The Building as a Classroom: Training Commissioning Providers through Interactive Activities and Energy-saving Projects.

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ABSTRACT

A challenge with publicly-funded, energy-efficiency trainings is the difficulty of attributing energy savings to educational efforts. This paper focuses on a training series where energy savings data are captured. The PG&E Pacific Energy Center's Existing Building Commissioning (EBCx) workshop series is now in its seventh year, and we have been collecting energy savings data on student projects since 2008.

The paper is divided into three parts: overview of the training series, example training modules, and student projects with energy-savings data. All participants in this year-long workshop series are required to bring into the trainings a commercial building that they can access in order to apply the commissioning skills covered in the monthly class meetings. Class topics include defining a scope of work, building benchmarking, system diagrams, the use of data loggers and trend data, functional tests, measurement tool applications, data analysis techniques, calculating energy and cost savings, and the development of system manuals. The paper also explores the class website, supplemental resources, field labs and homework assignments.

The paper finishes with findings and savings data from student projects. These case studies represent a variety of building types and commissioning measures, and address the specific ways the trainings influenced projects and contributed to improved building operation. The methods used by program attendees to quantify the energy benefit of their commissioning efforts are included.

Development of Existing Building Commissioning (EBCx) Workshop Series

The PG&E Pacific Energy Center (PEC) is a publically-funded, utility-managed training and customer support facility located in San Francisco. The PEC has a commercial building focus and supports hundreds of trainings on energy efficiency, demand response and renewable energy each year. We offered one of the earliest trainings on building commissioning (Cx) in 1993[1], and commissioning-related classes continue to be a robust portion of our educational offerings. Topics addressed in our commissioning trainings have included Airside Economizers; Chilled Water & Condenser Water Systems; the Commissioning Process; Control Logic Diagrams; Design Review; Facility Operations; Fans, Ductwork & Air Handling Components; HVAC Controls (digital and pneumatic); Heating Hot Water & Steam Systems; Lighting Controls; Pumps; System Diagrams; Variable Speed Drives and VAV Systems.

A number of factors contributed to the early development of what is now known as the "Existing Building Commissioning" or "EBCx" Workshop series. These early discussions date back to the second half of 2004. We recognized that existing commissioning certification programs, while credible, did not adequately focus on the field experience that is so critical to a

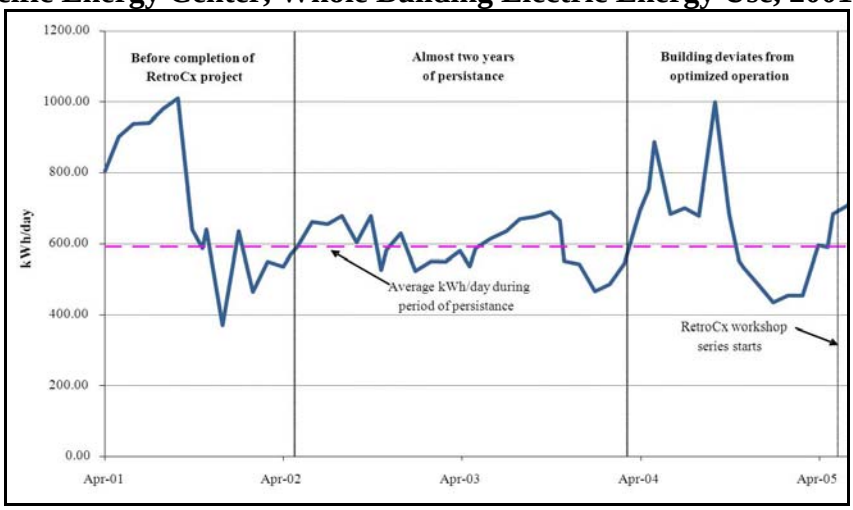
[1] See Portland Energy Conservation Inc. website with the history of building commissioning: http://www.peci.org/ncbc/cx_history.html.

commissioning provider's education. This was reinforced by the fact that many of our class attendees expressed a desire for more hands-on, field-based commissioning trainings. Commissioning certification programs were mostly geared toward understanding the Cx process, from defining project scope to required documentation. Little if any time was spent assessing trend data, conducting functional tests or trouble-shooting problems. The need for Cx providers to have substantial field experience is noted in a California Commissioning Collaborative (CACx) document describing minimum requirements for commissioning provider certification. Independent of degrees or time in the classroom, the CACx recommends that all certification programs require candidates to have worked on "two major or four smaller new construction or rehab projects or equivalent existing building projects."[2]

A reference and inspiration for the EBCx Workshop Series was the Vital Signs Curriculum Materials Project. Coordinated through the Center for Environmental Design Research at the University of California-Berkeley, Vital Signs was designed to encourage architecture students to apply investigation techniques in the study of existing building performance. The Vital Signs approach utilized simple measurement tools and dataloggers with resource packages that include detailed background information and protocols for different types of investigations. The Vital Signs Project was housed within the Pacific Energy Center from 1995 to 1999.

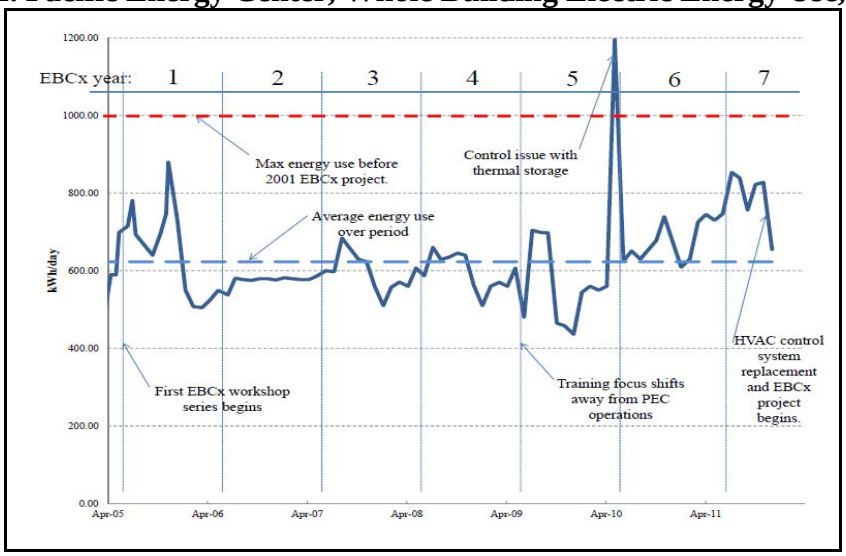
The ten-year old Pacific Energy Center was re-commissioned in 2001, and the project produced a 26% reduction in annual energy use in 2002 and 2003. By late 2004, we began to see significant increases in whole-building energy use (see Figure 1). We saw this persistence problem as an opportunity; we could track the operations more closely and limit the number of building performance issues that arose by using our instructors and a small group of students to monitor the facility as part of an ongoing training series. The success of these efforts can be seen in the second graph (see Figure 2) of whole-building energy use data.

Figure 1. Pacific Energy Center, Whole Building Electric Energy Use, 2001-2005



[2] The California Commissioning Collaborative provides a list of required knowledge for qualified commissioning providers: "Commissioning providers require a unique combination of engineering, design fundamentals and building operations knowledge including: energy systems design, installation and operation, commissioning planning and process management, hands-on field experience with energy systems performance, interaction, start-up, balancing, testing, troubleshooting, operation, and maintenance procedures and energy systems automation control knowledge." http://www.cacx.org/resources/documents/Commissioning_Certification_Specification.pdf

Figure 2. Pacific Energy Center, Whole Building Electric Energy Use, 2005-2012



Because of our other commissioning-related classes, we felt we could manage an intensive, year-long workshop series. We had a large repository of lecture materials, case study examples and in-class exercises that we could utilize. We could also take advantage of the well-organized building documentation and systems manual from the 2001 commissioning of the Center. The workshops would also be able to access equipment from the PEC's Tool Lending Library[3], and we had an instructional team familiar with the building's systems and controls.

Description of Existing Building Commissioning (EBCx) Workshop Series

In May 2005 the Pacific Energy Center kicked off the first EBCx Workshop Series. The series involves monthly workshops scheduled over the course of the year that expose participants to the planning, decision-making and diagnostic aspects of commissioning by actively working on a real facility (for the first few years the lab facility was the PEC). The format of the workshop series allows students to experience all Cx activities and immediately apply what they've learned through structured, hands-on activities under the supervision of qualified commissioning experts. A unique aspect of these workshops is that most of the planning and all of the findings occur in the context of the class with the students directly involved in making critical decisions and analyzing collected data. There are no pre-baked solutions here, nor are all the problems known in advance. Each workshop is structured around morning lectures on Cx-related topics and afternoon labs. The lectures are designed to provide the necessary background information on building systems or commissioning processes so participants are prepared for the labs. Topics covered in the lectures include functional testing, trend data analysis, hydronic systems, air systems, miscellaneous systems, controls, systems manuals and other documentation, and persistence.

The intent from the beginning was to allocate as much time as possible for the field work. For the labs the class typically divides into three small groups for each task, each group with an instructor and a student leader selected on a rotating basis. The leader is responsible for organizing group efforts and reporting out their findings and suggestions at the completion of each workshop. The groups rotate through the various tasks exposing everyone to different

[3] The Tool Lending Library is a PEC program that loans monitoring equipment to California ratepayers for free.

systems, measurement equipment and real data sets. Lab activities include tutorials on surveying a project and collecting user input, developing a retro-commissioning plan, benchmarking utility billing data, Cx resources and software, prioritizing activities, compiling a findings list, defining the work scope for a service contractor, setting up and analyzing trend data, and testing equipment. One specific lab involves a pump test to assess pump and system performance where participants contrast various system conditions and pressure measurement techniques.

The Introduction of Independent Student Projects

By the end of the second workshop series, we decided to expand our building assessment effort beyond the Pacific Energy Center. While still using the PEC as the test lab for the monthly sessions, we required that all class participants have access to a commercial building where they could apply their newly-learned commissioning skills. For the 3rd and 4th EBCx sessions we had students work on independent projects but the final group project continued to focus on the PEC. Since the 5th session the final projects have focused on the independent building projects. To track the overall energy impact of the class, each facility is benchmarked using Energy Star Portfolio Manager and EnergyIQ. Students report the energy savings and other study impacts as part of a final presentation given at the last workshop of the year-long series. The results of some student projects are included in the case study section of this paper.

In addition to expanding the impact of the workshops, the reported energy savings from student projects allow us to see the tangible energy benefits of these trainings. Attributing savings to energy education is a tremendous challenge since the energy impact can happen months or years after the training has concluded.[4] With the EBCx series we have the benefit of sharing immediately applicable strategies like controls tuning and O&M strategies. Instructors also work with the class participants for an extended period of time, and most students after twelve months in the training have some tangible building performance, documentation or energy-saving benefit to report. Currently the EBCx series represents a pilot project with the energy savings data from 2010-2012 to be reported to the California Public Utilities Commission. The CPUC oversees PG&E's portfolio of publically-funded energy programs including PEC classes.

Raising the Bar and Attendee Selection Criteria

Interest in this unique training experience has increased over its history. We now typically have over sixty (60) people vying for twenty-one (21) spots in each workshop series. To maximize the educational and energy savings impacts of the series we have established clear workshop requirements around attendance and completion of assignments that we communicate to all candidates. To assure individuals are qualified and can meet our expectations, we have

[4] ACEEE Report Number U113 (S. Nowak, M. Kushler, M. Sciortino, D. York, and P. Witte. 2011.) addresses the challenge of associating energy impacts to training and education efforts. The report states that "energy saving impacts from education and training are hard to measure, and many states do not give credit toward EERS (Energy Efficiency Resources Standards) compliance for the energy savings that result from them" (education and training efforts). Another ACEEE paper (Anderson and Jessen, 2005) acknowledges the "difficulty in measuring effects of training" for Energy Efficiency.

established several selection criteria for participants. Occasionally we have been forced to remove students from the series because of their inability to meet these requirements.

From the outset the workshop series has required that all candidates take a pre-requisite class that provides an overview of existing building commissioning. This training emphasizes "obvious indicators" that Cx providers would look for in a building when conducting an initial site survey. This course also covers a number of fundamental concepts that all participants should understand before attending the first workshop in the series. Despite the presence of this class the instructional team recognized during the first few EBCx workshop series that a significant amount of class time was dedicated to HVAC fundamentals and the basic capability of Excel for data analysis efforts. Because of the time required for these topics, less time could be allocated to supporting the independent projects and the field labs. To address this issue, we made an effort to assure a minimum knowledge level for all participants. We now provide an HVAC fundamentals quiz and an Excel quiz at the first meeting and a mystery graph quiz at the second session. We also offer independent classes on these topics to help prepare students for the EBCx experience. Occasional quizzes occur at the beginning of the year-long experience on material covered in previous sessions. Students that perform poorly on the quizzes and are not able to keep up with the rest of the class are typically asked to drop out of the program. Most intend to work on their skills and participate the following year.

In addition to the quiz scores, other selection criteria have been added to assure that we provide the best learning experience for all participants. Because the training series is now built around the students' independent projects, only candidates with access to a facility are permitted to attend. Since missing several sessions negatively impacts an attendee's ability to follow the lectures, contribute to the field labs and keep up with independent project work, we have all candidates sign an agreement that they will attend every session (we also understand that the occasional absence is inevitable). We create monthly assignments for the class based on the material covered at each workshop. These homework assignments typically relate to the independent projects and include defining an EBCx scope of work, developing benchmarking scores in Portfolio Manager or Energy IQ, writing a functional test, executing a functional test, collecting and graphing energy management trend or data logger data, calculating the potential energy savings of implementing an energy efficiency measure or measures, and creating presentation updates. Students who miss several classes or do not keep up with the monthly assignments are dropped from the workshop series.

The remaining selection criteria address our California funding, a recognition of the value of diversity and the need to create the best group dynamic. Because our funding comes from California ratepayers through the California Public Utilities Commission (CPUC) we give first priority to customers that contribute to this funding through their utility bills. In cases when more than one person from a single company wishes to participate, we have requested that only one candidate from said company continue with the workshops. We also recognize the value of having women and minorities included in the training series. In fact, the percentage of non-white males participating in the EBCx series is over 48%, a far higher representation than in the building professions. Finally we emphasize the importance of collaboration, openness and respect. Because many of the labs are group projects, the candidates must be able to work well together. It is important that all participants be willing to share their project details while respecting the needs of classmates whose findings must be kept confidential to the classroom. With all these selection criteria clearly defined at the outset of each workshop series, most

participants drop the class on their own initiative if they cannot keep up with the work. We have always managed to get to a workable class size (less than 30 people) by the sixth session.

Class Infrastructure and Instructor Support

To get the most out of this training experience, participants must immerse themselves in the topic, especially if they have limited previous exposure to HVAC systems and controls. To facilitate this exposure, we distribute an abundance of materials to the class participants each month. Some materials are directly tied to lectures and labs and others are provided for additional reading. Rather than print materials, handouts and supplemental resources are posted as electronic files on the class website. The website also includes the workshop schedule, the PEC's system manual and other relevant documents, descriptions of the homework assignments, and the class roster. The resources section provides hotlinks to other relevant web pages. Also of note, the lead instructor for the workshop series has a blog site with an abundance of material that the students access over the course of the workshop series.[5]

Because the twelve class sessions are packed with lectures, labs and student presentations, there is little time to handle project-specific questions from attendees. We always allocate time after the workshops for questions, but this time is not sufficient. For several years now we have made the afternoon prior to the workshops available as office hours for students with questions. We are able to meet with students in-person at the PEC or through web-based tools like GoToMeeting. Most of these support sessions are scheduled for hour-long slots and are focused on the participants' independent projects. The instructional team is also available for in-person or remote support at other times between the monthly meetings, but the day-before format works well since the scheduling is predictable and most questions surface as the next class date approaches.

Workshop Series Outline

The sequence of lecture topics, labs and assignments is modified each time the workshop series is offered. This is partly due to our efforts to continuously improve the learning experience and is partly due to our need to keep the format flexible so we can gear sessions toward a pressing topic, necessary skill set or availability of guest instructors. Now in our seventh year, we have settled on a preferable sequence for most of the course content. The initial session of each series includes an overview of the workshops, the HVAC and Excel quizzes, a lecture on defining the scope of work for commissioning projects, a building benchmarking demonstration and a facility treasure hunt. Subsequent classes include lectures on Cx and HVAC fundamentals and labs on system diagrams, trend data analysis and writing functional tests. Early homework assignments ask attendees to apply the lab material to their independent projects. During the fifth, sixth and seventh sessions the participants are divided into subgroups and work together to execute functional tests at the PEC. The students are rotated though a VAV box test, a pumping system test and an air-handler test.

At the midway point in the workshop series the focus shifts to the student projects. By the sixth month each student has produced a Cx scope of work, building benchmarking scores, a system diagram, a functional test write-up, and at least two graphs of building performance data. This collection of work is assembled into mini presentations on their projects. Based on the

[5] The blog site is called a "Field Perspective on Engineering" and is located here: http://av8rdas.wordpress.com/

feedback provided by the instructors and fellow students, the class participants follow the prescribed next steps, pursue building performance improvements and update their project presentations. The students then present their preliminary findings to the class twice during the seventh through eleventh sessions. During this time period the participants execute a functional test and continue to collect and analyze trend and datalogger data at their facilities. The second half of the class includes modules on Cx documentation including system manuals, energy saving calculations, and persistence of performance improvements. The remaining class time is dedicated to topics that students wish to explore; most of these are driven by specific challenges they have encountered working on their independent project buildings. The last workshop is dedicated to the final project presentations.

An outline of the training schedule for the 2011-2012 EBCx series is included in Table 1. It includes columns for the lectures, labs, homework assignments and relevant resources. Most sessions include multiple lecture topics with at least one morning and one lunch presentation. The labs typically require the attendees to rotate through three distinct activities with an instructor facilitating each lab.

Table 1. Typical EBCx Workshop Schedule

Month	Lecture Topics	Lab Topics	Homework	Resources
1	Overview of workshop series. Defining EBCx work scope, Cx Assistant. Building Benchmarking. Presentations by past EBCx students. Student/project introductions.	HVAC fundamentals quiz. Excel quiz. Building benchmarking exercise. EBCx Treasure Hunt	Prepare EBCx work scope. Describe building systems and note observed opportunities. Gather utility bills and benchmark building.	Cx Assistant; CACx.org; Energy Design Resources.
2	Present HW#1: benchmarking scores. Treasure hunt results. More student/project introductions. Review HVAC quiz. Observations from the Cx process. System diagrams.	Mystery graph quiz. Develop system diagram lab of chilled water loop. Review excel quiz. Control loop demonstration.	Develop system diagram for system of investigation. Develop points list and monitoring plan for same system at project facility.	Reading list on mechanical systems fundamentals. Control Spec Builder. Functional Test Library: tool and guide.
3	Present HW#2: system diagrams. Mechanical systems fundamentals. Common and uncommon uses of interval data.	ECAM and Universal Translator demonstrations. System diagram workshop.	Compile and analyze collected trend or datalogger data for system at project facility.	ECAM and Universal Translator software.
4	Present HW#3: data analysis. Pump opportunities. Guest lecturer: PG&E RCx programs. Using functional tests to target a problem.	Quiz on mechanical system fundamentals. Functional test logistics. Exploring Functional Test Library. Advanced excel applications.	Write functional test for building system.	Functional Test Library: test guide, sample tests and test templates. Reading list on water systems.
5	Present HW#4: functional test write-ups. Water-side opportunities. Guest lecturer: Cx docs.	Break into teams and execute functional tests: Pumping system, AHU and VAV boxes.	Conduct 2nd analysis effort and develop data graphs of findings.	Ed Tufte readings on graphic excellence.

6	Present HW#5: data graphs. Chilled water systems. PowerPoint Fun.	Break into teams and execute functional tests: Pumping system, AHU and VAV boxes.	Produce 3-5 minute presentation as an update of project facility effort.	Reference PowerPoint files.
7	Present HW#6: project updates. Guest lecturer: controls contractor. Sketch-up system diagram demo.	Break into teams and execute functional tests: Pumping system, AHU and VAV boxes.	Run functional test at independent facility. Update project presentations.	Reading list on air systems.
8	Continue presentations of HW#6: project updates. Present HW#7: functional test reports.	Loop tuning demo. Functional testing of lighting controls. Control logic diagram (Eikon) demo.	Use Eikon software with provided logic diagram. Project update. Ongoing data analysis.	Eikon software.
9	Continue presentations of HW#6: project updates. Air-side opportunities.	Review Control logic diagram (Eikon) project. Systems manual workshop. Flexible activity.	Gather, graph and analyze trend data. Update project presentations.	Identify resources targeted at student projects and questions.
10	Present HW#7: project updates round 2. Building and system load calculations.	Cooling and steam load calculations. Power and energy equipment. Building data disaggregation. Flexible activity.	Perform a load calculation of your facility or room in facility. Outline and begin to organize systems manual	Identify resources targeted at student projects and questions.
11	Continue to present HW#7: project updates round 2. Miscellaneous systems.	Pneumatic control demonstrators. Energy calculations. Flexible activity.	Calculate possible energy and cost savings. Prepare final presentations.	Identify resources targeted at student projects and questions.
12	Final project presentations (HW#8). Persistence.	Discussion of class experience.	NA	Class website. David's blog. Workshops for EBCx graduates.

Independent Student Projects

After the first two EBCx workshops, all participating students are required to bring to the class information and data from a commercial building facility where they begin to apply the lessons learned from the trainings. Table 2 provides a snapshot of these student efforts. It includes the building type, the focus of the student investigation, the annual energy savings data and notes about how the energy savings data was generated.

Table 2. Example Student Projects from 2010-2011 EBCx Workshop

Building	EBCx project scope	Energy saved	Notes on savings calculations
Wine distribution center	Combination of equipment scheduling and load shifting.	35,200 kWh in 7 months.	Actual savings verified through utility billing data.
Church	HVAC tune-up and lighting retrofit.	18% reduction in energy use	Actual savings verified through utility billing data.
Service center	Upgrade controls, chiller sequence.	8.6% reduction in energy (gas & electric)	Actual savings verified through utility billing data.

Research facility	Correct fan schedule, economizer, night setbacks, boiler operation, cooling staging, air balancing and simultaneous heating and cooling.	115,000 kwh/year for fan scheduling and setbacks	Combination of field measurements and computer simulation.
Office building	Over-cycling supply fan and broken economizers.	95,310 kwh/year	Calculated savings using bin-simulation with climate data.
Branch library	Address throttled pumping, control optimization and calibration.	36,331 kWh & 268 therms/yr	Calculated measures.
High school	Condensing boiler, VFDs, tuning.	$52,000/year	Calculated measures.
Office building	Modified fountain pumping, VFD retrofit for fans, utilize water-side economizer.	416,434 kWh/year	Calculated measures.
Community center with offices	Calibrate sensors, change setpoints & fix scheduling issues.	11,973 kWh & 4,522 therms/yr	Calculated measures.
Restaurant	Adjust pump schedule, balancing HVAC system, adjust set-points, & upgrade lighting systems.	8,137 kWh/year	Calculated measures.
Office building	VFD and optimization of condenser water system	36,787 kWh/year	Calculated measures.
Lab/office building	Fix broken chilled water valve, adjust schedule, add control resets, address HHW sequence, fix fume hood dampers, retrofit boiler.	950,000 kWh/year	Calculated measures using bin analysis and measured data.
Office building	VFD retrofits and control tuning.	113,235 kWh/year	Measured savings at individual loads & billing data.

Comments on Energy Savings Data

While a unique feature of this training series is that energy savings data are captured, it is important to include some notes about these results. In many cases the savings data provided are realized savings from the implementation of energy efficiency measures that took place during the course of the workshop series. However, on some cases the savings data are based on proposed projects that the students promoted to building ownership that may not have been realized. It is also worth noting that the energy savings data comes directly from the students. While the instructional team did review the integrity of their calculations, these values are not verified by an independent third party. With a future workshop it is our hope that some of our students' projects will be independently verified. Projects listed in Table 2 that provided proposed (calculated) energy savings vs. realized (measured) savings are identified in the notes field.

The emphasis of the educational content in the series is on existing building commissioning opportunities. Using the lectures and labs, we try to expose the students to commonly-occurring EBCx measures like broken economizers, building control issues and oversized pumping systems. The students often find other opportunities that may not fit perfectly within an EBCx project scope. In some cases, the students pursue equipment retrofit projects that fall outside of building tune-ups commonly associated with EBCx projects. I have tried to

acknowledge these occasions with the sample of projects provided above using the column in Table 2 labeled “EBCx project scope”.

The energy impact of the training series goes beyond the students’ participation in the workshops as they can apply the EBCx concepts they’ve learned to future projects. While we are trying to collect ongoing information from our EBCx graduates, it is difficult to get energy savings data from past EBCx participants after they have finished the series. One vehicle for ongoing updates is an occasional workshop we offer just for EBCx graduates. At these sessions, past EBCx participants are encouraged to bring questions, example data sets and system diagrams from their current projects. Input and guidance are provided by the EBCx instructional team and the other EBCx grads. It is worth noting that future savings data from EBCx graduates may be attributable from a regulatory standpoint to retrofit or RCx incentive programs and can therefore not be solely attributable to the workshop series.

Conclusions

The primary lesson here is that energy savings data can be attributed to training and education programs, but that this is not an easily replicated model. Key components of this effort are instructors that are generous with their knowledge, small class sizes, multiple instructors to facilitate simultaneous lab activities, time dedicated to managing class materials and student projects, and a teaching facility where students can actively engage the building systems and controls. Other utilities considering similar endeavors should recognize the staff time and budget requirements these workshops require; the utility coordinator (and co-instructor) spends approximately 20 hours per month in support of these trainings and the PEC spends $10,000 per session on outside instructors and other costs.

We’ve learned much over the last seven years about how to best sequence the trainings and transform the participating students into capable Cx service providers (the evolution of the class is documented in this paper). Certainly anyone considering a similar training series will benefit from our experiences and can model their program on our workshops. Most of the resources, materials, quizzes, and lab activities exist in the public domain and can be utilized by others. The most difficult element to replicate is our lead instructor, whose capabilities as a teacher and familiarity with building systems and commissioning are unmatched.

We continue to find ways to improve the training series. To maximize the reported energy savings from student projects, we need to dedicate more time supporting these efforts in and out of the classroom. This will force us to spend less time on fundamental concepts which in turn will require that we provide more mechanisms for students to prepare for the EBCx series before the first session. Our HVAC Fundamentals and Basic Excel trainings will need to be scheduled before the first EBCx session, and future participants will be encouraged to take newly-developed on-demand trainings on mechanical system and Cx topics. We will also need to diligently enforce the minimum required knowledge of HVAC systems and Excel for all interested candidates.

Another issue worth addressing is the rigor surrounding the identification of EBCx opportunities in the project facilities and the energy savings calculations for the student projects. The focus of these projects and legitimacy of the results will improve with the availability of guidelines and calculators for specific project types. We are in the process of developing monitoring protocols that provide step-by-step instructions for identifying, analyzing and quantifying specific building tune-up measures. Each protocol will provide monitoring requirements and include a defined calculation procedure for determining energy savings. When appropriate the calculation routine will be integrated into our Universal Translator (UT) software tool.[6]

Other changes to the program we are considering address the challenge of covering an immense amount of material while still managing to coach the participants toward quantifiable energy savings. We are entertaining the idea of expanding the series to 13 sessions with the additional meeting taking place at one of the student project facilities. This would happen early in the workshop series and would include an effort to identify opportunities and create a system diagram on the fly at the facility we visit.

Another challenge we need to address relates to the building operators who participate in the program. In many ways these facility engineers are ideal EBCx implementers. They have access to a facility where they can readily apply the low-cost, EBCx measures we advocate. They begin with a good understanding of HVAC systems and controls, and the EBCx techniques we teach add value to the services they already provide. At the outset of each series, we have a good representation of building operators in the class. In the current session they represented about 10% of the initial group and this increased to 25% at the midway point as others dropped out. However we lost the majority of these attendees as each was pulled back to the daily activities (and crises) at their facilities. We plan to capture feedback from facility engineers that have participated in past EBCx workshops to determine how we can better retain them in future offerings

Acknowledgements

The existence of the EBCx workshop series can be largely credited to David Sellers of Facility Dynamics Engineering who is responsible for coming up with the initial concept of the training series and for contributing the majority of the technical content. David's willingness to share lessons learned from past experiences (both good and bad) is remarkable. I know of no one who is more generous with his time, nor as knowledgeable about HVAC systems, controls and commissioning as David.

A debt of gratitude must also be paid to the other EBCx instructors: Tony Pierce, Larry Luskay, Gary Kawabuchi, Mark Porter and Ron Simens of Facility Dynamics Engineering; Kristin Heinemeier of the Western Cooling Efficiency Center; and Bill Koran of NorthWrite Inc.

[6] The Universal Translator is a free data management and analysis software tool developed by the PG&E Pacific Energy Center that can be downloaded from this website: http://www.utonline.org.

I also wish to thank all past and present EBCx students especially those whose work I am showcasing here.

Credit must be given to Cris Benton, of the University of California-Berkeley for his contributions to both the Vital Signs Project and the PEC's Tool lending Library and for his efforts to encourage the building professions to rigorously assess actual building performance. I wish to thank Bill Burke of the PEC for reviewing this paper, and Ann Camperson of PG&E deserves recognition for her help accessing utility billing data.

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