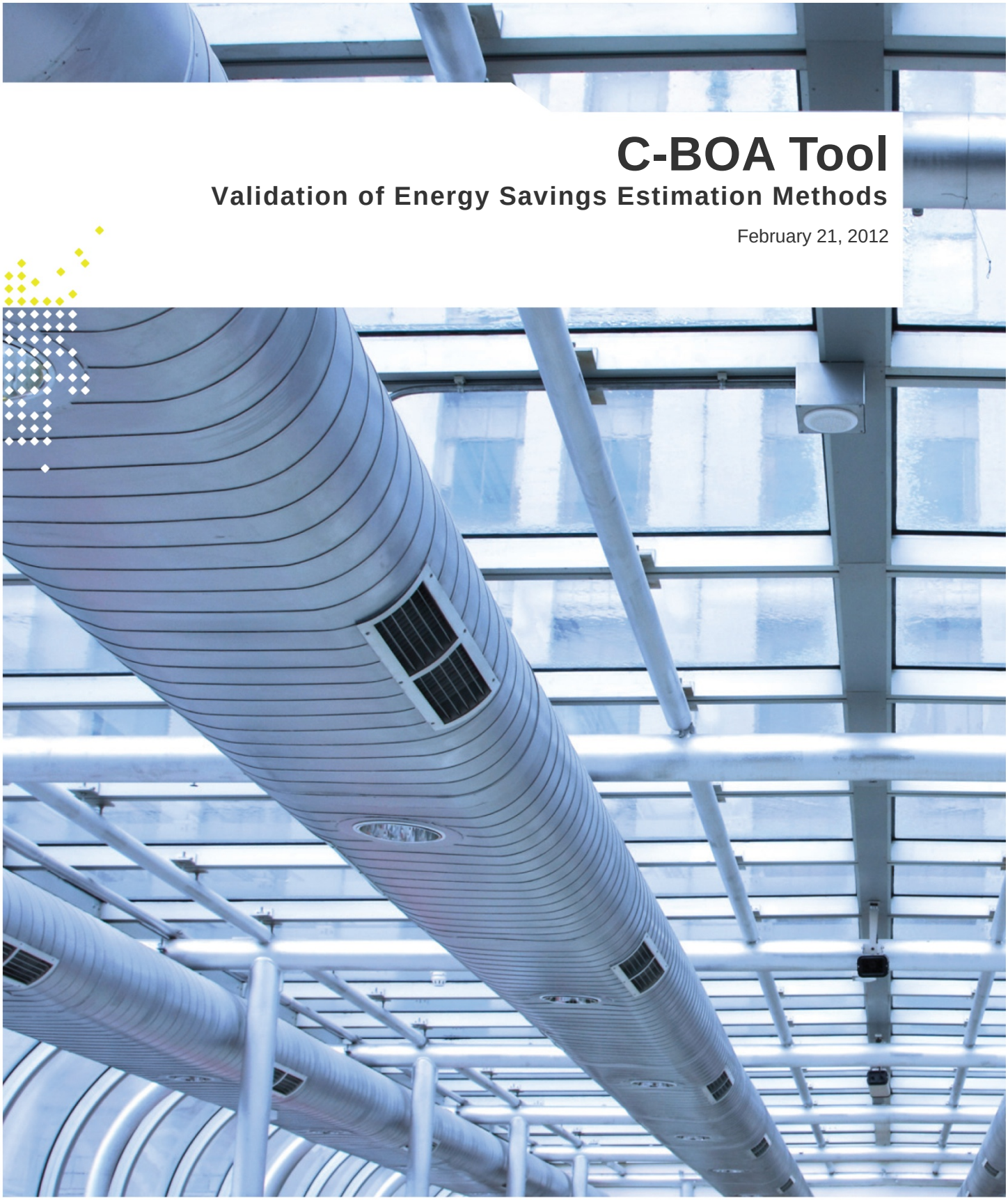
C-BOA Tool

Validation of Energy Savings Estimation Methods

February 21, 2012



PECI

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Summary

This report summarizes how the annual energy savings calculated by the new C-BOA Tool (Custom Building Optimization Analysis Tool) were validated through a rigorous development and testing process. It also includes the outcomes from the comparison of C-BOA results to the energy savings estimated by other approaches. The conclusions will help California utilities gain confidence in using the C-BOA Tool for estimating energy savings as part of utility retrocommissioning programs in California.

Recommendation

Based on the results of this analysis, which are detailed in the body of this report, we are comfortable with the savings produced by the C-BOA Tool and recommend its use in California's utility retrocommissioning programs. We suggest using the C-BOA Tool in concert with the BOA Tool – the BOA Tool would be used for lower savings measures (<75,000 kWh and <5,000 therms), and the C-BOA Tool would be used for higher savings measures.

Evaluation Approach

The energy savings estimated by the C-BOA Tool have been validated through a rigorous process. This process included engaging a technical advisory group from industry, developing detailed technical specifications for the tool, ongoing engineering review and testing during development, documentation of as-built calculation approaches, and final tool testing and result comparisons to other calculation methods. Each of these steps is discussed below.

Technical Advisory Group Oversight

At the beginning of the project, a Technical Advisory Group (TAG) was assembled. This group of utility program managers and commissioning providers provided guidance and review of our overall project, including the technical approaches utilized, throughout the development process. The TAG advised the development team on technical issues such as the method used to calculate peak demand savings, as well as technical issues related to the calculation methodology used for each ECM.

Project Specifications

Early in the project, AEC and PECI worked together to develop detailed specifications for the overall tool and for the calculation methodology related to each ECM. These specifications were also reviewed by the TAG. General requirements included details on the objectives, tool capabilities, the approach used to account for measure interactions, how energy and peak demand savings are calculated, as well as required reports and outputs.

The technical specifications also included a section for each energy conservation measure (ECM). The objectives, the required inputs, the calculation methodologies, and any assumptions and limitations related to the ECM are included in the project specifications.

Engineering Review during Development

AEC conducted the tool development and PECI managed the project and provided technical oversight with assistance from Eaton. During this development process, the calculation approach used for each measure was reviewed multiple times by engineers at AEC, PECI, and Eaton.

AEC engineers created a spreadsheet demonstrating the methodology that was to be used for a specific ECM. This method, which may have been revised since the tool specification, was reviewed by PECI and then coded into the tool to apply these calculations to each of the weather bins. Since the calculations within the tool are written in Visual Basic, it is not easy to review the

calculation method by reviewing this code directly. Instead, the engineers at PECI and Eaton conducted multiple tests on each calculation to ensure 1) the spreadsheet methodology was correct, and 2) the results produced by the tool matched the spreadsheet results.

The testing and evaluation process identified multiple issues. Each issue was documented and tracked until resolved. For issues that had an impact on the energy or demand savings estimates, the resolution included revision to the tool followed by another review to confirm that the changes were successfully implemented.

Documentation of As-Built Energy Calculations

The calculation approaches are detailed in the "Help" file associated with the C-BOA Tool. The Help file is an executable file that can be opened directly or opened from within the C-BOA Tool.

Final Tool Testing and Comparisons

For the final testing phase, the C-BOA Tool was used to calculate energy savings for some example projects and then those savings were compared to the savings estimated by other common calculation methods. There are inherent limitations in this approach since this evaluates one estimate to another estimate, neither of which may be considered 100% accurate. Measured savings data was not available to conduct this comparison.

To provide additional comparison data, we utilized the results from the California utility retrocommissioning programs from 2006 to 2009 to establish an expected range of values for each of the ECMs. The program data for affected measures, which included almost 500 ECMs, provides energy savings per square foot, and covered eight of the nine measures in the C-BOA tool. These values were utilized to ensure the results from the modeling tools – both C-BOA and the common calculation methods – were reasonable. In some cases the utility program data may result in lower than expected per square foot savings because the ECM may have only affected a portion of the facility, while the per square foot data assumes that the ECM affected the entire square footage of a building. Determining the precise scope, including square footage, of each of the utility program ECMs is outside the scope of this effort. The program data is shown in Table 1.

Table 1: California Retro-commissioning Projects 2006 - 2009

Measure	# Projects	Min of kWh Savings per Square Foot	Average of kWh Savings per Square Foot	Max of kWh Savings per Square Foot	Min of Therm savings per Square foot	Average of Therm savings per Square foot	Max of Therm savings per Square foot
ECM-1: Optimized Economizer Performance	56	0	0.262	1.238	(0.016)	0.006	0.181
ECM-2: Optimize AHU scheduling	137	0	0.202	6.209	0	0.008	0.198
ECM-3: Reset Supply Air Temperature	9	0	0.278	1.718	0	0.012	0.063
ECM-4: Reset Discharge Static Pressure Setpoint	79	0	0.209	1.254	0	0.004	0.067
ECM-5: Add VFD on Supply Fan	59	(0.004)	0.168	1.370	(0.002)	0.001	0.013
ECM-6: Add VFD on Chilled Water Pump	96	(0.020)	0.253	2.366	0	0	0

Measure	# Projects	Min of kWh Savings per Square Foot	Average of kWh Savings per Square Foot	Max of kWh Savings per Square Foot	Min of Therm savings per Square foot	Average of Therm savings per Square foot	Max of Therm savings per Square foot
ECM-7: Reset Chilled Water supply Temperature	32	0	0.173	1.001	0	0	0
ECM-8: Reset Condenser Water Temperature	27	0	0.290	2.119	0	0	0
ECM-9: Add VFD to Cooling Tower Fans	0	NA	NA	NA	NA	NA	NA

1.1.1 Air-Handling Example

The first project example is based on a project executed by Eaton in northern California, and included four of the five measures that affect the air-side calculations. The data from the project was used to estimate savings in the C-BOA Tool and also in a bin-based spreadsheet model utilized by Eaton. For the fifth measure, 'Add VFD on Supply Fan', a test scenario was evaluated. These results were compared to one-another, and also to the results from the California RCx programs and are summarized in Figure 1 and in Figure 2: Estimated Therm Savings.

The key observations from these results are:

- The energy savings estimates from Eaton's bin model and the C-BOA Tool are reasonable and within range of the expected values from the California Program data for all but one ECM (SAT Reset).
- Overall energy savings for the project estimated by the C-BOA tool were lower than the Eaton model or the California program data for both gas and electric, indicating estimates are conservative.
- Some variations in the energy savings between the two models exist, but are understandable and reasonable:
    - ECM-2: The scheduling measure savings are within range, but the stacking order of the ECMs is different between the tools. Eaton's tool evaluated scheduling last, which accounts for the higher savings for this ECM from C-BOA Tool. Gas savings are lower and more conservative in the C-BOA Tool.
    - ECM-3: The SAT reset measure in the C-BOA Tool appropriately applies a fan penalty, while the Eaton method does not. Although there is an increase in electricity usage, there are positive cost savings due to reduced reheat energy.
    - ECM-4: Reducing static pressure setpoint does not typically result in gas savings. The CA RCx programs show gas savings, maybe because the airflow rate was also affected by the ECM for certain instances.
    - ECM-5: The Eaton tool utilized a different methodology (ASHRAE 90.1 Inlet Guide Vanes) as the baseline whereas C-BOA uses Englander and Norford[1] analysis. Also, the Eaton approach did not include a VFD efficiency penalty in the calculations, resulting in higher savings.

[1] Englander, S.L. and Norford, L.K. (1992) Measured Energy Consumption of Variable-Air-Volume Fans under Inlet Vane and Variable Speed Drive Control, ASHRAE Transactions, 98 Part 2.

1.1.2 Central Plant Example

The second project example is based on a project executed by Eaton in southern California and includes all four of ECMs included in the C-BOA Tool related to central cooling plant systems. This project data was used to estimate savings in the C-BOA Tool and in an eQuest model. These results were compared to one-another, and also to the results from the California RCx programs, and are summarized in Figure 1 and in Figure 2: Estimated Therm Savings.

The key observations from these results are:

- The energy savings estimates from Eaton's bin model and the C-BOA Tool are reasonable and within range of the expected values for all ECMs.
- Overall energy savings for the project estimated by the C-BOA tool were slightly lower, indicating conservative estimates.
- Some variations in the energy savings between the two models exist, but are understandable due to differences in the analysis techniques:
    - The eQuest model utilizes 8,760 hourly data, whereas the C-BOA Tool analysis is based on bin data.
    - The eQuest model does not utilize a VFD efficiency penalty, which is included in C-BOA.
    - The two chiller plant models, which included multiple chillers, pumps and cooling towers, have differences in the way the equipment is sequenced at part load conditions.
    - EQuest includes a chilled water pumping penalty when resetting temperatures, where the C-BOA Tool does not. The C-BOA Tool assumes that the chilled water temperature difference is the same in the baseline and proposed cases.

Figure 1: Estimated kWh Savings

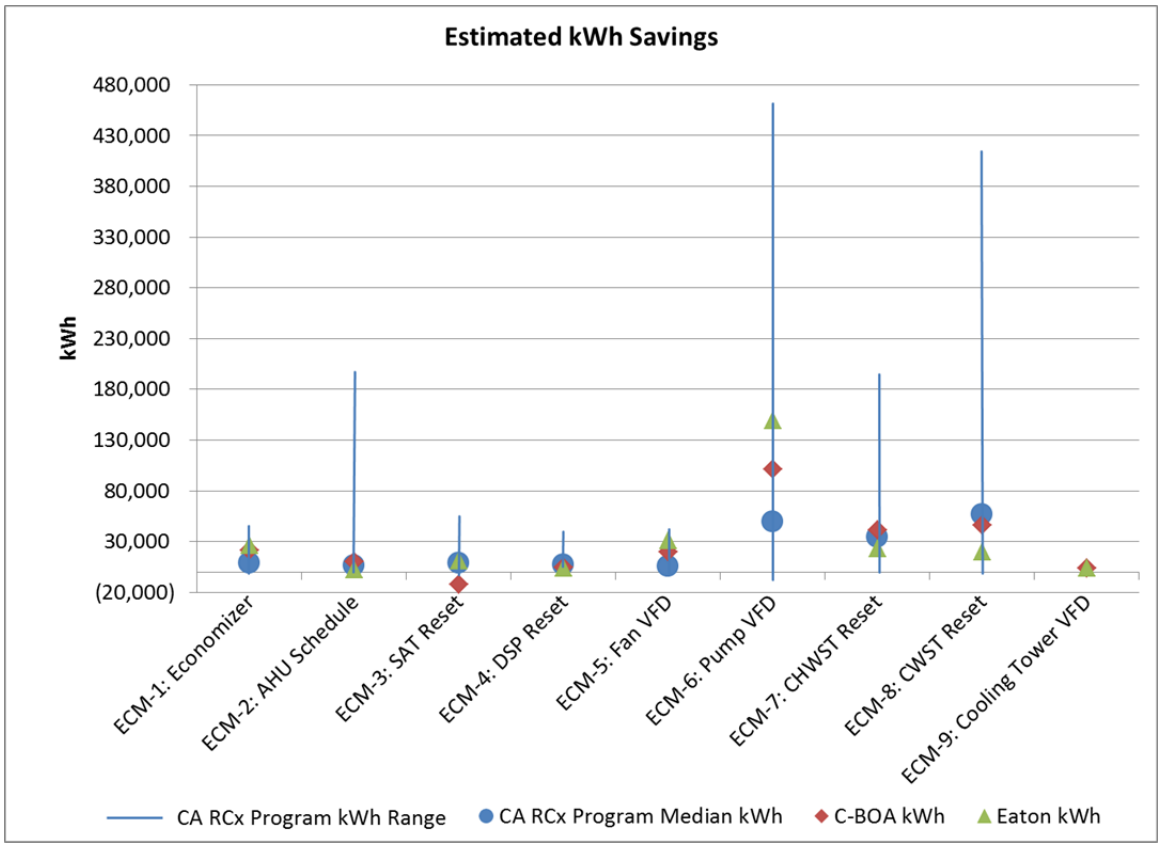

Figure 2: Estimated Therm Savings