Preparing Building Technicians for Energy Efficient Operations of High Performance Facilities

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ABSTRACT

Building technicians have a significant impact on maintaining and optimizing energy efficiency in facilities. Work that has been traditionally associated with a blue collar occupation with narrowly defined job tasks is increasingly gaining the status of an energy professional skilled at diagnosing and problem-solving complex energy usage patterns. This paper describes the development of an educational program designed to teach system-level high performance building operations, and highlights innovative instructional strategies developed at an urban community college in Oakland, California. Course sequences in Commercial HVAC Systems and Building Automation Systems are described in which energy efficiency principles and practices are addressed across the curriculum. Furthermore, problem-based learning scenarios are introduced through which students are encouraged to solve open-ended problems in groups, honing their team work skills, system level thinking, and problem-solving capabilities.

Introduction

The work of building systems technicians is becoming increasingly challenging and complex due to rapidly evolving technologies and changing building owner expectations and policy requirements. As a growing number of buildings are retrofitted with new automated systems, the demand for more highly skilled technicians is rapidly outpacing supply (BIG, 2010; Dierdoff, et al., 2009).

Laney College, an urban community college in Oakland, has been closely monitoring developments in the building sector over the last eight years and has implemented new programs and curricula to reflect the changing education and training needs for building technicians. The National Science Foundation (NSF) has supported the college's efforts through its Advanced Technology Education program, including funding industry-driven research to inform program and curriculum expansion (Laney ECT, 2012). This paper highlights the need for a comprehensive technician education, which can address the need for energy efficiency as well as system-level diagnostics and problem-solving skills required for today's commercial building technician (BIG, 2010). It then introduces Laney's building technician curriculum and describes several key instructional strategies.

Background: Shortage of Adequately Trained Building Technicians

Under the direction of Laney's NSF-funded project, the Building Intelligence Group (BIG) prepared the research report *Current Situation and Trends in Building Operations* to support Laney's curriculum development efforts for its Environmental Control Technology (ECT) program (BIG, 2010). Based on primary research (surveys, interviews, and focus groups involving 300 participants) and secondary research (literature review including government and trade association resources and observations of current practices), the study highlights current trends and future directions of building operations, building control systems, and sustainability issues, with a special focus on technician skill gaps and education and training needs for building systems technicians operating high performance buildings.

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) provides the following definition of a “high performance” building: “A building and its systems are operated in a manner that increases environmental performance and economic value over time, seeks to establish an indoor environment that supports the health of occupants, and enhances satisfaction and productivity of occupants through integration of environmentally preferable building materials and water-efficient and energy efficient systems.” (ASHRAE, 2012) Building systems technicians are defined here as skilled technicians who install, operate, and maintain high performance building systems, including mechanical and electrical, fire/life safety, security, lighting, water, building automation, and energy management systems.

The BIG study identified that the primary challenges in high performance building operations have to do with the disconnect between the design and operations phases, gaps in communication between stakeholders, skill gaps among technicians, and the organizational culture of facilities overall, rather than technology shortfalls. Building technicians are often caught between multiple stakeholder groups, attempting to reconcile conflicting mandates, such as short-term occupancy comfort and long-term building energy efficiency (BIG, 2010).

The study identified a number of converging trends affecting the commercial building sector that are impacting the skill requirements for building technicians. These trends include a combination of rapidly evolving new technologies, economic drivers, and environmental concerns propelled by the convergence of information technology with automated building control and energy management systems, the need to contain rising energy costs by improving energy efficiency, and an increasing public and policy pressure for building owners to address sustainability concerns (BIG, 2010). Building systems technicians work on the frontline of the building operations and enable building owners to optimize building performance, contain operational costs, meet occupant needs for comfort, safety, and function, and reduce the carbon footprint of commercial buildings (PECI, 1999). For example, a case study of nine facilities shows that providing HVAC preventative maintenance can decrease energy bills by 6 – 19% (Abramson & Magee, 1999), and recent evaluations performed for the Building Operator Certification (BOC) training identified measurable energy savings resulting from improved operational practices after completion of the training (Navigant Consulting, 2011).

The authors of the BIG study also point to the absence of a widely accepted industry certification or national standard clearly addressing system level diagnostics and energy efficiency strategies. A major initiative by the U.S. Department of Energy to fund efforts to map national skills standards for building technicians reinforces the growing recognition of the need for the enhancement of building technician skills (DOE, 2012). These job/task analyses for the commercial building sector, once completed, are expected to inform national dialogue and decision-making on education and training needs.

The BIG study recommends development of clearly focused degree programs for technicians that include hands-on system-level problem-solving experience through labs and/or field experiences, communication skills, and negotiation skills to navigate building stakeholder dynamics (BIG, 2010). While a number of professional certifications exist for the commercial sector (including BOMI International’s Systems Maintenance Technician designation, Building Operator Certification (BOC) level I and II, Association of Energy Engineers’ Building Energy

& Sustainability Technician certification, United Green Building Council's LEED-O&M), the training modules and testing procedures for these certifications are generally more focused on theory than hands-on practice. To date, there is no equivalent in the commercial sector to the comprehensive Building Performance Institute's (BPI) certification process for the residential sector, and the full range of skill-sets required of today's commercial building technicians is not yet reflected in any single certification (BIG, 2010, Bobker, Joseph & Aslanian-Persico, 2010).

The need for education and training to develop enhanced skill sets for building technicians has been echoed by workforce and policy reports, including the Occupational Information Network (O*NET) (Dierdoff, et. al, 2009) and the Advanced Technology Environmental and Energy Center (ATEEC)'s report *Preparing Energy Technicians for the 21st Century Workforce* (ATEEC, 2010). The ATEEC report states:

> In the past, energy equipment installers were generally construction tradesmen. In the future, this work will likely be done by technicians who will service and maintain the equipment, as well as install it. HVACR technicians in the future will be expected to understand building science and smart monitoring and do energy audits. And the technicians who take the place of retiring commercial building operators will be expected to have higher-level skills to maximize the energy efficiency of sophisticated environmental control systems (p.20).

In 2009, the Centers of Excellence of the California Community Colleges (COECC) published *Energy Efficiency Occupations in the Bay Region*, which presented key findings of its research on energy efficiency occupations and employers in the San Francisco Bay Area. COECC found that more than 70% of surveyed employers reported difficulty in finding qualified HVAC mechanics, technicians, and installers. A total of 80% experienced difficulty in finding qualified building control systems technicians (COE, 2009).

Similarly, two related companion studies of the energy efficiency services sector by Lawrence Berkeley National Laboratories (LBNL) examined workforce size, expectations for growth, and workforce education and training needs (Goldman, et al., March 2010, September 2010). The reports noted an anticipated significant expansion in the energy services sector workforce, which is expected to increase by two-fold (low scenario) or even four-fold (high scenario) by 2020. According to one of the reports, "there is a concern among policy makers, program administrators and others that there is an insufficiently trained workforce in place to meet the energy efficiency goals being put in place by local, state, and federal policymakers." (Goldman et al., September 2010, p.1) The authors add, "Our results suggest that there are not enough certificates or degrees being awarded to meet the growing need." (p.84) While the actual jobs created in the weatherization sector appear below the predicted rates, in part due to expected building incentives not having been enforced, the projections for the HVAC and commercial sector remain high. For example, the Bureau of Labor Statistics (BLS) projects "excellent" job prospects for HVAC technicians, with faster than average job growth of 28% from 2008 – 2018 (BLS, 2010). The above studies underscore the urgent need for expanded training opportunities for building technicians.

Changing Skill Sets and Training Needs for 21st Century Building Systems Technicians

The advent of high performance buildings as defined above is changing the skill sets and training required for building systems technicians in order to adequately prepare them to operate increasingly sophisticated building systems. High performance buildings not only have more complex control systems than traditional buildings but have tighter control parameters to maintain optimal performance and meet specialized functions. Building systems technicians must have a deeper knowledge of building science and technology in order to solve the more complex problems posed by high performance buildings. According to the BIG study, this includes a comprehensive knowledge of the design of the building envelope, building systems and automation technologies, electrical distribution systems, systems integration capabilities, use of metering data, and how to communicate technical information to finance, procurement, building managers, owners, and occupants (BIG, 2010). The study emphasizes that there are a number of higher-level skills needed by building system technicians that should be integrated into community college HVAC curricula. These include: evaluating and measuring building energy performance, analyzing systems, calculating return on investment (ROI), measurement and verification of energy systems, fault diagnostics, and ongoing performance measurement (including energy efficiency, carbon footprint, occupant comfort and satisfaction). In addition to advanced technical skills, building technicians also need higher order thinking skills, including critical thinking, problem solving, and systems thinking. Technical skills, cognitive skills, and such soft skills as effective communication and teamwork are needed to be part of a building management team in high performance buildings.

Key Role of Community Colleges in Expansion and Improvement of Building Systems Technician Education

Currently, there are an estimated five million commercial buildings in the United States, supported by more than one million building maintenance technicians and over 300,000 HVAC technicians (BLS, 2011). For many years through the 1980's, building systems were relatively stable, familiar, and predictable; commercial building technicians were members of craft unions who learned their trade primarily "on-the-job" (OJT) by observing others and performing similar work under supervision. Due to the convergence of trends described above, beginning in the 1990's but with even greater intensity in the most recent decade, building control technology has advanced rapidly in sophistication and complexity, and now requires the mix of high level skills identified earlier. Community colleges have the capacity to significantly contribute to the emergent education and training needs for highly skilled building technicians. Because of their capacity to teach core STEM (science, technology, engineering, and mathematics) disciplines, they are well positioned to offer the breadth of academic disciplines to provide an in-depth education for building systems technicians incorporating physics, math, engineering, energy management, technical knowledge, and hands-on skill development, thereby complementing on-the-job (OJT) apprenticeship models that have been traditionally focused on training for more narrowly defined professional skill sets emphasizing component-level troubleshooting over system-level problem-solving (Bobker, Joseph & Aslanian-Persico, 2010).

Laney's Response to Integrated Technician Education

Starting in 2003, Laney convened focus groups and industry advisory meetings in order to explore the changing skill sets of the building technician and update its curriculum. Focus and advisory groups have involved stakeholders from industry, LBNL, Pacific Gas and Electric, and the California Energy Commission (Crabtree, et al., 2003). During these meetings, industry advisors repeatedly emphasized the importance of higher order systems thinking and problem-solving skills in anticipation of the demands on high performance building technicians, suggesting a list of course topics that is deeper and more rigorous than typically encountered in technician education and training. Funded by the Advanced Technology Education (ATE) program of the National Science Foundation (NSF) since 2005, Laney has consequently fully revised its HVAC curriculum and added a certificate and AS degree in Building Automation Systems. Based on the college's own observations, industry feedback, and research findings, both the HVAC Systems and the Building Automation program are now characterized by a system-level education and infusion of energy efficiency content throughout its curriculum. In addition, a track for Energy Management Technicians is in development.

Rigorous Building Technician Programs Infused with Energy Efficiency Content

Key characteristics of Laney's Curriculum include:

- Solid foundation in math and physics, contextualized in building systems: technical Math course offered in the first semester; Physics for Building Science required as core course for the Building Automation program.
- Mechanical and electrical skills: Most courses offer a lecture and lab component, providing for hands-on practice on actual equipment.
- HVAC systems installation, operation, and maintenance (residential, light commercial, and commercial) with emphasis on diagnostic skills: Courses reinforce system-level problem solving from multiple angles. Laney's full-size commercial HVAC system and multi-vendor building automation system provide for multiple opportunities for solving system-level challenges; supported by building systems software.
- Building performance and energy management: Energy efficiency is embedded throughout the curriculum. Energy efficiency strategies are addressed from the standpoint of component and equipment-level troubleshooting, equipment sizing and installation strategies, system-level problem solving and design, commissioning, energy efficient sequences of operations in control systems, and data analysis of building energy performance.
- Communication and team work: Students frequently work in teams, practicing their interpersonal and group process skills, including collaborating on scenario-based problems (see below).

Course titles are listed in Tables 1 and 2 to provide an overview of curriculum breadth and depth:

Table 1: Certificate and AS Degree in HVAC Systems, Laney College

First Semester	Second Semester
Fundamentals of Refrigeration	Advanced Refrigeration
Mechanical and Electrical Devices and Controls	Refrigeration Equipment Troubleshooting
Technical Mathematics for ECT	Fundamentals of Heating and Air Conditioning
Mechanical and Electrical Blueprint Reading	Heating and Air Conditioning Troubleshooting
Fundamentals of Electricity	HVAC Installation Practices
Mechanical and Electrical Codes	Motors and Drives
Welding for ECT Technicians	Energy Management and Efficiency in Building Systems
Third Semester	**Fourth Semester**
Commercial HVAC Systems	Advanced DDC Controls
Commercial HVAC Systems Troubleshooting	Indoor Air Quality and Building Envelope
Introduction to Building Commissioning	HVAC Systems Design
Testing, Adjusting, and Balancing	Data Analysis for Performance Monitoring
Commercial Electricity for HVAC Applications	Advanced Building Commissioning
Psychrometrics and Load Calculations	Introduction to Control Systems Networking

Table Source: Laney ECT, 2012

Table 2: Certificate and AS Degree in Building Automation Systems, Laney College

First Semester	Second Semester
Technical Mathematics for ECT	Mechanical and Electrical Devices and Controls
Fundamentals of Electricity for ECT	Commercial HVAC Systems
Physics for Building Science	Commercial HVAC Systems Troubleshooting
Introduction to PC Hardware and Software for Building Technicians	Introduction to Direct Digital Controls
	Introduction to DDC Hardware for Building Automation Systems
	Motors and Drives
Third Semester	**Fourth Semester**
Advanced Direct Digital Controls	Control Routines for Energy Efficiency
Introduction to Building Commissioning	Control Systems Integration
Blueprint Reading and Interpretation for ECT	Energy Issues, Policies, and Codes
Control Systems Design	Data Analysis for Performance Monitoring
Control Systems Networking	Advanced Building Commissioning
Testing, Adjusting, and Balancing	

Table Source: Laney ECT, 2012

Several other community colleges have also developed comprehensive curriculum with specializations in various focus areas of building technicians. However, few have the same level of breadth and depth as Laney's two programs described above. For example, Georgia Piedmont Technical College offers a 67 credit certificate in Building Automation Systems with a detailed sequence on building automation systems design, programming, and integration. Milwaukee

Area Technical College offers a certificate in Sustainable Building Operations that includes courses in building performance, auditing, measurement and verification, energy management software, and commissioning. Seneca College in Toronto offers a two-year diploma in Building Systems Engineering that integrates courses in HVAC, engineering, controls, energy efficiency, and energy technologies. A few colleges offer 12–18 month sequences in energy management, with Elgin Community College and Salt Lake Community College linking energy management most directly to efficient HVAC systems maintenance practices and building operations. Internships and capstone projects that allow for applied and integrated learning are integrated in several of the programs identified above.

As part of its NSF-funded efforts, Laney has established a national network of building performance and HVAC instructors and launched a resource sharing website (www.bestcte.org) that also serves as a communication clearinghouse. The purpose of the network is to highlight curriculum models across the country and provide a platform to encourage rich peer interaction so that community colleges can benefit from each others' important work in this area. For example, over the last three years, Laney hosted a regional conference for building performance instructors, a national 2-day intensive workshop, as well as two webinars addressing issues of program and curriculum development and certification.

Example of Successful Instructional Strategies: Problem-based Learning

Problem-based learning (PBL) is a learner-centered pedagogy in which students explore a subject in the context of complex, multifaceted, and realistic problems. Students are immersed in open-ended scenarios simulating real-life work situations. The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation (Barell, 2006). Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. The role of the instructor is that of facilitator of learning who supports student teams throughout the process. Originally pioneered in medical schools, PBL has been further developed with National Science Foundation Funding to be applied in career and technical education (PBCL, 2012).

It is important to distinguish problem solving from troubleshooting in this context (the latter of which is often taught in building technician or apprenticeship programs as part of a component-level check-list approach, typically resulting in one correct solution). Problem solving is an open-ended inquiry, considering multiple contributing factors and multiple potential solutions that may go beyond the initial definition of the problem. It offers a broader system-level approach to learning. In PBL, typically, a problem or scenario is presented as it would be in the real world, i.e., with a set of knowns and unknowns. The scenario is open-ended allowing for critical thinking and analysis, thus generating a range of possible solutions. Students determine if the problem suggested is the real problem or whether there is a different problem that needs to be solved. PBL is an investigative methodology: It exposes students to scenarios where there are interactions between complex and competing variables. Students are encouraged to learn how to learn and to develop adaptive expertise, which is an increasingly important asset for the building technician's role as an effective operator of complex facilities. At Laney, scenarios have been developed by instructors who are simultaneously working in the industry as building technicians, building engineers, HVAC mechanical engineers, commissioning agents, and energy managers. All scenarios are based on real-life contexts, some use real-life building data of actual buildings.

Laney's students represent a mix of working professionals and incumbent workers, career changers, and, to a lesser degree, high school graduates. Structured interview responses have shown that the PBL approach benefits each of these learner groups.

At Laney, instructors attended several problem-based learning workshops sponsored by the National Science Foundation and have since continuously adapted the approach to its student population.

Scenario topics have included:

- Solid foundation in math and physics, contextualized in building systems: technical Math course offered in the first semester; Physics for Building Science required as core course for the Building Automation program.
- Mechanical and electrical skills: Most courses offer a lecture and lab component providing for hands-on practice on actual equipment.
- Developing a plan for solving major indoor air quality issues in a conference room.
- Measuring air flow and developing an air balancing report of a classroom.
- Creating a commissioning plan for a specific facility (with team members playing roles of different professionals in the commissioning process), including defining the design intent, creating a description of a new/existing facility's energy requirements (Title 24), and creating a construction checklist.
- Designing a small HVAC system for a residential house.
- Balancing critical facility operations with energy savings when there are high stakes, such as saving a critical science experiment in a specific research facility while the chiller was faulty.
- Investigating the reason for a control light being on in a university laboratory (involves understanding complex sequences of operation).

An external evaluator has followed Laney's efforts closely and has reported his findings in his annual evaluation report, , based on structured interviews conducted with students, as well as on-line student surveys (Saflund, 2011). Questions asked of students include their reflections of their experience working in groups, what learning experiences they felt most or least comfortable with, what the biggest difference of this project was compared to other classes they have taken, to what degree the skills learned would help them in other classes or on the job, as well as open-ended questions describing a problem they had to solve and where else the skills learned may apply. Findings include:

- Increased tolerance for ambiguity, lack of information and the absence of an obvious "right answer"
- Improved understanding of the value of finding out what the *real* problem is as opposed to wasting time on what the problem first appears to be
- Appreciation for having to simulate a real job situation, including documenting the analytical steps to present to the class so that others will understand what happened
- Having to think and plan before diving in and trying to fix things
- Appreciation of other team members' perspectives
- Appreciating the value of asking questions before having answers

According to student survey data, 80.8% would select a course involving problem-based learning versus a traditional lecture class. 84.6% of students would recommend a course including problem-based learning elements to a fellow student (Saflund, 2011).

Structured interview responses suggest that almost all students were able to identify specific skills practiced under this mode of instruction that were different from traditional classes, particularly: working with others; listening to other points of view; learning from others; and how to offer opinions that differ from those of others. Furthermore, 80% of students interviewed were able to offer at least two ways that what they learned from the PBL experience would help them in future classes or on the job. The most often offered answers contained some mention of getting a bigger picture as a result of the PBL research and teamwork activities (Saflund, 2011).

Student testimonies from structured interviews include:

> *"What we work with now is so much more complex and the lab at Laney really helped me understand how the new systems work"*

> *"You look at a problem differently, it's not just about fixing the problem. You look at what's happening overall, at the whole picture, and don't rely on others pointing out to you what's wrong. You don't go to the problem first, but think before and after looking at that part of the system, you look at it in a better view if you know the whole system."*

Laney has not yet tracked students who have completed PBL scenarios to determine the application of PBL skills on the job. This would be an important area of future research. The implementation of PBL at Laney College has not been without challenges, however. These include:

- Students being initially skeptical and resistant because they are expecting to be told what to do and are not used to taking responsibility for their own learning. As they begin to practice open-ended problem solving in groups and learn with their more experienced peers, and especially as they repeat the PBL process in future semesters, they begin to embrace the unique value of learning in this way.
- Instructors who are initially more comfortable with lecture-style teaching or utilizing a traditional troubleshooting approach in lab-work have needed support in embracing more open-ended problem-solving.
- There has been a perceived pressure by instructors that PBL takes away from content to be covered.

The Laney team has found that each of these challenges can be overcome over time as students and instructors become increasingly familiar with the learner-centered approach of PBL. Laney ECT faculty members now convene at least twice a semester for a professional development meeting to collaborate on PBL scenarios and curriculum integration and to provide each other with feedback and encouragement. Instructors have reported that they have begun to really enjoy utilizing the PBL approach and have noticed students becoming significantly more engaged in the learning process.

Conclusion

Building technicians must play a prominent role as proactive energy champions in their facilities, in order to meet increasingly stringent energy performance and greenhouse gas reduction requirements. A significant barrier identified in this paper is the insufficient knowledge and skill level of building technicians operating sophisticated high performance buildings. This paper introduced system-level curriculum for building technicians developed by Laney College and highlighted problem-based learning as a successful instructional strategy that stimulates the adaptive expertise required of building technicians to optimize building performance. Laney's and other partner colleges' curriculum models are intended to provide a valuable resource for community colleges nation-wide seeking to develop and enhance programs in the dynamic field of building operations for high performance buildings. In the future, Laney plans to continue and expand its professional development and program dissemination efforts, further documenting Laney's and partner colleges' best practices in system-level building performance education and training.

References

Abramson, B.C.; M.S. Magee. 1999. "Quantifying the Energy Benefits of HVAC Maintenance Training and Preventive Maintenance." *Energy Engineering* 96(2): 46-60.

[PECI]. Portland Energy Conservation, Inc. 1999. *Operations and Maintenance Assessment: A Best Practice for Energy Efficient Building Operations. PECI O&M Best Practices Series*. Prepared with funding from the U.S. EPA and U.S. DOE

[ASHRAE] American Society for Heating, Refrigeration, and Air Conditioning Engineers. 2012. *ASHRAE Standard 189.1: Standard for the Design of High Performance, Green Buildings*. http://www.ashrae.org/resources publications/bookstore/standard-189-1

[ATEEC] Advanced Technology Environmental and Energy Center; American Association of Community Colleges, National Science Foundation. December 2010. *Preparing Energy Technicians for the 21st Century Workforce: A Report of the National Energy Technician Education Summit*, December 8-10, 2010 in Washington, D.C.

Barell, John, F. 2006. *Problem-Based Learning: An Inquiry Approach*. Corwin Press, Thousand Oaks, Calif..

[BIG] Building Intelligence Group. 2010. *Current Situation and Trends in Buildings and Facility Operations*. Prepared for Laney College, NSF Advanced Technology Education Project DUE.www.laney.edu/wp/environmental_control_tech/building_operations_report/0802595

[BLS] Bureau of Labor Statistics. 2011. *Careers in Green Construction.* www.bls.gov/green/construction

[BLS] Bureau of Labor Statistics. 2010. *Occupational Outlook Handbook*, 2010-11 Edition; http://www.bls.gov/oco/home.htm

Bobker, M., V. Joseph, A. Aslanian-Persico. 2010. "Addressing the Operator as a Driver of Building Performance." *ACEEE Summer Study on Energy Efficiency in Buildings*. American Council for an Energy Efficient Economy ACEEE.

[COE] Centers of Excellence. 2009. *Energy Efficiency Occupations: Bay Region*. Economic and Workforce Development Division. California Community Colleges Chancellor's Office. Greater Silicon Valley and San Francisco Bay Area. http://www.coeccc.net/energy.

Crabtree, Peter, Nick Kyriakopedi, Evan Mills, Philip, Haves, Roland J. Otto, Mary Ann Piette, Peng Xu, Rick Diamond, Joseph J. Deringer, Chuck Frost. 2004. "Developing a Next-Generation Community College Curriculum for Energy-Efficient High-Performance Building Operations." *Summer Study on Energy Efficiency in Buildings*. American Society for an Energy Efficient Economy (ACEEE). Washington, D.C.

[DOE] Department of Energy. 2012. "Draft Job and Task Analyses." Commercial Building Initiative. http://www1.eere.energy.gov/buildings/commercial_initiative/workforce_task.html

Dierdoff, E., J. Norton, D. Drewes, C. Kroustalis, North Carolina University; D. Rivkin, P. Lewis, The National Center for O*NET Development. 2009. *Greening of the World of Work: Implications for O*NET-SOC and New and Emerging Occupations*. Prepared for the U.S. Department of Labor, Employment, and Training Administration, the Office of Workforce Investment, Division of Workforce System Support, Washington, D.C.

Goldman, C.A., J.A. Peters, J. Albers, E. Stuart, and M. Fuller. March 2010. *Energy Efficiency Services Sector: Workforce Education and Training Needs*. Lawrence Berkeley National Laboratories. Environmental Energy Technology Division. Prepared for and funded by the Office of Energy Efficiency and Renewable Energy, Weatherization and Intergovernmental Program and Office of Electricity Delivery and Energy Reliability-Permitting, Siting and Analysis Division of the U.S. Department of Energy under Contract No. DEAC02-05CH11231

Goldman C., M. Fuller, E. Stuart, J. Peters, M. McRae, N. Albers, S. Lutzenhiser and M. Spahic. LBNL-3987E. September 2010. *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth*. Lawrence Berkeley National Laboratories. Environmental Energy Technology Division. Prepared for and funded by the Office of Energy Efficiency and Renewable Energy, Weatherization and Intergovernmental Program and Office of Electricity Delivery and Energy Reliability- Permitting, Siting and Analysis Division of the U.S. Department of Energy under Contract No DE-AC02-05CH11231

Laney ECT. 2012. "Laney College Environmental Control Technology Program" http://www.laney.edu/wp/environmental_control_tech/

Navigant Consulting. 2011. *Evaluation of MN BOC Training*. Prepared for: Midwest Energy Efficiency Alliance and Minnesota Office of Energy Security Chicago, IL

[PBCL] "Problem-based Case Learning." 2012. http://www.makinglearningreal.org/index.html

Saflund, Peter. 2011. *Year 3 Evaluation Report, DUE 0802595, Laney College*. The Saflund Institute, Covington, WA