

Final Technical Report

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Curriculum for Commissioning Energy Efficient Buildings

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Executive Summary

In July 2010, the U.S. Department of Energy (DOE) awarded funding to PECI to develop training curriculum in commercial energy auditing and building commissioning. This program was created in response to the high demand for auditing and commissioning services in the U.S. commercial buildings market and to bridge gaps and barriers in existing training programs. Obstacles addressed included: lack of focus on entry level candidates; prohibitive cost and time required for training; lack of hands-on training; trainings that focus on certifications & process overviews; and lack of comprehensive training.

PECI organized several other industry players to create a co-funded project sponsored by DOE, PECI, New York State Energy and Research Development Authority (NYSERDA), California Energy Commission (CEC), Northwest Energy Efficiency Alliance (NEEA) and California Commissioning Collaborative (CCC). After awarded, PECI teamed with another DOE awardee, New Jersey Institute of Technology (NJIT), to work collaboratively to create one comprehensive program featuring two training tracks. NJIT's Center for Building Knowledge is a research and training institute affiliated with the College of Architecture and Design, and provided e-learning and video enhancements.

This project designed and developed two training programs with a comprehensive, energy-focused curriculum to prepare new entrants to become energy auditors or commissioning authorities (CxAs). The following are the key elements of the developed trainings, which is depicted graphically in Figure 1:

- Online classes are self-paced, and can be completed anywhere, any time
- Commissioning Authority track includes 3 online modules made up of 24 courses delivered in 104 individual lessons, followed by a 40 hour hands-on lab. Total time required is between 75 and 100 hours, depending on the pace of the independent learner.
- Energy Auditor track includes 3 online modules made up of 18 courses delivered in 72 individual lessons, followed by a 24 hour hands-on lab. Total time required is between 50 and 70 hours, depending on the pace of the independent learner.
- Individual courses can be taken for continuing education credits.
- Assessments are included for each course, and a score of at least 80% is required for completion.
- Completion of Modules 1 through 3 is prerequisite for participating in the laboratory. More experienced participants have the option to test out of Modules 1 and 2 and complete Module 3 to progress to the laboratory.

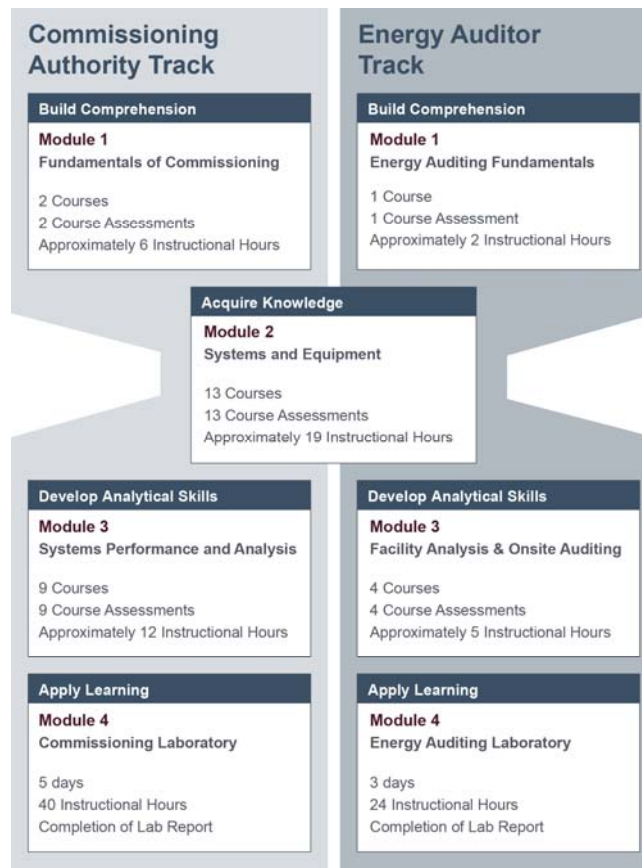


Figure 1: Overview of Training Programs

The resulting training programs are expected to benefit junior engineers as well as those with experience in other commercial building trades. Both the Energy Auditing and Commissioning Authority programs are sequenced so that participants build comprehension of fundamental concepts in Module 1, acquire knowledge of systems and equipment in Module 2, develop analytical skills through analysis of systems performance in Module 3, and apply the training in a lab setting using practitioner's tools in Module 4. Systems and equipment content (Module 2) is the same for both programs.

The curriculum includes the following topics:

- Testing and performing diagnostics of energy using systems required to identify opportunities for energy efficiency
- Estimating energy savings and costs related to the implementation of energy improvement measures.
- Providing guidance and oversight on implementation of energy efficiency measures
- Identifying and providing guidance for correcting design issues in new high efficiency systems
- Commissioning for energy efficiency and improved performance.
- Verifying and monitoring system performance to ensure the energy performance goals are reached and benefits persist

The training programs will be administered through an on-line learning management system being deployed through learn.peci.org. Courses will be available in early 2013. Detailed specifications outlining the requirements for the energy auditing and for the commissioning laboratory sites were created, and

several appropriate sites for the lab portions of the curriculum have been identified in California and New York. Lab manuals have been created for both energy auditing and commissioning labs. They include instructor and participant manuals, which will be customized for each lab site. The first lab sessions are expected to be held in the second quarter of 2013.

Expected Energy Benefits

Commercial buildings are very energy intensive and are a target for energy savings. In the U.S. alone, buildings are responsible for 36% of total energy use and 65% of electricity consumption. The creation of these training programs will directly impact energy use in buildings by producing a larger pool of active energy auditors and commissioning authorities whose work will improve efficiencies and decrease energy use in commercial buildings. PECl projects the enrollment and completion of the programs by 2014 is anticipated to be at least 400 in the Commissioning Authority track and at least 400 in the Energy Auditor track. Approximately half of these participants are expected to be from California. The range of expected annual energy impacts from these individuals is shown in Table 1.

Table 1: Summary of Expected Energy Benefits

Location	Savings Low (therms)	Savings High (therms)	Savings Low (kwh)	Savings High (kwh)
United States	136,266,592	478,023,876	10,963,266,720	38,459,193,660
California	54,708,016	190,555,068	4,401,508,560	15,331,021,380

Expected Non-Energy Benefits

While the energy benefits described above are an important outcome of this training program, there are also several non-energy benefits to note. The availability of quality training fills a professional development gap for entry level professionals who are motivated to up-level their skills and knowledge in their respective fields. Employers benefit by having access to cost-effective training for their staff, as well as a better trained labor pool. Additionally, building owners and commercial real-estate firms benefit from the services of skilled professionals who improve operational performance of buildings-resulting in tenant satisfaction, reduction in energy use and financial savings. Finally the industry as a whole benefits by having access to well-documented best practices in energy efficiency field. The curriculum aggregates the skills and knowledge of seasoned industry professionals and resources.

Introduction

In July 2010, the U.S. Department of Energy awarded funding to PECI for developing training in commercial energy auditing and commissioning. PECI organized several other industry players to create a co-funded project sponsored by PECI, New York State Energy and Research Development Authority (NYSERDA), California Energy Commission (CEC), Northwest Energy Efficiency Alliance (NEEA) and California Commissioning Collaborative (CCC). After awarded, PECI teamed with another DOE awardee, New Jersey Institute of Technology (NJIT), to work collaboratively to create one program to be commercialized by PECI. NJIT's Center for Building Knowledge is a research and training institute affiliated with the College of Architecture and Design, and provided enhancements.

This project designed and developed two training programs with a comprehensive, energy-focused curriculum to prepare new entrants to become commercial energy auditors and commissioning authorities (CxAs). This program was created in response to the high demand for auditing and commissioning services in the U.S. commercial buildings market and to bridge gaps and barriers in existing training programs. Obstacles addressed included: lack of focus on entry level candidates; prohibitive cost and time required for training; lack of hands-on training; trainings that focus on certifications & process overviews; and lack of comprehensive training.

The project period spanned more than two years, and was a process of vetted steps as shown in Figure 2. Throughout this process, a PECI relied upon industry experts, and also assembled a Technical Development and Review Committee. These advisors were utilized throughout the project.

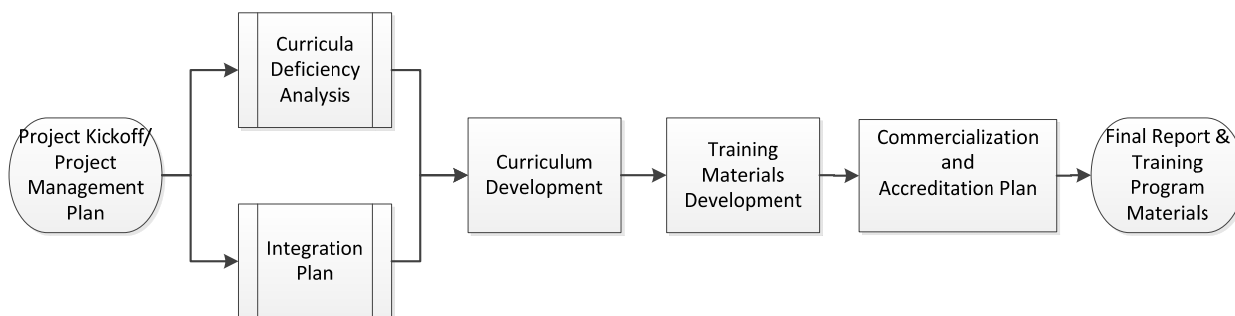


Figure 2: Overview of Entire Project

Funding

The development of the energy auditor and commissioning authority training programs were instigated by the Department of Energy's solicitation for curriculum development. PECI co-funded the project, and gained additional support and funding from several other organizations including: New York State Energy and Research Development Authority (NYSERDA), California Energy Commission (CEC), Northwest Energy Efficiency Alliance (NEEA) and the California Commissioning Collaborative (CCC).

The contributions from the various funders are shown in Table 2. No special allocations or projects were designated to any contributor.

Table 2: Project Contributions

Organization	Contribution	Percentage
DOE	\$ 749,153	47%
PECI	\$ 400,000	25%
NYSERDA	\$ 250,000	16%
CEC	\$ 120,000	8%
NEEA	\$ 30,000	2%
CCC	\$ 25,000	2%
	\$1,574,153	100%

Market Analysis and Planning

The first step in the project after kickoff was market analysis and planning. This consisted of two concurrent efforts: a *Curricula Deficiency Analysis* and an *Integration Plan*.

The *Curricula Deficiency Analysis* focused on two key actions:

- 1) Identify where gaps exist between the market demand for employees who can perform energy auditing and commissioning activities and the training available in the market;
- 2) Recommend a general approach to developing the needed training for auditors and commissioning providers.

PECI's research showed that a gap exists between the market demand for employees who can perform energy auditing and commissioning activities and the training available in the market:

- Organizations and individuals in the energy efficiency sector have identified a shortage of well-trained applicants for job openings, and the demand for services is growing;
- Existing training offered targets already established professionals, rather than junior engineers, and often focuses on preparing for a certification exam or earning continuing education units;
- Most training in both auditing and commissioning covers process while offering little or no technical hands-on training;
- Recent graduates from engineering school lack hands-on experience working with building systems and equipment;
- Firms struggle to find employees who know the technical aspects of commissioning, yet most training focuses on process;
- The cost of training is a significant barrier for employers.

Conducted in parallel, the *Integration Plan*, researched how to address specific workforce development needs and developed recommendations on the curriculum including key topics, concepts and sequencing of the training programs. This occupational analysis documented the knowledge, skills and abilities (KSAs) that the curriculum would address as well as the organization and duration of curriculum topics.

The *Integration Plan* focused on two key actions:

- 1) Document the knowledge, skills and abilities (KSAs) that the curriculum will address;
- 2) Illustrate the organization and duration of curriculum topics to meet project objectives.

To ensure the technical merit of the curriculum, a Technical Development Committee was formed with members including industry experts, subject matter experts (SMEs) and the PEI project team.

The development of the curriculum framework began by identifying the knowledge, skills, and abilities (KSAs) that commissioning authorities and energy auditors need to succeed in the workplace. These major functions and key activities, as well as the technical supportive enablers, were identified through an occupational analysis method known as the Systematic Curriculum and Instructional Development (SCID) process. An example of how the occupational analysis used to develop KSAs is shown in Table 3.

Table 3: Example of Occupational Analysis

Duties		Tasks	Knowledge, Skills & Abilities
A	Develop Design Phase Cx Plan	A.1 Determine Cx scope. A.2 Outline the design phase Cx process. A.3 Define roles and responsibilities of Cx team. A.4 Determine schedule of Cx activities. A.5 Document Cx communication channels. A.6 Document Cx team and contact information A.7 Write Design Cx Plan	Knowledge of: Design & construction phase commissioning process (ASHRAE, ACG, NEBB, LEED) Construction communication protocol Skills to: Writing Plans
B	Develop/Review Owner's Project Requirements (OPR)	B.1 Verify OPR meets Owner's Goals & Objectives B.2 Verify OPR is specific to project. B.3 Verify OPR meets minimum requirements. B.4 Verify OPR provides design & construction team sufficient direction. B.5 Develop comments.	Knowledge of: Facility requirements Sustainability and energy requirements Facility design and construction requirements Minimum Requirements of Owner Project (OPR) Skills to: Write OPR Ability to: Review and Comment on OPR

Through this exercise, the project team developed preliminary descriptions of the duties and tasks for each job category. Then, experts in each category assisted in reviewing and modifying the preliminary descriptions to accurately describe their job functions. This data was verified, ranked and then used to guide the selection of key topics and concepts to be included in the curriculum.

The resulting report described the occupational analysis employed to determine the required knowledge, skills, and abilities that energy auditors and commissioning providers require; discusses the rationale for the curriculum design, key topics and concepts; and addresses the organization and sequencing of subject matter content to meet the project objectives.

The Curriculum Outline addresses these recommendations. Essential features are:

- Energy auditing and commissioning are covered in separate, but complimentary tracks.
- The content focuses on fundamental and advanced technical topics geared towards entry-level engineering graduates, experienced technicians and engineers transitioning into the fields of auditing and commissioning.
- Technical hands-on activities are integrated to provide a more realistic application of knowledge that participants will be able to apply in actual occupational situations.
- New construction and existing building commissioning content is provided.
- Training breadth and depth is sufficient to create a transformative experience for those interested in gaining the knowledge, skills and abilities to enter the field initially.

- Training will incorporate blended learning, utilizing different learning environments and formats.

The Curriculum Outline presents a high-level view of the curriculum design. It is a critical element in the training program development; it establishes the structure of the curriculum. This outline, the key instructional topics and concepts, and the flow of the curriculum were developed utilizing the KSAs for each job category. Each KSA was analyzed and grouped into instructional modules, each building on sequential knowledge and skill development.

Figure 3 and Figure 4 summarize the preliminary curriculum outlines, which have changed slightly during further development. Both the Energy Auditing and Commissioning Authority programs are sequenced so that participants build comprehension of fundamental concepts in Module 1, acquire knowledge of systems and equipment in Module 2, develop analytical skills through analysis of systems performance in Module 3, and apply all learning in a lab setting using practitioner's tools in Module 4. Systems and equipment content (Module 2) is the same for both programs.

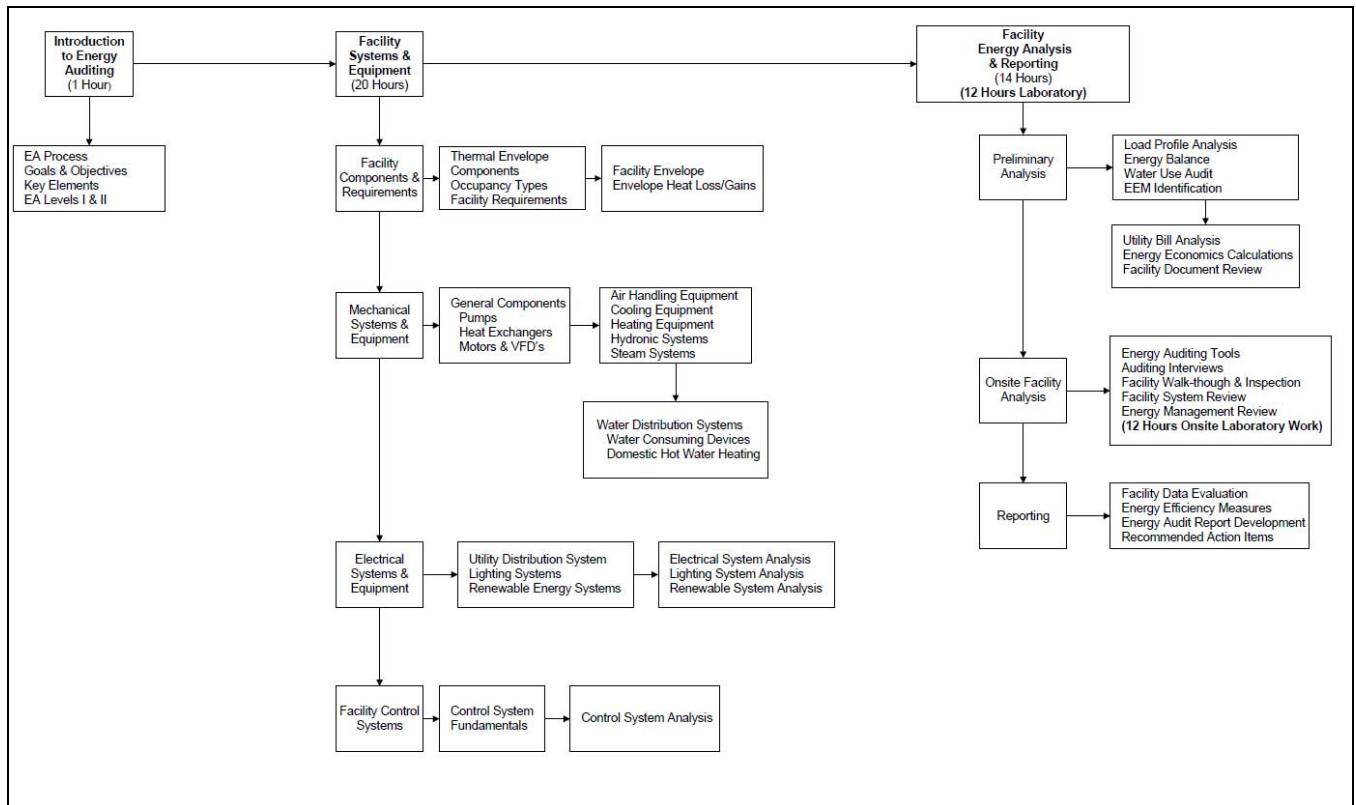


Figure 3: Summary of Preliminary Curriculum Outline for Energy Auditing

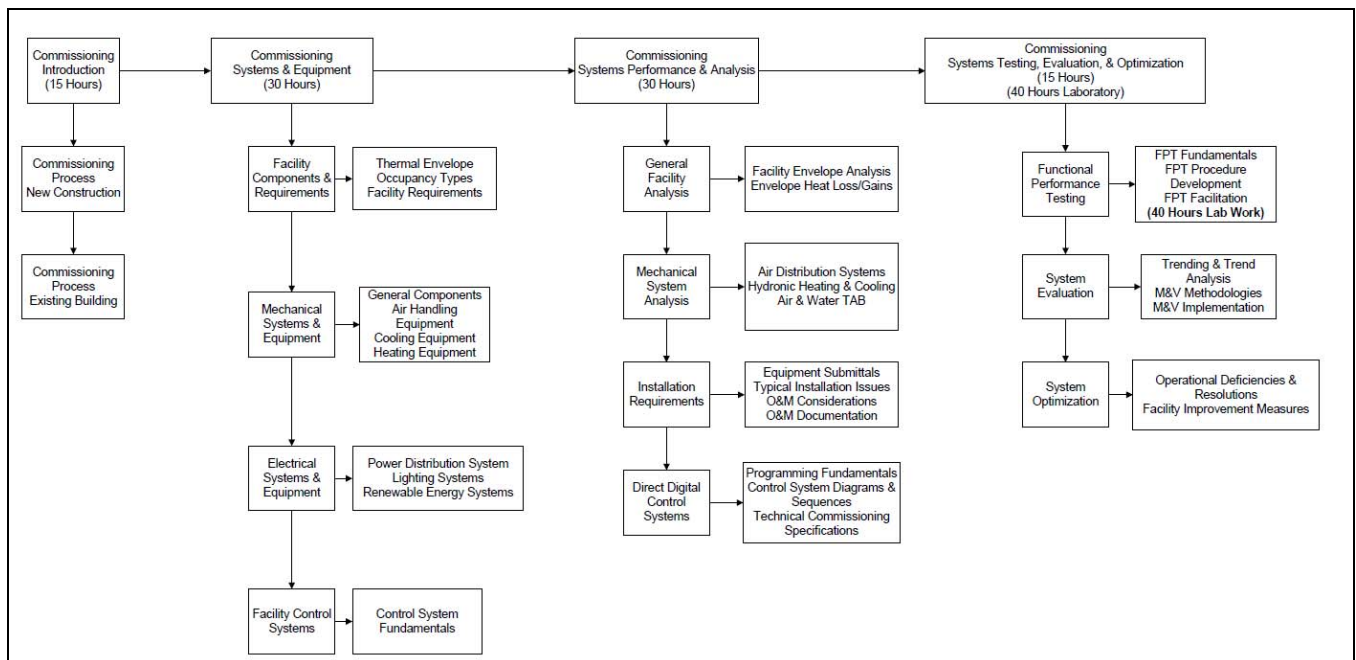


Figure 4: Summary of Preliminary Curriculum Outline for Commissioning

Training Materials Development

The next step in the project prior to developing the raw training materials was to take the KSAs and Curricula Outlines and develop instructional goals and learning objectives. Instructional goals are broad statements of what the participants will be able to do once they have successfully completed each module. Learning objectives are statements that define three core components resulting from the completion of a specific instructional unit. Each learning objective has three core components: an observable action or behavior, conditions of the performance and a measureable level of acceptable performance.

An evaluation of each KSA, related topics and tasks was conducted to develop a comprehensive list of learning objectives for each occupation. Learning objectives were further refined, organized, and assigned time durations. Course durations range from one to four hours in length and are comprised of individual lessons. Each lesson is between thirty and fifty minutes in length.

PECI developed the instructional goals and learning objectives to develop detailed scopes of work, and used a targeted solicitation approach to engage several industry experts. These subject matter experts (SMEs) created the required content through a multiple review and development process administered by PECI. Unfortunately, this process resulted in disappointing results, as the SMEs were unable to meet schedules, provide quality materials, or follow guidelines. PECI engineers finalized the materials, but this process created a delay in the program schedule and required shifting budgets.

A portion of the raw materials were further developed and produced into e-learning format by a subcontractor to PECI. The remainder of the raw training materials was delivered to NJIT, who enhanced them with additional content and produced them into e-learning format. PECI provided review and feedback during the production process.

Concurrent with the production of the e-learning materials, PECI developed a web-based learning management system to administer the online portion of the curriculum (learn.peci.org) and provide a laboratory registration feature. The learning management system serves as a marketing website and a platform for program administration. Participants gain access to the curriculum by purchasing a license on the learn.peci.org site. Participants may purchase a license for an entire track, or for a particular course and their license for the material is good for one year from purchase date.

In parallel, PECI staff designed the curriculum and developed training materials for the commissioning and energy auditing laboratories. Course flow and hands-on field activities are detailed in instructor guides and participant workbooks. Specifications detailing the requirements of facilities hosting the labs were developed, and several suitable sites were identified in California and New York where they are expected to be initially held.

Program Commercialization

PECI developed a detailed plan, documented in the *Commercialization and Accreditation Plan*, to commercialize the curriculum into a self-sustaining long-term program. It also addresses the approach to and plan for long-term program accreditation. ISO¹ 29990:2010 was selected as the most appropriate standard for the program, and the curriculum and program was designed and built to fulfill all requirements of this standard, although accreditation has not yet been solicited.

PECI selected program names that directly describe the training to be offered:

¹ International Organization for Standardization (ISO)

Commissioning Authority Training *powered by PECI*
Commercial Energy Auditor Training *powered by PECI*

The programs developed will provide certificates of completion for participants, although PECI will not offer a certification. Professional certifications are generally administered by an independent party that reviews and verifies that certification requirements (such as training) have been met. As the administrator of the training program, PECI is not structured to also offer a companion certification. Rather, completing the curriculum will be tied to other certification options that are important to participants. For example, the Building Commissioning Association (BCA) will provide some credit towards their commissioning certifications, Associate Commissioning Professional (ACP) and Certified Commissioning Professional (CCP), based on completion of the PECI commissioning training. A similar arrangement for certification has not yet been set for the energy auditor program.

Continuing education units (CEUs) are important to many individuals, and will be offered through the American Institute of Architects (AIA) Continuing Education System, which offers one CEU for each 60-minute period of instruction. In addition, PECI will pursue continuing education credits through the Green Building Certification Institute (GBCI). These credits are offered for instruction that is applicable to the maintenance of a variety of certifications offered through the United States Green Building Council (USGBC). One credit is offered for each 60-minute period of instruction.

Project Outcomes

Fulfillment of Project Goals

This project has successfully met all of its intended objectives. The intent of the project was to design a training program with a comprehensive, energy-focused curriculum to prepare new entrants to become energy auditors and commissioning authorities (CxAs). PECI, NJIT, and industry subject matter experts along with a Technical Development and Review Committee created two technical curricula address the knowledge, skills and abilities (KSAs) required for these positions.

The PECI training programs offer:

- A comprehensive curriculum for learners with a bachelor's degree in engineering and less than five years of building systems experience, or an equivalent level of education and experience;
- Hands-on technical training;
- For commissioning specifically, training applies to both new construction and existing buildings;
- A blended learning approach that includes multiple training formats;
- Reduced total cost to employers of training employees by using asynchronous e-learning.

Results

The primary results of this project are the two training programs which will be deployed in 2013 via learn.peci.org:

Commissioning Authority Training *powered by PECI*
Commercial Energy Auditor Training *powered by PECI*

The following are the key elements of the developed trainings, which are depicted graphically in Figure 5:

- Online classes are self-paced, and can be completed anywhere, any time
- Commissioning Authority track includes 3 online modules made up of 24 courses delivered in 104 individual lessons, followed by a 40 hour hands-on lab. Total time required is between 75 and 100 hours, depending on pace.

- Energy Auditor track includes 3 online modules made up of 18 courses delivered in 72 individual lessons, followed by a 24 hour hands-on lab. Total time required is between 50 and 70 hours, depending on pace.
- Individual courses can be taken for continuing education credits.
- Assessments are included for each course, and a score of at least 80% is required for completion.
- Modules 1 through 3 are prerequisite for participating in the laboratory. More experienced participants can choose to test out of Modules 1 and 2.
- A detailed list of courses and lessons is included as an Appendix.

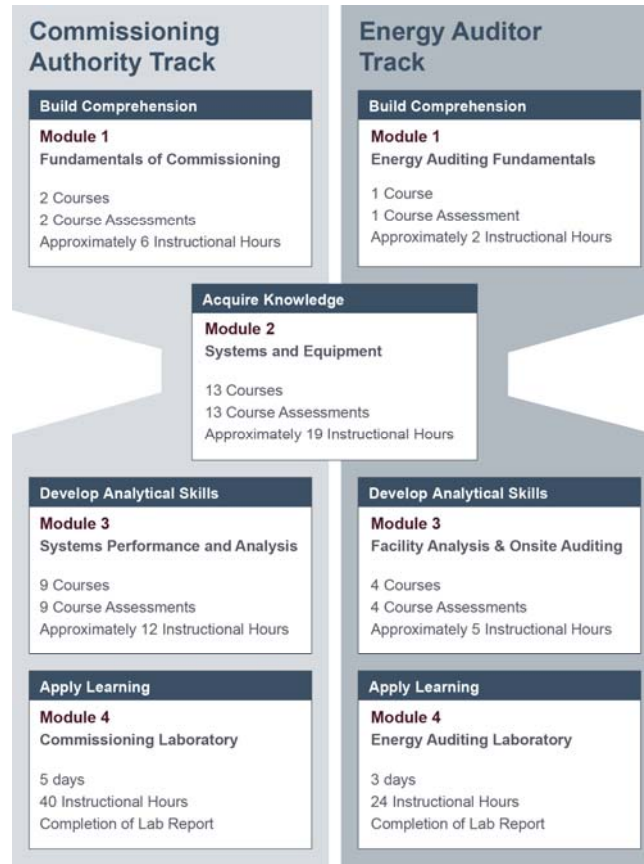


Figure 5: Overview of Training Programs

The resulting training programs are appropriate for junior engineers as well as those with experience in other commercial building trades. The suggested requirements for each track are shown in Table 4. The requirements for the energy auditing track are less rigorous than the commissioning track.

Table 4: Prerequisites for Training Programs

Commercial Energy Auditor	Commissioning Authority
• Junior and mid-level Commercial Energy Auditors • Entry-level engineers • Experienced facility operators, energy managers, energy analysts, mechanical or electrical technicians, and building design professionals (5 years+)	• Junior and mid-level CxA professionals • Senior facility operators or mechanical and electrical technicians (10 years+) • Building design professionals or energy engineers

Although not available until 2013, PECCI has determined the initial pricing for the programs, which is detailed in Table 5. The full curriculum (online + lab) is purposely intended to be the best value to encourage participation in the labs. The hands-on lab piece is considered vital in these training programs. The pricing for individual courses for CEUs is not yet available.

Table 5: Cost of Training Programs

Item	Commercial Energy Auditor	Commissioning Authority
Full Program	\$1,800	\$2,800
Online Only	\$1,600	\$2,400
Lab Only*	\$700	\$1,400
*Must complete online modules to enroll in lab		

Commissioning Authority Training will launch and be available for purchase in Q1 of 2013. Energy auditor training will launch subsequently. The commissioning training program will be delivered in partnership with the Building Commissioning Association (BCA). BCA, the nonprofit international authority on building commissioning offered under a co-branding agreement with the Building Commissioning Association (BCA). The BCA logo will figure prominently on promotional materials and PECCI and BCA will collaborate to market the program and to improve and update the programs over time.

Additional benefits of the program include the following:

- Upon completion of the entire commissioning track, participants receive a certificate from PECCI and will be listed on a national Commissioning Professional Registry. The Registry will be developed jointly by PECCI and BCA and will serve as an online directory of program graduates. Individual courses can be completed a-la-carte to satisfy continuing education requirements
- Earn AIA (American Institute of Architects) CEU credits
- Apply credits toward maintenance and renewal of USGBC certifications like LEED (Pending approval from USGBC)
- Excellent preparation and some credit towards the requirements for certifications from the BCA's Associate Commissioning Professional (ACP) and Certified Commissioning Professional (CCP)

Expected Energy Benefits

Commercial buildings are very energy intensive and are a target for energy savings. In the U.S. alone, buildings are responsible for 36% of total energy use and 65% of electricity consumption. The demand

for energy efficient building is growing and contributes to economic recovery and growth, improves that asset value of the nations' building stock and creates sustainable environments that minimize the further effects of climate change. This move for buildings that consume less energy also reduces our dependence on foreign and domestic fossil fuel production, meets current and future state, local, and federal regulations for energy reduction, and introduces new technologies for capturing and generating energy

The creation of these training programs will directly impact energy use in buildings by producing more active energy auditors and commissioning authorities whose work will improve efficiencies and decrease energy use in commercial buildings. PECI projects the enrollment and completion of the programs by 2014 is anticipated to be at least 400 in the Commissioning Authority track and at least 400 in the Energy Auditor track. Approximately half of these participants are expected to be from California.

Expected annual savings from each category of participants were calculated assuming these individuals worked on projects in large commercial office buildings, and are shown in Table 6 below. These estimates are based on savings estimates for commissioning projects from Mills², the CEUS³ average energy use intensities, and the average size for a large commercial office building. Savings from energy auditing are based on engineering experience. The expected annual energy impact for the United States is calculated in Table 7 and the impacts for California in Table 8.

Table 6: Expected Annual Energy Benefits Per Individual

Category	# Project /Year	Size	Kwh/s q	therm/s q	Savings (low)	Savings (High)	Savings Low (therms)	Savings High (therms)	Savings Low (kwh)	Savings High (kwh)
Energy Auditor	80	190700	17.7	0.22	7%	25%	234,942	839,080	18,902,184	67,507,800
CxA - New Construction	8	190700	17.7	0.22	13%	29%	43,632	97,333	3,510,406	7,830,905
CxA - Existing Buildings	10	190700	17.7	0.22	8%	31%	33,563	130,057	2,700,312	10,463,709

Table 7: Expected Total Annual Energy Benefits in United States by 2014

Category	Number Created in US	Savings Low (therms)	Savings High (therms)	Savings Low (kwh)	Savings High (kwh)
Energy Auditor	500	117,471,200	419,540,000	9,451,092,000	33,753,900,000
CxA - New Construction	200	8,726,432	19,466,656	702,081,120	1,566,180,960
CxA - Existing Buildings	300	10,068,960	39,017,220	810,093,600	3,139,112,700
Totals:	1,000	136,266,592	478,023,876	10,963,266,720	38,459,193,660

Table 8: Expected Total Annual Energy Benefits in California by 2014

Category	Number Created in CA	Savings Low (therms)	Savings High (therms)	Savings Low (kwh)	Savings High (kwh)
Energy Auditor	200	46,988,480	167,816,000	3,780,436,800	13,501,560,000
CxA - New Construction	100	4,363,216	9,733,328	351,040,560	783,090,480
CxA - Existing Buildings	100	3,356,320	13,005,740	270,031,200	1,046,370,900
Totals:	500	54,708,016	190,555,068	4,401,508,560	15,331,021,380

Expected Non-Energy Benefits

While the energy benefits described above are an important outcome of this training program, there are also several non-energy benefits to note. The availability of quality training fills a professional development gap for entry level professionals who are motivated to up-level their skills and knowledge in their respective fields. Employers benefit by having access to cost-effective training for their staff, as well

² Mills, E. 2011. "Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions in the United States." Energy Efficiency, 4(2):145-173

³ California Energy Use Survey (CEUS)

as a better trained labor pool. Additionally, building owners and commercial real-estate firms benefit from the services of skilled professionals who improve operational performance of buildings-resulting in tenant satisfaction, reduction in energy use and financial savings. Finally the industry as a whole benefits by having access to well-documented best practices in energy efficiency field. The curriculum aggregates the skills and knowledge of seasoned industry professionals and resources.

Secondary Results

In addition to the planned deployment of the Commercial Energy Auditor Training and Commissioning Authority Training programs, several other secondary items were developed. These additional results include:

- Web links to play lessons developed. This includes all lessons developed, whether or not they are deployed yet on learn.peci.org.
- The raw power point files and materials used to develop the e-learning content.
- Laboratory manuals (Instructor and Participant) for both tracks; specifications for the laboratory sites; hand-held tools for laboratory activities.

Unfunded Results

In addition to the activities funded by the project, PECI has completed or is underway with several other related initiatives. These activities are to support the roll-out of the training programs, and include:

- Presented on the project at ACEEE Summer Study 2012 (Brooks, Pinit, Webster, and Fischer. *Bridging the Training Gap: Development of New Curriculum for the Commissioning Industry*), <http://aceee.org/files/proceedings/2012/start.htm>.
- Developed additional materials to support program deployment via learn.peci.org including course catalogs and marketing materials.
- Submitted materials and received approval from AIA for continuing education credits; submission of USGBC credits is underway.
- Execution of a beta testing is underway on the Commissioning Authority Training. This pilot program is funded via DOE through Penn State, and is being executed by NJIT and PECI.
- Program administration of learn.peci.org is underway by PECI. The website provides a registration function and allows users to purchase a one-year license to access an entire curriculum track or individual courses. The website is the platform through which participants access the e-learning components and program administrators perform tracking, evaluation and recordkeeping activities.
- Once launched, PECI staff will be managing the training programs. This will include: providing participant support with registration, navigation, content, assessments, CEUs, and labs; planning and administering hands-on lab sessions; trouble-shooting LMS operations; and maintaining and updating content.
- In an effort to further improve and expand these programs, we have received additional funding from NEEA to develop a manual for the new construction commissioning process course (Cx1.1).

Conclusions

This research and development project should be considered a success. It has filled a gap in the industry for workforce development training for commercial building experts that provides comprehensive training, includes entry level participants, and provides hands-on training. One of the keys to this project's success was a high level of industry involvement. Not only was funding supplied from many interested parties, guidance and input was provided by a Technical Development and Review Committee, the Building Commissioning Association and other industry experts. Inclusion of these subject matter experts in the program development helped to ensure high quality programs and to gain market acceptance.

The primary funders in this effort - DOE, PECI, NYSERDA, and CEC – were all extremely easy to work with. Although the administrative burden of multiple clients was greater than a typical project, all of the funding parties were very accommodating of changing schedules and other project modifications. This was a very important element in this multiple year research project. There were some challenges, however, with successfully utilizing all of the available funds due to some contract clauses which limited the ability to move funds between tasks and personnel.

In addition, the teaming of PECI and NJIT into one project team increased the quality of the deliverables by pooling efforts. DOE's willingness to leverage the multiple awards DOE made on similar scopes of work improved both the depth and quality of the training programs.

PECI is very grateful to the funders of this effort and look forward to successfully deploying the training programs developed.

Appendix

Detailed Course Listing

Course. Lesson #	Name	Number of slides	Approx. run time (minutes : seconds)
CX MODULE 1			
	COURSE CX 1.1: New Construction Building Commissioning		
CX 1.1.1	Pre Design Phase	27	12:09
CX 1.1.2	Design Phase Commissioning Plan	27	13:04
CX 1.1.3	Design Review	29	13:23
CX 1.1.4	Construction Phase- Submittal Review	28	13:02
CX 1.1.5	Construction Phase Commissioning- Site Observation	31	16:08
CX 1.1.6	Construction Phase- Functional Performance Testing	31	14:08
CX 1.1.7	Construction Phase- SM and O&M Documents	32	17:51
CX 1.1.8	Operation and Maintenance Training	30	17:38
CX 1.1.9	Operation/ Occupancy Phase	20	6:52
	COURSE CX 1.2: Existing Building Commissioning		
CX 1.2.1	Scoping/Planning Phase- ID Goals and Document Review	50	26:13
CX 1.2.2	Scoping/Planning Phase- Building Walkthrough	47	22:13
CX 1.2.3	EBCx Plan	47	23:59
CX 1.2.4	Investigation Phase- Reviewing Docs and Interviewing	43	23:17
CX 1.2.5	Investigation Phase- Analyzing Facility Performance	37	20:06
CX 1.2.6	Investigation Phase- Testing, Monitoring and Reports	57	32:54
CX 1.2.7	Implementation Phase	44	24:45
CX 1.2.8	Handoff Phase- Training System, Manuals and Reporting	34	21:30
CX 1.2.9	Ongoing Commissioning Phase	36	22:33
CX- EA MODULE 2: Building Commissioning			
	COURSE CX-EA 2.1: Facility Envelope Components		
CX-EA 2.1.1	Building Thermal Envelope	48	16:07
CX-EA 2.1.2	Building Thermal Envelope- Thermal Characteristics	28	07:06
CX-EA 2.1.3	Building Thermal Envelope- Below Grade and Wall	24	09:27
CX-EA 2.1.4	Building Thermal Envelope- Fenestration and Roofing	38	09:04
	COURSE CX-EA 2.2: Facility Operating Requirements		
CX-EA 2.2.1	Occupancy and Facility Characteristics	38	14:06
CX-EA 2.2.2	Room Conditions	32	09:09
	COURSE CX-EA 2.3: Facility Energy Considerations		
CX-EA 2.3.1	Design Conditions and Weather Data	44	19:14
CX-EA 2.3.2	Energy Reduction Requirements, Regulations and Incentives	56	27:44
CX-EA 2.3.3	Energy Analysis	59	32:35
CX-EA 2.3.4	Energy Economic Calculators	44	29:31
	COURSE CX-EA 2.4: Intro MEP Systems & Equipment		
CX-EA 2.4.1	MEP Fundamentals- Mechanical Drawings	43	24:01
CX-EA 2.4.2	Fan Terms, Types and Configurations	41	21:14
CX-EA 2.4.3	Pump Components and Characteristics	42	16:21
CX-EA 2.4.4	Describe Heat Exchanger Types and Characteristics	47	27:07
CX-EA 2.4.5	Explain Motor Fundamentals	29	11:54
CX-EA 2.4.6	Motor Types and Efficiencies	33	15:42
CX-EA 2.4.7	Variable Frequency Drive Applications and Characteristics	28	17:01
CX-EA 2.4.8	Piping Systems & Accessories	54	34:22
	COURSE CX-EA 2.5: MEP- AHU		
CX-EA 2.5.1	Air Handling Equipment	32	21:24
CX-EA 2.5.2	Principals of Psychometrics	41	19:12

Course. Lesson #	Name	Number of slides	Approx. run time (minutes : seconds)
CX-EA 2.5.3	Psychometric Analysis	33	28:08
CX-EA 2.5.4	Air Handling Components and Configuration	42	28:40
CX-EA 2.5.5	Make-up Air Systems and Heat Recovery	36	24:16
CX-EA 2.5.6	Duct Terminal Air Flow Devices	31	14:59
CX-EA 2.5.7	Room Terminal Air Flow Devices	41	18:23
	COURSE CX-EA 2.6: Cooling Equipment		
CX-EA 2.6.1	Principals of Vapor Compression Refrigeration	46	25:04
CX-EA 2.6.2	Unitary Cooling Equipment	38	25:20
CX-EA 2.6.3	Evaporative Cooling Equipment	42	17:02
CX-EA 2.6.4	Chillers and Cooling Towers 1	42	15:14
CX-EA 2.6.5	Chillers and Cooling Towers 2	49	16:57
	COURSE CX-EA 2.7: Combustion and Boilers		
CX-EA 2.7.1	Heating Equipment	46	31:21
CX-EA 2.7.2	Furnaces and Heaters	43	22:46
	COURSE CX-EA 2.8: Chilled Water Systems		
CX-EA 2.8.1	Hydronic Heating and Cooling	44	32:28
CX-EA 2.8.2	Describe Condenser Water Systems	45	27:28
	COURSE CX-EA 2.9: Hot Water & Steam Heating		
CX-EA 2.9.1	Hot Water Heating Systems 1	38	14:37
CX-EA 2.9.2	Hot Water Heating Systems 2	42	19:49
CX-EA 2.9.3	Steam Systems 1	46	21:18
CX-EA 2.9.4	Steam Systems 2	51	24:45
	COURSE CX-EA 2.10: Domestic Hot Water Systems		
CX-EA 2.10.1	Domestic Water Distribution Systems	37	22:11
CX-EA 2.10.2	Domestic Hot Water Systems	41	24:30
	COURSE CX-EA 2.11: Electrical Systems and Equipment		
CX-EA 2.11.1	Electrical Drawings and Documents	34	10:45
CX-EA 2.11.2	Electrical Distribution Systems 1	40	16:20
CX-EA 2.11.3	Electrical Distribution Systems 2	42	19:24
CX-EA 2.11.4	Lighting Systems	34	22:12
CX-EA 2.11.5	Lighting Controls	33	18:41
CX-EA 2.11.6	Renewable Energy Systems	44	24:38
	COURSE CX-EA 2.12: Control Systems Fundamentals		
CX-EA 2.12.1	Control System Fundamentals Lesson 1: Control System Terms	46	26:16
CX-EA 2.12.2	Types of Control Systems	44	28:16
CX-EA 2.12.3	Modes of Operation	46	24:53
CX-EA 2.12.4	Control System Elements	49	23:31
	COURSE CX-EA 2.13: Control Systems		
CX-EA 2.13.1	DDC Systems	36	15:12
CX-EA 2.13.2	DDC Systems 2	41	24:17
CX-EA 2.13.3	Control System Drawings and Documents	35	20:32
CX MODULE 3			
	COURSE CX 3.2: Design Review		
CX 3.2.1	Mechanical Design Review	43	32:29
CX 3.2.2	Plumbing Design Review	14	07:50
CX 3.2.3	Electrical Design Review	42	22:28
	COURSE CX 3.3: Mechanical System Analysis - Air Distribution		
CX 3.3.1	Analysis of Packages HVAC Equipment	37	18:16
CX 3.3.2	Analysis of Air Moving Equipment	42	15:47
CX 3.3.3	Analysis of Duct Design	41	19:51
CX 3.3.4	Analysis of Space Airflow and General Exhaust	41	27:57
	COURSE CX 3.4: Mechanical System Analysis - Hydronic		
CX 3.4.1	Analysis of Chilled Water Systems	39	15:48

Course. Lesson #	Name	Number of slides	Approx. run time (minutes : seconds)
CX 3.4.2	Analysis of Hot Water Heating Systems	25	09:34
CX 3.4.3	Analysis of Hydronic Piping Systems	32	08:45
CX 3.4.4	Analysis of Hydronic Pumping Systems and Terminal Units	26	10:07
	COURSE CX 3.5: Mechanical System Analysis - Tab		
CX 3.5.1	Air System Testing, Adjusting and Balancing	37	25:36
CX 3.5.2	Air Testing, Adjusting and Balancing Issues	34	13:13
CX 3.5.3	Water Testing, Adjusting and Balancing	31	18:32
CX 3.5.4	Water Testing, Adjusting and Balancing Issues	25	12:07
	COURSE CX 3.6: Electrical Analysis		
CX 3.6.1	Analysis of Electrical Distribution Systems Deficiencies and Resolutions	35	15:10
CX 3.6.2	Analysis of Lighting Control Systems	34	19:11
CX 3.6.3	Analysis of Photovoltaic Systems	33	11:18
	COURSE CX 3.7: Control System Analysis - DDC		
CX 3.7.1	Direct Digital Control Systems	46	23:42
CX 3.7.2	Energy Efficiency Control Strategies	44	22:02
CX 3.7.3	DDC Installation and Operation Issues	46	30:02
CX 3.7.4	DDC Sensor Installation	40	18:59
	COURSE CX 3.8: Control System Analysis - Air Handling & Hydronic Systems		
CX 3.8.1	Analysis of Duct Station and VAV Terminal Control	50	23:20
CX 3.8.2	Analysis of VAV Reheat and Supply Air Temperature Control	46	23:20
CX 3.8.3	Economizer Control	52	25:03
CX 3.8.4	Analysis of Outside Control	48	24:43
	COURSE CX 3.9: Functional Performance Testing		
CX 3.9.1	FPT Development: HVAC	48	26:07
CX 3.9.2	FPT Development: Plumbing	49	26:19
CX 3.9.3	FPT Development: Electrical	48	30:36
CX 3.9.4	FPT- Development: Lighting Controls	53	24:16
	COURSE CX 3.10: System Evaluation		
CX 3.10.1	Monitoring and Trending	51	37:58
CX 3.10.2	Analyzing Monitoring and Trending Results	33	18:11
CX 3.10.3	M & V Fundamentals	46	30:08
EA MODULE 1			
	COURSE EA 1.1: Intro to Energy Auditing		
EA 1.1.1.	Energy Auditing Process: Goals & Objectives	30	13:11
EA 1.1.2.	Energy Auditing Process: Preliminary Energy Use Analysis	72	32:46
EA 1.1.3.	Energy Auditing Process: Audit Level I	71	26:07
EA 1.1.4.	Energy Auditing Process: Audit Level II	52	33:21
EA 1.1.5.	Energy Auditing Process: Audit Level III	52	31:44
EA MODULE 3			
	COURSE EA 3.1: Building Energy Assessment		
EA 3.1.1	Preliminary Energy Analysis - Summary Development	30	16:59
EA 3.1.2	Preliminary Energy Analysis - Document Review	26	15:43
EA 3.1.3	Preliminary Energy Analysis - Identifying FIMs	23	17:40
	COURSE EA 3.2: Energy Audit Procedures		
EA 3.2.1	Energy Auditing Instructions	35	15:56
EA 3.2.2	Facility Inspection: Interviewing Staff and Occupants	33	20:19
EA 3.2.3	Facility Inspection: Building Walk-Through	31	16:12
EA 3.2.4	M & V Fundamentals	46	30:08
	COURSE EA 3.3: Facility Evaluation		
EA 3.3.1	Evaluating Envelope Systems	23	12:33
EA 3.3.2	Evaluating HVAC&R Systems	48	36:00
EA 3.3.3	Evaluating Domestic Hot Water Systems	27	14:33
EA 3.3.4	Evaluating Electrical Systems	36	27:00

Course. Lesson #	Name	Number of slides	Approx. run time (minutes : seconds)
EA 3.3.5	Evaluating Building Automation Control Systems	33	25:10
	COURSE 3.4: Energy Audits		
EA 3.4.1	Energy Audit Analysis of Process and Results	30	16:02
EA 3.4.2	Energy Audit Implementation Costs and Benefits	22	24:07