guideline Project Committee (SGPC) and its associated Research Project (RP-1711) are sponsored by ASHRAE's Technical Committee (TC-1.4): Control Theory and Application.

ANSI/ASHRAE Standard 135 (BACnet™ - A Data Communication Protocol for Building Automation and Control Networks). This protocol provides mechanisms by which control system equipment exchange information, regardless of function, and has facilitated control system integration and augmentation throughout the industry. The Standard is ANSI accredited, which means it has met ANSIs' mandatory requirements, including public reviews.

ASHRAE Standard 223P (Design and Classification of Semantic Tags for Building Data) is proposed by the ASHRAE BACnet Committee, Project Haystack, and the Brick Initiative with the goal of unification and standardization enabling interoperability on semantic information across the building industry, particularly in building automation. The unified effort is meant to ease the exchanging of data over established communication protocols like Haystack web services or BACnet, and when applied on data stored in databases and cloud applications, will support machine interpretation of the semantics of such data. The committee's goal is for the standard to be adopted as an ISO standard to achieve a wider (global) acceptance.

United States Green Building Council (USGBC)

The USGBC is dedicated to sustainability in the built environment. Its mission is to transform the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life. Membership typically professionals in architecture, construction, engineering, planning and interior design. The USGBC's Greenbuild Conference and Expo occurs annually in November. The 2019 event is in Atlanta, GA.

Association of Energy Engineers (AEE)

The AEE is a non-profit professional society of over 18,000 members in more than 100 countries. AEE's Mission is to promote the scientific and educational interests of those engaged in the energy industry and to foster action for sustainable development through live and online

seminars, conferences, journals, etc. Local chapters meet regularly. Membership is drawn from commercial, industrial, institutional, governmental, energy services and utility sectors. AEE offers certification in several areas, including energy management, energy auditing, building commissioning, energy simulation, and green building engineering. Annual conferences are as follows:

- East Coast Energy Management Conference (April 2020, Cincinnati, OH)
- West Coast Energy Management Conference (June. 2020, Seattle, WA
- World Energy Engineering Congress (September 2020, Denver, CO.).

International Building Performance Simulation Association (IBPSA)

IBPSA is an international, non-profit society of building performance simulation researchers, developers, and practitioners, dedicated to improving the built environment. IBPSA's biennial Building Simulation Conference in September includes opportunity to share information about simulation tools and applications. 2021 venue is Bruges, Belgium. The US affiliate of IBPSA (IBPSA-USA) brings together researchers and early-adopter practitioners at its biennial conferences (run jointly with ASHRAE), its semi-annual meetings (co-located with the ASHRAE semi-annual meetings) and regular chapter meetings in several major metropolitan areas.

Project Haystack

Project Haystack is a non-profit, open source initiative to streamline working with data from the Internet of Things. The initiative is to standardize semantic data models and web services with the goal of making it easier to unlock value from the vast quantity of data being generated by smart devices that permeate homes, buildings, factories, and cities. Applications include automation, control, energy, HVAC, lighting, and other environmental systems. The Project Haystack website targets owners and consultants, system integrators and manufacturers. The Haystack Connect conference is a biennial event that next takes place in May 2021.

Tridium

Tridium is an independent business entity of Honeywell International, Inc. Their products facilitate integration of building management systems using open and proprietary communications protocols such as Modbus, LonWorks and BACnet. The Tridium product is built upon the proprietary Niagara Framework, which is a universal software infrastructure that allows controls integrators, mechanical subcontractors and controls subcontractors to build custom, web-enabled applications for accessing, automating and controlling smart devices real time via local network or over the internet. Common Tridium controllers are Java Application Control Engines (called "JACEs"), which are typically comprised of several open and proprietary protocols on a scalable platform. Tridium promotes their Niagara Summit conference biennially. The next conference is due to occur in April of 2020.

Owners

The following are descriptions and definitions of the various owners, landlords, and real estate managers and associated professional societies mentioned in the main body of this report.

Governmental Agencies

The following are descriptions and definitions of the various governmental agencies mentioned in the main body of this report.

US Department of Defense (DoD)

The US Department of Defense (DoD) is the federal government executive branch department, charged with coordinating and supervising all agencies and functions of the government concerned directly with national security and the US Armed Forces. The DoD is the largest employer in the world with nearly 2.8 million active duty servicemembers, National Guardsmen and Reservists from the four services and civilians. The Army Corps of Engineers and the Naval Facilities Engineering Command (NAVFAC) are responsible for establishing building standards and adopting technology and solutions for military bases and other buildings that house part of the DoD's 2.8 million active servicemembers.

Army Corps of Engineers

The Army Corps of Engineers has many centers of excellence to support various DoD agencies. This includes HVAC and controls, supported by the U.S. Army Engineering Support Center Huntsville, Alabama. Support includes answering technical questions; performing technical submittal and design reviews; providing specialized training related to HVAC systems; providing HVAC system planning and designs; investigating, identifying and solving HVAC related problems; developing statement of work/performance work statements; developing criteria ; evaluating products/technologies; assessing condition of HVAC systems; providing commissioning related oversight; conducting performance verification / acceptance testing and monitoring of HVAC systems; and conducting HVAC related energy performance audits/studies.

Naval Facilities Engineering Command (NAVFAC)

NAVFAC is the Naval Shore and Expeditionary Systems Naval Command that plans, builds, and maintains sustainable facilities, delivers environmental, utilities and other bas services; and acquires and manages expeditionary combat force systems and equipment.

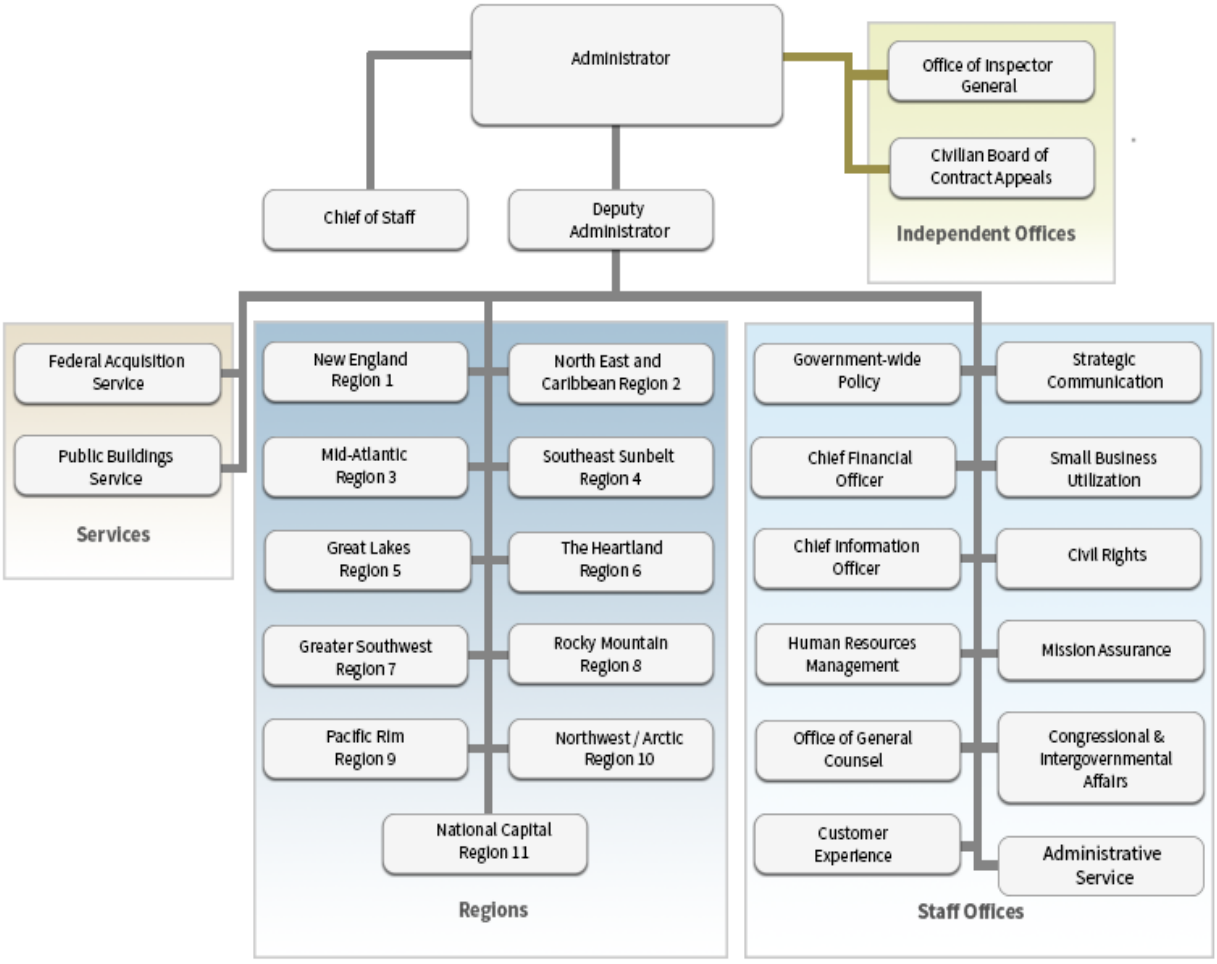
General Services Administration (GSA)

The GSA is an independent agency of the US government. Amongst other duties, the GSA provides workplaces by constructing, managing, and preserving government buildings and by leasing and managing commercial real estate. GSA also promotes management best practices and efficient government operations through the development of government-wide policies.

Through 11 US regional offices, the GSA constructs, manages, and preserves government buildings and leases and manages commercial real estate. Some regions have control standards. The project team intends to discover which regions have such standards and approach their leaders. Additionally, the GSA has several branches, subbranches (see Figure 3), and projects that might be interested in the OBC process and tools, including the Public Buildings Service (PBS) and its Office of Design and Construction and its Office of Facilities Management and Services Programs, the Office of Government-wide Policy Overview and its Office of Federal

High Performance Building (OFHPB), along with its Green Building Advisory Committee, and two programs falling under "Emerging Building Technologies": the GSA Proving Ground (GPG) and the Pilot to Portfolio (P2P).

Figure 3: GSA Organizational Chart



Source: https://www.gsa.gov/about-us/gsa-organization

GSA's Federal Acquisition Service offers private sector professional services, equipment, supplies, and IT to government organizations and the military.

GSA's Public Buildings Service (PBS) acts as the landlord for the civilian federal government acquiring space on behalf of the federal government through new construction and leasing and acting as a caretaker for federal properties across the country. PBS owns or leases over 8,000 assets, maintains an inventory of more than 370 million square feet of workspace for 1.1 million federal employees, and preserves more than 500 historic properties. PBS works with federal agencies to cut costs, increase productivity, reduce real estate footprint, and create greener offices. PBS also establishes and maintains policies and criteria regarding architecture and engineering design practice and building technology, building systems, products, and

materials based on the objectives established for the national capital program. Their *Facilities Standards for the Public Buildings Service* (P-100) establishes design standards and performance criteria for the GSA Public Buildings Service.

PBS includes several sub-offices, including the Office of Design and Construction and the Office of Facilities Management and Services Programs. The Office of Design and Construction offers advice on topics including includes Building Information Modeling (BIM), commissioning, design and construction excellence. PBS's Office of Facilities Management and Services Program is implementing a smart building strategy and working aggressively to modernize existing buildings and establish new standards for design and construction in order to achieve department and administration goals of energy efficiency and sustainability while still providing superior workplaces for federal customer agencies at good economies to the American taxpayer.

GSA's Office of Government-wide Policy Overview includes the Office of Federal High-Performance Buildings (OFHPB), which develops best practices, guidance and tools for government-wide use and advances Federal building innovations in planning, design, and operations to reduce costs, enable agency missions, enhance human health and performance, and minimize environmental impacts. The Green Building Advisory Committee provides independent policy advice and recommendations to the OFHPB. The current Designated Federal Official for this advisory committee is the OFHPB's Ken Sandler (in Washington, DC).

Under GSA's current listed Government Initiatives are "Greening Federal Buildings" and "Sustainability". The latter heading includes "Emerging Building Technologies", which has two programs: the GSA Proving Ground and the Pilot to Portfolio (P2P), which provides information regarding envelope, energy management, HVAC, lighting, on-site power and renewables and water.

GSA conducts its business activities through 11 regional offices throughout the US. Some regions have control standards. The project team intends to discover which regions have such standards and approach their leaders.

US Department of Energy (DOE)

The US Department of Energy is a cabinet-level department of the US government concerned with US policies regarding energy and safety in handling nuclear material. Amongst its responsibilities are energy conservation and energy-related research. DOE sponsors more research in the physical sciences than any other US federal agency. The majority of which is conducted through its system of National Laboratories.

DOE, through their Building Technologies Office (BTO), develops and maintains two significant BEM software packages: EnergyPlus and OpenStudio. EnergyPlus is the successor to DOE-2.1E and DOE releases two annual updates. OpenStudio is an open-source, cross-platform collection of software tools to support whole building energy modeling using EnergyPlus and advanced daylight analysis using Radiance.

The DOE's Annual Energy Exchange and Better Buildings Summit are annual events that attract thought leaders from federal, private, education and state and local government sectors to accelerate the adoption of energy/water efficiency, integrated resilience, emerging and secure technologies, and replicable renewable energy solutions.

The Energy Exchange provides training and includes themes such as Optimizing Design, Operations and Maintenance for Smarter Buildings, and High Impact and Secure Technology Applications. The 2020 Energy Exchange is scheduled for August 11-13, in Atlanta, GA.

The Better Buildings Summit is a national meeting where leading organizations across key sectors explore emerging technologies and share innovative strategies in energy and water efficiency. Over 650 participants attended the 2019 Summit in Arlington, VA. The 2019 Summit will be held June 8-10 in Arlington, VA.

Federal Energy Management Program (FEMP)

With more than 350,000 energy-using buildings, the federal government is the largest energy consumer in the United States. Mandated by law, the US FEMP promotes energy efficiency and the use of renewable energy resources at federal sites, helping agencies save energy, save taxpayer dollars, and demonstrate leadership with responsible, cleaner energy choices. FEMP's efforts have resulted in a 49% reduction in energy intensity since 1975. FEMP's Facility and Fleet Optimization focus area coordinates processes to integrate mission assurance with optimized and cost-effective facility and fleet operations, including commissioning, laboratories, metering, net zero water and waste, and operations and maintenance plans. FEMP's Strategic Programming and Integration Planning focus area provides information and resources to help agencies reduce energy and water use. FEMP offers many free online training courses and design guides.

Northwest Energy Efficiency Alliance (NEEA)

The NEEA is an alliance of more than 140 Northwest utilities and energy efficiency organizations working on behalf of more than 13 million energy consumers. Since 1997, the region has delivered over 1,400 MW of energy efficiency through market transformation. NEEA supports regional stakeholders in energy code development and adoption and serve as a source of technical experts during US DOE rulemakings to encourage adoption of federal appliance and equipment efficiency standards.

California Department of General Services (DGS)

The Department of General Services (DGS) serves as business manager for the state of California. General Services helps to better serve the public by providing a variety of services to state agencies through procurement and acquisition solutions, real estate management and design, environmentally friendly transportation, professional printing, design and Web services, administrative hearings, legal services, building standards, oversight of structural safety, fire/life safety and accessibility for the design and construction of K-12 public schools and community colleges, and funding for school construction.

International District Energy Association (IDEA)

The International District Energy Association (IDEA) represents over 2,200 members from 26+ countries who own, operate or provide technology and services to district energy systems that supply steam, hot water, chilled water and energy services to multiple buildings in cities, communities, campuses, airports, military bases, industry and healthcare facilities. IDEA works to foster the success of its members as leaders in providing reliable, economical, efficient and environmentally sound district energy. IDEA has an annual conference and trade show, attended by IDEA members and professionals in district energy, combined heat and power (CHP), and microgrid industries. IDEA2020 will be in Washington, DC from June 22-25. IDEA's annual Campus Energy Conference attracts representatives from college and university campuses, along with manufacturers, service providers, consultants, and public officials. Just under 835 participants attended the 2018 conference in Baltimore, Maryland, which included technical presentations on masterplanning and system design, optimization, metering and controls, operations, sustainability, and renewables. The 2020 conference is scheduled for February 10-14 in Denver, CO.

Realcomm

Realcomm Conference Group, LLC is a worldwide research and event company at the intersection of technology, innovation, and real estate operations. Through annual conferences, webinars, workshops, forums, and other strategic services, they provide networking and collaboration opportunities while educating industry professionals about the latest business solutions and technologies to improve commercial real estate development, leasing, management, and operations. Two of its 13 sectors include construction and development and facilities management.

Realcomm promotes three annual conferences: the Intelligent Buildings Conference (IBCon), Realcomm, and CoRE Tech.

IBCon's audience consists primarily of commercial and corporate real estate facilities and technology professionals. Realcomm's annual conference gathers thousands of commercial and corporate real estate professionals from around the world to discuss and debate how technology, automation, and innovation continues to impact the use, transaction, and operation of real estate. The 2019 combined RealComm/IBCon conference in Nashville, TN drew over 2,500 leaders from 20+ countries.

CoRE Tech’s focus is technology innovations impacting the corporate real estate industry and their target audience is corporate real estate and facilities professionals. Their 2019 conference will be held November 13–15 in San Jose, CA and themed, "REcalibrate: Using Innovation to Turn Challenges into Opportunities".

International Facility Management Association (IFMA)

The International Facility Management Association (IFMA) is the world's largest and most widely recognized international association for facility management professionals, supporting 24,000 members in more than 100 countries. There are 136 regional chapters 16 industry specific

councils and six communities covering specific areas of interest. They conduct research, produce publications, maintain a knowledge library, offer credentialing programs and educational courses, and produce the world's largest series of facility management conferences and expositions, including World Workplace and Facility Fusion conferences.

The World Workplace conference series is held in various international host cities. The event promises to facilitate idea-sharing and knowledge-exchange between all professionals who support the work environment. 2020 hosts include Amsterdam, Netherlands (March 18-20); Singapore (April 7-9) and Chicago, IL (September 30-October 2). Amongst the 12 learning categories to be presented at the Phoenix conference are FM Technology and FM Solutions.

Faculty Fusion promises to provide attendees the insight, imagination, and foresight to excel at facility management (FM) in the broader built environment by exploring emerging technology and ideas, engaging with FM thought leaders, establishing relationships with FM and built environment professionals, understanding how FM fits into and enhances the broader built environment, and participating in the unique sharing and collaborative community. The 2018 conference drew over 1,000 facility professionals. The 2020 event is scheduled for April 14-16 in San Francisco, CA. Past conferences have included Technology and Operations & Maintenance as two of their educational tracks.

Building Owners and Managers Association International (BOMA)

The Building Owners and Managers Association International (BOMA) is a federation of 88 BOMA US associations and 18 international affiliates. BOMA represents the owners and managers of all commercial property types, including nearly 10.5 billion square feet of US office space. Its mission is to advance a vibrant commercial real estate industry through advocacy, influence, and knowledge. BOMA's annual International Conference and Expo is scheduled for Philadelphia, PA, from June 27-30, 2020. Building Operations, Performance and Management is one of the five conference educational tracks. BOMA's 2020 Medical Office Buildings + Healthcare Real Estate Conference held April 29-May1 in San Diego, CA.

Controls Manufacturers and Controls Subcontractors

The following are descriptions and definitions of the various control-related professional organizations mentioned in the main body of this report.

Continental Automated Buildings Association (CABA)

CABA is an international not-for-profit industry association dedicated to the advancement of intelligent home and building technologies. The organization is supported by an international membership of nearly 400 companies involved in the design, manufacturer, installation and retailing of products relating to home and building automation. Public organizations, including utilities and government are also members. CABA provides networking and market research opportunities, encourages the development of industry standards and protocols, and leads cross-industry initiatives. There are three CABA councils that develop, document, and disseminate information on cooperative and collaborative activities: The Information Council, the Connected Home Council, and the Intelligent Buildings Council. The Intelligent Buildings

Council works to strengthen the large building automation industry through innovative technology-driven research projects. CABA's annual Smart Buildings Summit is a "by invitation only" event that limits attendance to 100-120 executives from leading North American Building Industry companies, based on customer base, market influence and breadth of service. Call for papers appears to be open to non-invitees. The 2020 Summit will be held May 3-5 in Ponte Vedra Beach, FL.

International Society of Automation (ISA)

ISA is a global, nonprofit organization with more than 40,000 members. ISA develops standards, certifies industry professionals, provides education and training, publishes books and technical articles, and hosts conference and exhibitions for automation professionals. The Building Automation Systems Division is a home for building automation professionals within the larger automation society. It markets itself to peers as a source of certification and education. Through its Automation Federation, ISA is working with CABA to provide education, training, and certifications for building automation professionals. ISA hosts a few conferences, but none of the 2020 conferences are dedicated to Building Automation Systems.

Commissioning Agents

Building Commissioning Association (BCxA)

The BCxA is an international non-profit organization made up of professionals from the commercial building industry, committed to the highest standards and practices for the commissioning process. Their mission is to advance best practices and education throughout the building industry, and to promote the benefits of building commissioning to achieve functional buildings. The BCxA supports certification programs for commissioning professionals who manage the total building commissioning process.

The BCxA hosts the annual National Conference on Building Commissioning (NCBC). Past conferences have offered educational tracks in Cx Essentials, Higher Education Cx Trends, Cx Management, Cx Programs and Tools, Cx Systems, and Case Studies. The 2020 conference will be September 23-25, 2020 in Phoenix, AZ.

Utilities

The following are descriptions and definitions of the various utility-related organizations mentioned in the main body of this report.

Regional Energy Efficiency Organizations (REEOs)

REEOs are a national network of organizations working through funded partnerships with the US Department of Energy (DOE), and utilities, third-party program administrators, public officials, various advocacy groups, businesses, and foundations. REEOs actively contribute to and reference materials and initiatives of the US DOE and the US EPA's SEE Action Network to help states and local governments take energy efficiency to scale and achieve all cost-effective energy efficiency by 2020. REEOs include:

Northwest Energy Efficiency Alliance (NEEA)

The NEEA is by far the largest of the REEOs. It was formed of an alliance of more than 100 utilities and energy efficiency organizations. It accelerates adoption of energy efficient products, services, and practices; impacts codes and standards and covers Washington, Oregon, Idaho, and Montana.

Northeast Energy Efficiency Partnerships (NEEP)

NEEP receives approximately 1/3 the funding of NEEA and covers the following Northeast and Mid-Atlantic states: Maine, New Hampshire, Vermont, Connecticut, Delaware, Massachusetts, New York, New Jersey, Pennsylvania, West Virginia, Maryland, and D.C.

Midwest Energy Efficiency Alliance (MEEA)

The MEEA oversees a 13-state region including North and South Dakota, Nebraska, Kansas, Missouri, Iowa, Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, and Kentucky.

Southeast Energy Efficiency Alliance (SEEA)

The MEEA oversees a 10-state region: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia.

Southwest Energy Efficiency Alliance (SWEEP)

SWEEP oversees a six-state region: Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming.

South Central Program for Energy as a Resource (SPEER)

SPEER oversees Texas and Oklahoma.

Electric Power Research Institute (EPRI)

EPRI is an independent, non-profit organization that conducts research and development related to the generation, delivery and use of electricity to help address challenges in electricity, including reliability, efficiency, affordability, health, safety, and the environment. Triggered by Great Northeastern Blackout of 1965. Members are mostly electric utilities. Others are businesses, government agencies, regulators and public or private entities engaged of generation, delivery, or the use of electricity. Together they represent ~90% of the electric utility revenue generated in the US. EPRI extends to 35 countries. Principal offices and laboratories are located in Palo Alto, CA; Charlotte, NC; Knoxville, TN and Lenox, MA. EPRI's Commercial Building Efficiency committee meets in January.

Gas Technology Institute (GTI)

The GTI is a non-profit research and development organization that develops, demonstrates, and licenses new energy technologies for private and public clients, with a focus on the natural gas industry. Located in Des Plaines, Illinois. Formed by the Institute of Gas Technology and the Gas Research Industry (GRI) in 2000 when the tax on interstate gas shipments that funded the federally-born GRI was phased out.

Consortium for Energy Efficiency (CEE)

The CEE is a utility-funded, US and Canadian consortium of gas and electric efficiency program administrators who work to accelerate development and availability of energy efficient products and services for lasting public benefit. Generally, CEE is a link between research advocacy and utilities, and is active in various areas including HVAC and generally focused on equipment/appliance efficiency standards with EnergyStar as a starting point. In general, CEE does not focus on systems.

New Buildings Institute (NBI)

The NBI is a Portland, OR based non-profit organization driving better energy performance in commercial buildings. Works collaboratively with industry market players to promote advanced design practices, innovative technologies, public policies, and programs that improve energy efficiency. Also develops and offers guidance and tools to support the design and construction of energy efficient buildings. Works with partners to set higher standards in Energy Codes and support adoption of advanced energy codes locally.

E Source

E Source is a Boulder, CO based company providing focused research and consulting for utilities and customers. Use market research data, expert analysis, and industry experience to help utilities put customers first, meet business objectives and solve corporate challenges. Consult regarding energy efficiency program planning, design, execution, and benchmarking. Marketing potential.

American Council for an Energy Efficient Economy (ACEEE)

ACEEE is a non-profit organization acting as catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviors. Amongst actions, ACEEE holds conferences and workshops for energy efficiency professionals. Relevant conferences would be the "Summer Study on Energy Efficiency in Buildings" and the "National Conference on Energy Efficiency as a Resource". The former occurs during August in even number years and will be held at Pacific Grove, CA in 2020. The latter occurs in October of odd number years and will be held in , MN in October 2019.

Alliance to Save Energy (ASE)

The ASE is non-profit, bipartisan alliance of business, government, environmental and consumer leaders advocating for enhanced energy productivity to achieve economic growth, a cleaner environment and greater energy security, affordability, and reliability. The ASE hosts the annual Energy Efficiency Global Forum (EE Global) that draws 400+ attendees. This Forum is considered by-invitation-only, but its website offers online NGO/Government applications and for-profit tickets (for a fee). The 2019 Forum is in Washington, DC over June 11-12. EE Global draws together its leaders and advocates from across sectors and continents for actionable dialogues on advancing energy efficiency. The Forum has spurred public-private partnerships, generated investment in efficiency and delivered a lasting global impact.

American National Standards Institute (ANSI)

ANSI's Energy Efficiency Standardization Coordination Collaborative (EESCC) published a strategic roadmap in June 2014 detailing the standards and conformity assessment programs needed to enable a more energy- and water-efficient built environment. Developed by over 160 public- and private-sector experts from more than 50-member organizations and 4 federal agencies, this roadmap established national framework to which US industry, government, standards developing organizations, and others can look to enable greater energy and water efficiency capabilities for the nation's buildings.