# AC 2012-4534: DEVELOPING RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL ASSESSMENT PROGRAMS IN COMMUNITY COLLEGES

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# Developing Residential, Commercial, and Industrial Assessment Programs in Community Colleges


## Abstract

Environmental issues, U.S. dependence on foreign oil and depleting fossil fuel reserves: all of these issues are increasing awareness for the need for energy efficiency education programs in community colleges. Almost half (49%) of all energy produced in the U.S. is consumed by the building sector. This is almost the same amount of energy consumed by both transportation (28%) and industry (23%) combined. According to the U.S. Energy Information Administration [1], fossil fuels supply 76% of the total building sector energy consumption.

The development of training programs which teach residential, commercial, and industrial energy assessments can be accomplished with a series of seven courses:

1. Weatherization Training
2. Building Performance Training
3. Architectural Energy Analysis
4. Introduction to Energy Management
5. Energy Control Strategies
6. Commercial and Industrial Assessment
7. Capstone Project

Weatherization Training incorporates hands-on training of the installation of various types of insulation, performance testing with the blower door and duct blaster, air sealing procedures and verifications, indoor air quality standards and verification, and combustion appliance zone safety testing. Building Performance Training incorporates many of the subjects covered in weatherization training but focuses on the assessment procedures with respect to utility study, data collection, moisture and mold issues, systems operation, and indoor air quality. Architectural Energy Analysis covers in-depth building sciences, energy use simulation software operation, in-depth utility analysis with statistical procedures, estimation of energy savings and cost associated with retrofits of designs, and report format and writing. Introduction to Energy Management incorporates utility rate structure, energy management programs, and a survey of energy saving opportunities in commercial and industrial facilities. Energy Control Strategies incorporates spreadsheets, computer programs, and performance simulation software to estimate energy savings, implementation costs, CO2 reduction, and utility cost savings with the implementation of energy saving opportunities. Commercial and Industrial Assessment incorporates utility analysis, on location assessment format, operation of data collection equipment, and compiling final reports. The Capstone Project provides the real-world experience of the entire assessment experience.


## Introduction

The sequence of seven courses teaching energy assessment of residential, commercial, and industrial buildings and facilities, are a sequence of courses in an the Energy Management

degree program at Sinclair Community College in Dayton, Ohio. The program includes standard general education courses, but most importantly includes math and sciences courses and introductory courses in heating and air conditioning. As the Weatherization Training and Building Performance Training are designed to prepare the student for the Building Performance Institute [2] certification testing for the Envelope Professional and Building Analyst Professional, these two courses can be taken as stand-alone courses. However, their focus is primarily on residential buildings. The remainder of the seven courses that teach the student the complete assessment process of residential, commercial, and industrial buildings and facilities are intended to be sequential with each course building on the previous course's material. Architectural Energy Analysis introduces heat transfer, thermal resistance and thermal conductivity of building components, standard construction procedures, HVAC systems, and overall energy analysis procedures and is the first in the sequence of courses. Architectural Energy Analysis is a co-requisite to Introduction to Energy Management which focuses on the energy saving opportunities of commercial assessment in industrial building and facilities. Energy Control Strategies, Commercial and Industrial Assessment, and the Capstone Project are taken as a sequence with both Architectural Energy Analysis and Introduction to Energy Management as prerequisites. This sequence requires a minimum of four terms to complete.

The courses and the program are strengthened if they incorporate real world field experience for the students. This requires establishing partnerships with local area non-profit organizations and local businesses in the related design and/or assessment industry that can provide these locations for field experiences. These partnerships can be established by assembling an Advisory Board to help ensure the program meets the needs of the community. The businesses of the Advisory Board members can also provide opportunities for internships and job locations for the students completing the program. As the students in this program are being prepared to enter the assessment industry in a wide range of capacities from weatherization of residential homes to managing energy use of complete facilities, a wide range of the industries is represented on the Advisory Board.

A complete description of each course makes explicit the prerequisite and co-requisite required. The descriptions also provide insight into the wide range of job opportunities for the graduates of the program and the wide range of business that can be represented on the Advisory Board.

**Weatherization Training**

Weatherization training focuses on residential new construction methods and existing housing retrofitting methods to reduce energy use and to maintain and/or insure indoor air quality. Weatherization training teaches proper installation of wall and ceiling insulation, air sealing methods and priorities, pre- and post-testing of air infiltration to ensure indoor air quality, pre- and post-testing of HVAC ductwork to determine total leakage and leakage to outside, pre- and post-testing of the combustion appliance zone for depressurization, and pre- and post-testing of combustion appliance spillage and undiluted carbon monoxide in the flue gases.

Proper equipment and facilities are required to teach a student the proper use of the blower door and to teach a student the methods to calculate the minimum air flow standards and requirements for mechanical ventilation. Equipment and facilities are also required to teach a student the

proper use of the duct blaster and methods to determine total duct leakage and leakage to outside the building's thermal envelope and air barrier. As indoor air quality is a priority, equipment and facilities are required to teach a student how to measure the depressurization of the combustion appliance zone and the maximum acceptable depressurization limits. Also important to indoor air quality is the determination of flue gas spillage from a natural drafting combustion appliance during the startup period of the appliance and its steady state carbon monoxide content in the undiluted flue gas. To determine the location of the air barrier and the location of air leakage through the air barrier, equipment and facilities are required to teach a student the use of a monometer to determine the air barriers location and the use of a pressure pan to determine the location of air leakage in both the air barrier and the ductwork. As retrofitting and/or construction methods are procedures the student is learning, mock-ups are required to teach the student proper methods to install the air barrier in ceiling, walls, floors, and around windows and doors, seal ductwork, and install various types of wall and ceiling insulations.

A course on weatherization includes old and new construction materials and procedures. The course also includes building science: R-values, U-factors, thermal barrier, air or pressure barrier and its alignment with the thermal barrier, and house as a system. The course also includes types of residential heating and air conditioning system, domestic hot water systems, electric appliance energy use and efficiencies, and lighting types, lighting efficiencies and controls, and phantom loads. To teach the student the importance of the thermal and air barriers, equipment and appliance efficiencies, and unregulated electric loads, the course includes examples of home energy use, separating out the heating and cooling requirements of the home components and the heating and cooling requirement of air infiltration, and the utility use of the unregulated electric loads.

The Building Performance Institute [2] offers Envelope Professional Standards [3] which can be used as a guideline to develop a weatherization training course.

**Building Performance Training**

Building performance training also focuses on new residential construction methods and existing housing retrofitting methods to reduce energy use and maintain and/or insure indoor air quality. However, building performance training focuses on teaching the student the performing of the original assessment and its procedures and outlining the retrofitting and/or indoor air quality issues to be addressed by the weatherization personal, and not on the actual performing of the retrofit measures and/or the original field construction. The course teaches the student to use all the same equipment and perform all the tests as the weatherization student and requires all the same equipment and facilities with the exception of the mock-ups for the installation of the insulation and the air sealing. The course also teaches the student building science as in the weatherization training. However, the building performance student additionally learns to analyze the utility bills, assess water and moisture issues, identify areas of thermal and air bypass, identify indoor air quality issues, and write a work scope to be addressed by the weatherization personal. The one additional facility requirement is a home or facility for the student to perform the assessment.

The Building Performance Institute [2] offers Building Analyst Standards [3] which can be used as a guideline to develop a building performance training course.

**Architectural Energy Analysis**

A course in architectural energy analysis can be taught as a stand-alone course to architectural students or as a necessary requirement in the assessment sequence. The course teaches the student to analyze and control the energy consumption of both residential and commercial buildings with the building's envelope, mechanical systems, and operational procedures. The course teaches the student the details of heat transfer: kinetic theory, conduction and conduction coefficients, convection and convection coefficients, radiation heat transfer, and body heat loss due to evaporation. The course also teaches the student the thermal resistance of different materials, R-values and U-factors, convection coefficients as a function location, interior or exterior and the effects of wind velocity on the convection coefficient. The student also learns basic sciences related to change of states, sensible and latent heat. Composite building components such as wall structures are studied to determine the resulting overall thermal resistance. The students learn window specification; solar heat gain factor, U-factor, infiltration, and visible light transmittance along with the effect of the window's location on heating and/or cooling loads. Exterior door specifications are also covered. Daylighting and its effect on the reduction of electric use for artificial light are also covered. As an introduction to heating systems the student learns the combustion process, products of combustion, high and low heating values and the technology of standard and condensing furnaces. Annual fuel utilization efficiency and sessional energy efficiency ratios gives the student insight into equipment efficiencies. The student is given an introductory education of commercial HVAC systems, chillers and chilled water systems, boilers and hot water distribution system, and outdoor air requirements along with the energy costs of conditioning outdoor air and demand ventilation systems.

The course teaches the student energy codes and how to access the energy codes as a function of state and local requirements. Code compliance procedures such as the prescriptive method, the UA-tradeoff method and simulation are covered in detail. The course covers the compliance software RES*check*, Com*check*, and REM/*Rate*. To effectively perform an energy assessment, the student is taught to collect field data and utility data from both residential and commercial buildings and enter the data into simulation software to accurately estimate the energy saving and cost savings for initiating retrofits and/or alteration in the envelope, the mechanical system, and the operational procedures. There are several good commercially available simulation programs on the market but e*QUEST* is available as a free download [4]. In order to understand the operation of simulation software, the students learn TMY and TMY2 weather files and their use by simulation programs.

The performing of an energy assessment of an existing building it is necessary to perform a complete utility analysis. This requires separation of the temperature dependent energy use from

the temperature independent energy use. The temperature dependent is a function of the heating and cooling of the building and the temperature independent is a function of the constant energy use such as domestic hot water, lighting, and office equipment. To perform this utility analysis a procedure of linear regression is used. To perform this linear regression actual weather file must be used. The course teaches the student where to access these actual weather files and how to use these files and utility data to construct a linear regression of the utility use. The slope of the line represents the overall UA of the building which is a function of the building envelope efficiency, the efficiencies heating and cooling systems, and the infiltration and/or mechanical ventilation of outside air to maintain indoor air quality. An example of a linear regression graph is given in Figure 1 below.

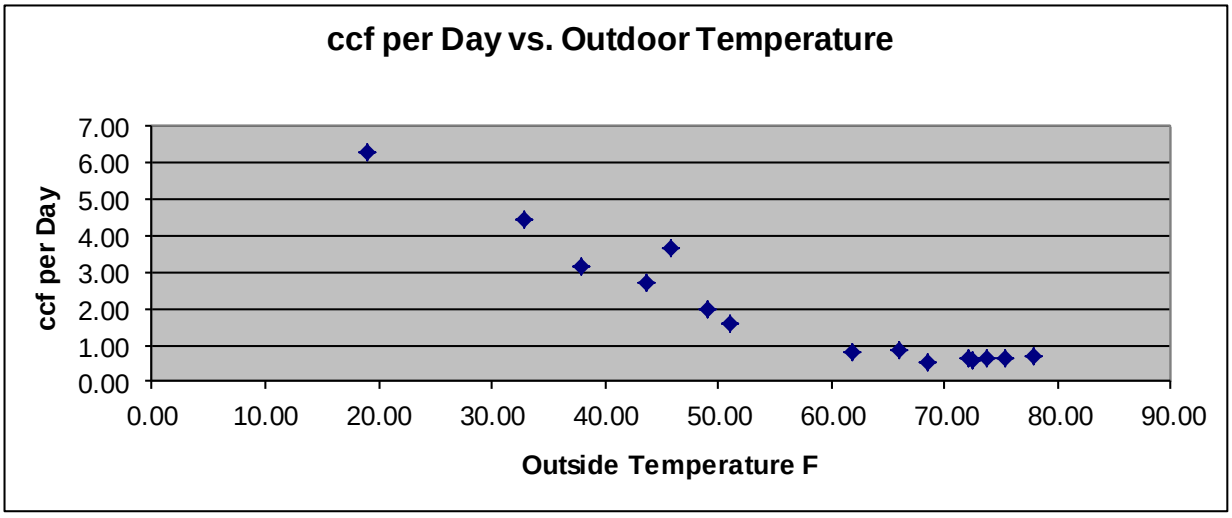


Figure 1. Example of linear regression graph. Natural gas use in ccf per day verses the outside temperature in degrees Fahrenheit.

With the proper units applied, the slope of the line has the units of Btu/h-F. Dr. Kelly Kissock, Director of the University of Dayton Industrial Assessment Center, University of Dayton, Dayton, Ohio has developed a program, ETracker [5], which constructs the linear regression. Dr. Kissock has actual weather files and a free copy of ETracker with the manual available.

The students are required to independently perform a residential energy assessment which includes a blower door test to determine the energy use as a function of infiltration. The student uses a data collection sheet and the utility analysis to perform a simulation and estimate the energy and cost reduction with specified retrofits. The student then submits a full audit report as a deliverable, course requirement.

**Introduction to Energy Management**

Introduction to energy management focuses on teaching the student energy saving opportunities in both commercial buildings and industrial facilities. The course covers a broad range of energy

saving opportunities and gives quantitative examples of each. The student learns these quantitative procedures in the next sequence of courses. The purpose of this course is to teach the student to complete a formatted assessment of a commercial building and/or an industrial facility and list the energy saving opportunities with some knowledge as the amount of energy and dollar savings potential.

The course begins covering global energy production and global energy use and known reserves of natural resources. Hubbert peak oil is covered in detail and related to today's reserves and production rates. The solar constant is introduced and compared to the global energy use. The potential for renewable energy is studied. Any energy conservation program begins with an effective energy management plan. Several plans are studied and the commonality between them is noted. The core of the course examines the energy saving opportunities with the building or facility envelope, the mechanical system of both commercial and industrial systems, operational procedures, and industrial systems such as process heating and cooling, compressed air, exhaust air, etc.

As the operation and components of the HVAC systems are a large influence on a facility's energy use, the examination begins with the heating and cooling systems. An overview of heating and cooling systems is studied with the topics ranging from the types of distribution systems, forced air, hydronic, steam, radiant and the advantages and disadvantages of each to boilers, chillers, cooling towers and many topics between. An in depth study proceeds with a complete glossary of terms covering system components, air conditioning, dehumidification, variable speed drives, two-way versus three-way valves, motor efficiencies, constant volume systems, variable air volume systems, dual-duct systems, system rightsizing, controls, demand ventilation, energy-efficient belts, constant and variable speed chillers, cooling towers, single-loop conversions for chilled water system, temperature resets, base-load and trim boilers, etc. Types of HVAC control system are studies and an overview. Many examples are presented to demonstrate the energy savings in addressing the topics studies.

Lighting systems and controls are the next topic of study with a detailed examination of different light sources and their efficiencies and characteristics. Many examples are presented to demonstrate the saving potential resulting from lighting and/or fixtures upgrades, fixture maintenance, lighting controls, and daylighting.

A detailed and complete building tune-up including addressing the building envelope is studied, and many examples are presented to estimate the energy and cost savings of each. The commercial energy saving opportunities is completed with a wrap up of other load reductions and a study of utility rate structure. The EPA has five publications which can be used as content for the commercial portion of this course [6], [7], [8], [9], [10]. An energy conservation assessment check is available as a guide to constructing a complete commercial course [11].

The industrial portion of the course teaches the student the energy saving opportunities that may exist in an industrial facility. Some of the opportunities in an industrial facility are the same as commercial opportunities but many are unique to industrial facilities. Lighting is the first are of investigation. The office areas in an industrial facility are similar to commercial, but the production area is different in that lighting is usually high and its purpose is to light actual work

space. Types of lighting and location of lighting relative to the workman many times provide opportunities. Industrial facilities frequently have warehouses with very unique lighting needs. Lighting types provide opportunities and as lighting is only a need in the area of occupancy, controls offer many opportunities. The student examines these lighting opportunities and many quantitative examples are given. Industrial facilities usually have a large number of electric motors driving presses, hydraulic pumps, etc. There are many opportunities simply involving turning the motors off when not in use. Many facilities rewind motors as apposed the purchasing new high efficiency motors. New, high efficiency motors can offer energy saving opportunities with a predictable and acceptable payback time. Pulley belt drives are in common use in industrial facilities and simply replacing smooth belts with notched V-belts results in energy and cost savings along with a reduced maintenance schedule. The student examines these opportunities, and, again, many examples are studied. Industrial facilities usually have many pumping operations which provide opportunities for right sizing pumps and installing variable frequency drives. The student examines these opportunities with many examples. Compressed air many times is a large energy consumer in an industrial facility. The compressed air systems are examined for storage, maximum pressure, base load and trim load compressor staging, drying equipment, and leaks. The student studies these opportunities with examples. Industrial facilities usually have high demand electric equipment, and their electric utility rates are a function of their demand. Staging of startup of the equipment and shift rearranging to reduce their peak demand offers a reduction I electric utility cost. The student studies peak demand management. Many industrial facilities have process heating and cooling. These present many opportunities such as using waste process heat for combustion preheat. The student examines this and other opportunities with quantitative examples. Many industrial facilities require large amounts of exhaust air to remove contaminates from the facility in order to maintain indoor air quality. Reducing exhaust air to a minimum, using variable frequency drives, and taking advantage of point source exhaust offers many energy and cost saving opportunities. Rutgers University has a manual available for industrial assessment [12]. Much of the manual covers the suggested assessment process to be used by the DOE supported Industrial Assessment Centers at twenty-four centers at universities throughout the nation. However, the manual can provide the opportunities available in industrial facilities.

**Energy Control Strategies**

This course is designed to teach the student to use all the spreadsheets, short-form simulation software of systems, and a number of complete energy simulation software programs to estimate the amount of energy and cost saving opportunities, and simple payback times, examined in the preceding course, Introduction to Energy Management Principles. The course begins, as all assessment begins, with an in depth utility analysis using linear regression. The student's knowledge of the regression is expanded from separating the temperature dependent energy use from the temperature independent to include a study of the energy use as a function of production, be it pounds of product, number of products, or number of student sections. There are many commercially available, complete energy simulation software programs whose site license can be obtained for educational institutions. However, the spreadsheets and short-form software programs to simulate individual system are not readily accessible. Many of the twenty-four Industrial Assessment Centers have software available on their websites. Also, the Department of Energy has many programs available that can be used in this course.

## Commercial and Industrial Assessment

This course teaches the student to use the data logging equipment to collect the information from a facility, commercial or industrial, to perform the assessment. The student learns to data monitor lighting for amount of electric use, demand use, and scheduling. The student learns to monitor the air distribution system for outside air temperature and humidity, supply and return air temperature and humidity, supply and return hot or chilled water temperature, and the pumps and fan motors current draw and scheduling. The student further learns to data log hydraulic pump motors and equipment motors for both continuous current draw and scheduling and startup current draw to determine advantages of turning motors off when not in use. The student learns to follow a format for logging all the systems and/or equipment in both commercial and industrial facilities.

## Capstone Project

The capstone project gives the student the opportunity to go to an actual facility, commercial or industrial, and perform a complete assessment and prepare an assessment report prioritizing the energy saving opportunities with estimated payback times. This course project, requires the student to use all the information and skills acquired in the preceding course sequence. This course project requires a community partner who is willing to allow the students access to utility bills and access to the facility to collect visual data, and help with data logging equipment and systems as required.

## Summary

This sequence of courses is designed to equip the student with the knowledge and skills necessary to perform energy assessments on single and multifamily homes, commercial buildings, and industrial facilities. The student learns formats for the assessment process, the use of diagnostic equipment and data logging equipment, and formats for preparing reports with prioritized energy saving measures


1. U.S. Energy Information Administration (2009). To create a U.S. Building Sector, the residential buildings (operations) sector, commercial buildings (operations) sector, and industrial buildings (operations and materials embodied energy estimates) were combined.

2. http://www.bpi.org/
3. http://www.bpi.org/standards_approved.aspx
4. http://doe2.com/equest/
5. http://academic.udayton.edu/kissock/http/Weather/default.htm
6. http://www.cleanaircounts.org/resource%20package/A%20Book/EStar%20Buildings/buildings%20manual/stage1.pdf

7. http://www.cleanaircounts.org/resource%20package/A%20Book/EStar%20Buildings/buildings%20manual/stage2.pdf
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