

Energy Research and Development Division  
**FINAL PROJECT REPORT**

# OpenBuildingControl

**DRAFT – NOT FOR CIRCULATION**

**California Energy Commission**

Gavin Newsom, Governor

April 2020 | CEC EPC-16-056



**PREPARED BY:**

**Primary Authors:**

Michael Wetter ([MWetter@lbl.gov](mailto:MWetter@lbl.gov))<sup>(1)</sup>

Paul Ehrlich<sup>(2)</sup>

Antoine Gautier<sup>(1)</sup>

Milica Grahovac<sup>(1)</sup>

Philip Haves<sup>(1)</sup>

Jianjun Hu<sup>(1)</sup>

Kun Zhang<sup>(1)</sup>

<sup>(1)</sup>Lawrence Berkeley National Laboratory  
One Cyclotron Road  
Berkeley, CA 94720  
Phone: 510-486-4000 | Fax: 510-486-4000  
<https://www.lbl.gov>

<sup>(2)</sup>Building Intelligence Group  
1751 SW Prospect Drive  
Portland, OR 97201  
Phone: 651-204-0105  
<https://www.buildingintelligencegroup.com>

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

**PREPARED FOR:**

California Energy Commission

Karin Perrin

**Project Manager**

Virginia Lew

**Office Manager**

**ENERGY RESEARCH AND DEVELOPMENT DIVISION - Energy Efficiency**

Laurie ten Hope

**Deputy Director**

**ENERGY RESEARCH AND DEVELOPMENT DIVISION**

Drew Bohan

**Executive Director**

### **DISCLAIMER**

**This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.**

## 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.

The authors would like to thank the following people and organizations for their contributions to the project:

Troy R. Maeder - Automated Logic

Caleb Clough, David Pritchard, Amy Shen, Paul Switenki - ARUP

Dave Robin - BSC Softworks

Brent Eubanks - Carbon Lighthouse

Brian Turner - ControlCo

Rick Stehmeyer - Cx Associates

Jay Santos, Jamie Nickels - Facility Dynamics

Mark Hydeman - Google

John Bruschi, Dave Guerrant, Andrea Traber, John Nelson, Fiona Woods - Integral Group

Jonathan Schoenfeld - Kodaro

Jim Kelsey - kW Engineering

David H. Blum, Janie Page, Mary Ann Piette, Anand Prakash, Marco Pritoni, Lisa Rivalin - Lawrence Berkeley National Laboratory

Francisco Ruiz, Rich Rockwood - Oracle

Yan Chen, Karthikeya Devaprasad - Pacific Northwest National Laboratory

Gerry Hamilton, Stanford Facilities Energy Management

Hwakong Cheng, Brandon Gill, Reece Kiriou, Steven T. Taylor - Taylor Engineering

## 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 report is the final 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](#) or contact the Energy Commission at 916-327-1551.

## ABSTRACT

Best practice control sequences are often not implemented correctly, or are not implemented at all, in large commercial buildings. This typically leads to 10-30% energy waste, along with reduced occupant productivity and unnecessary equipment wear. The current process of designing and implementing such control sequences is a manual process that starts with designers who often don't have adequate training, then requires controls programmers to interpret and program a verbose written sequence. This process has been shown to fail to deliver high performance control sequences at scale. The OpenBuildingControl project digitizes the current control delivery process. The project is developing tools for system designers to select control sequences, assess their energy performance and load flexibility potential using whole building simulation, specify the sequence for implementation using machine-to-machine translation by a control provider and formally testing the as-installed sequences by a commissioning agent. The project developed tools for each stage of this delivery process. The key innovation of the project is the development of the Control Description Language, a language that allows such a digitized control delivery process with end-to-end verification. Libraries of control sequences have been implemented using the Control Description Language, and their performance has been demonstrated using whole building energy simulation. An automated translation of such sequences to a commercial control product line has been conducted using a prototype translator. Tools for formal verification of as-installed control sequences relative to their specification have been developed and demonstrated. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) started the process of forming a committee to make this language an ASHRAE/ANSI Standard. This new standard will complement existing and emerging ASHRAE standards for building communication and semantic modeling by providing a standard for expressing the control logic - the actual brain of the building. We expect this language and the process it enables to be an important contribution to the deployment of high performance building control sequences at scale because it allows taming the complexity of the control delivery process, which is continually increasing due to the need for higher performance and increased load flexibility to meet goals for net zero energy and increased renewable integration.

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

Please use the following citation for this report:

Wetter, Michael. 2020. *OpenBuildingControl Final Project Report*. California Energy Commission. Publication Number: CEC EPC-XXX.