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Center for Energy Education Laboratory

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Center for Energy Education Laboratory

Introduction

Sinclair Community College in Dayton, Ohio, designed and constructed a Center for Energy Education Laboratory to support its Energy Management Degree and Energy Technology Certificate programs. As a renewable energy program is included in the Energy Management Degree, energy efficiency and renewable energy equipment, instrumentation and projects are included in the laboratory.

The laboratory was initially designed and constructed as student projects. The students received credit for the required internship in their programs. The initial laboratory contained an Energy Star home mock-up, biodiesel processor, ethanol distillation equipment, 1kW fuel cell, solar drag race exhibit to support a community outreach program, and kiosks with energy simulation software, code compliance software, and many Power Points and DVD's to educate the students and the community about energy efficiency and renewable energy. The initial laboratory equipment and instrumentation purchase was supported with a budget allocation from the Engineering Division.

Students Constructing Energy Star Mock-up

Biodiesel Processor and a Kiosk

As the renewable energy program grew, another budget allocation funded the purchase of an off-grid solar photovoltaic system, a solar thermal system, and a 1 kW wind turbine. Further equipment purchases were funded through the acquisition of grants and appropriations. The laboratory now has equipment to test the biodiesel fuel produced which is used in the grounds equipment to mow the grass and sweep the snow. To support the residential energy efficiency courses, there are blower doors, duct blasters, combustion analyzers, thermal imaging equipment and insulation blowing equipment. The renewable energy courses are further supported with a 1.4 kW additional solar photovoltaic system and an additional 3 kW wind turbine. The commercial and industrial energy efficiency courses are supported by pumps, motors, variable frequency drives, coils with two way and three way valves, and data logging equipment.

1 kW Wind Turbine

The Center for Energy Education Laboratory is a vital component in support of the renewable energy and energy efficiency courses. Laboratory projects are used to demonstrate energy efficient designs and retrofitting measures to existing building envelopes and mechanical systems. Equipment is used to teach assessment procedures for residential, commercial and industrial facilities. Such a laboratory is a necessary component in renewable energy and energy efficiency educational programs.

Laboratory for Residential Applications

The two processes which are addressed in the laboratory with respect to residential requirements are assessment and weatherization. Assessment requires equipment to quantify thermal envelope, air barrier, HVAC ductwork air tightness, combustion appliance performance and indoor air quality. Weatherization requires mock-ups to install insulation in the thermal envelope, mock-ups to install the air barrier, and HVAC ductwork sealing and insulation.

In heating climate zones, usually the largest contributor to the heating load is air infiltration. Residential indoor air quality is maintained by air infiltration, and therefore a minimum amount of infiltration is required, usually 0.35 air changes per hour. This is 35% of the total volume of the living space of the residence. However, in a large number of residences, the actual infiltration exceeds the required minimum. Therefore, there is a need to quantify the amount of infiltration and also to determine the locations of infiltration. This requires a blower door. A blower door is an adjustable speed fan mounted in an airtight frame which is installed in an exterior door. The fan speed is adjusted to create a pressure differential of 50 Pascal between the interior and exterior air pressure usually by pulling air out the residence and creating a vacuum relative to the exterior. The fan assembly has a read-out, in cubic feet per minute, of air flow that is required to maintain the pressure differential. The determined air flow is then adjusted to estimate the natural infiltration. The locations of the infiltration are usually readily determined by using a smoke pencil to detect air movement. After these locations of air infiltration are sealed, the blower door is used again to determine whether the minimum required infiltration is maintained. The largest required laboratory component with respect to measuring air infiltration is a facility for training the students in the proper use of the blower door and the interpretation of the results. A home mock-up serves well.

Student Performing Blower Door Test in Mock-up

In residences with air distributions systems, if the duct work is not properly sealed, a substantial amount of air can leak from the system. It is obvious that for the duct work or distribution system outside the thermal envelope, the leakage will be into unconditioned space. As a result, not only is conditioned air lost, but for every cubic foot of air lost from the envelope, air must infiltrate to replace it. The infiltration must then be conditioned to the desired conditions. What is not as obvious is that duct work or the distribution system that is wholly contained within the thermal envelope if not properly sealed can also result in air loss to the exterior. The duct work is contained in cavities within the envelope which become pressurized if leakage occurs. These pressurized cavities find communication with the exterior to form a pathway for air loss. The duct blaster is required to measure both the total duct leakage and the leakage to the exterior. The ductwork is pressurized to 25 Pascal with the duct blaster. The leakage is compared to the flow rate of the HVAC system. Also required is a duct work system to train the students in the proper use and interpretation of the results of the duct blaster.

Student Performing Duct Blaster Test

The thermal barrier of the envelope provides resistance to conductive heat losses or gains to or from the interior. The thermal barrier is the insulation. The unfinished basement or crawlspace insulation and ceiling insulation when exposed in an attic can be visually inspected to determine its material and thickness to obtain an estimated thermal resistance, R-value. However, when the ceiling insulation is not exposed in an attic and wall insulation is contained in a cavity, the estimation of its value is more difficult. A thermal imager is a necessary tool used to determine the effectiveness of the insulation in cavities. It is used to determine an estimated value of the insulation and to determine any missing portions of insulation.

Combustion appliances require complete combustion as indicated by flame configuration, carbon dioxide, carbon monoxide, oxygen and proper amount of excess air as measured in the flue gases. This requires a combustion analyzer. When combustion initiates in a cold flue, time is required for the flue to warm to a temperature at which a draft is established. During the time in which draft is being established, flue gases can spill from the natural draft inlet of a natural draft appliance. This spillage is determined with the use of a smoke pencil and the spillage time is measured to determine if it is within safe limits. The carbon monoxide content of the flue gases is important as that is the content in the spillage. A worst case depressurization of the combustion appliance zone is established by turning on all the exhaust fans, dryer and any other fan that will exhaust air from the interior of the residence. During this worst case depressurization of the combustion appliance zone, the draft in the flue is measured with respect to the outside air pressure. This requires the use of a monometer, drill and drill bit. To educate students in the proper operation of the combustion appliances requires HVAC equipment such as a natural draft gas furnace, an induced draft gas furnace, a condensing furnace, a natural draft gas water heater, a gas range, an air conditioner and an air source heat pump. This equipment should be in an area which allows for the depressurization and has access to the exterior for pressure measurements.

Student Working with HVAC System

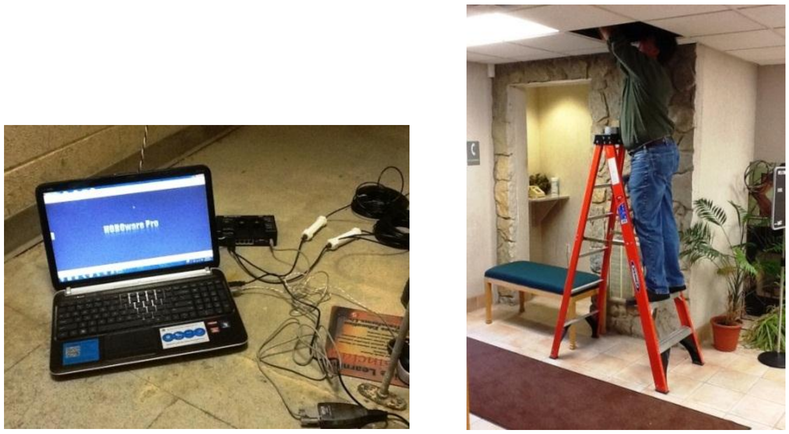
The following lists the equipment and facilities required for the laboratory to support the assessment of a residence. The Building Performance Institute [1] lists the equipment and the instrumentation recommended for assessment and weatherization training in their Policies and Procedures for Test Centers. The installation of the thermal and air barrier are addressed in weatherization. The air barrier is initiated at the ceiling level as the stack effect due to the rising of warmer air results in exfiltration at the ceiling level and infiltrating at the lower levels. Reducing the exfiltration at the ceiling results in the reduction of stack effect infiltration at the lower level. As establishing the air barrier is recommended to be initiated at the ceiling level, the laboratory has mock-ups of the top of the ceiling with normal electrical and plumbing penetrations, pipe chases, and drywall or lath and plaster attachments to the framing to allow for the instruction of the air sealing techniques. This ceiling mock-up is also used to teach the students the proper methods of blowing in attic insulation as well as ceiling batt insulation. The blowing of attic insulation requires an insulation blowing machine. Wall mock-ups are required for instructing the proper installation of wall insulation. Both open walls are necessary for batt wall insulation and cavity walls are necessary for blown wall insulation.

To collect and organize the equipment and facility requirements for the laboratory to support residential assessment and weatherization a listing is given below:

1. blower door
2. smoke pencil or equivalent
3. home mock-up
4. duct blaster
5. thermal imager
6. combustion analyzer
7. stop watch
8. monometer
9. drill and drill bit
10. natural draft gas furnace
11. induced draft gas furnace
12. condensing furnace
13. natural draft gas water heater
14. gas range
15. air conditioner
16. air source heat pump
17. ceiling mock-up
18. open wall and cavity wall mock-ups

Laboratory for Commercial Application

One of the major differences between residential and commercial buildings, except for very small commercial buildings, is that commercial buildings do not depend on infiltration to maintain indoor air quality but have positive outdoor air drawn into the HVAC system which distributes it throughout the building. Usually commercial buildings are maintained at a slightly positive indoor air pressure with respect to the exterior air pressure. This decreases infiltration but increases exfiltration. Therefore, infiltration is not usually addressed in commercial building except in extreme cases, but the outside air, referred to as ventilation, is monitored and controlled. Except where contaminates are introduced into the interior air of a building, the main purpose of the outside air is to maintain the carbon dioxide exhaled by the occupants diluted to safe levels. Many new commercial buildings design into the HVAC system demand ventilation. Carbon dioxide levels are measured in the return air and at strategic locations within the building to monitor the number of occupants and their activity level to control and minimize the amount of outdoor air drawn into the building. However, many existing buildings do not have demand ventilation. Such commercial buildings require the measuring and data logging of the outside air temperature and carbon dioxide content, the return air temperature and carbon dioxide content and the supply air temperature and carbon dioxide content. The relative humidity of the air is determined and logged at all three locations. This data is used to estimate the energy cost savings that can be obtained by the addition of a demand ventilation system. Therefore the laboratory has data loggers and sensors for measuring temperature, carbon dioxide and humidity. The replication of these commercial HVAC systems in the laboratory is not economically practical. Therefore, to provide the experience for the student, it is necessary to establish community partners that have such facilities and are willing to allow students to use them for their laboratory experiences.

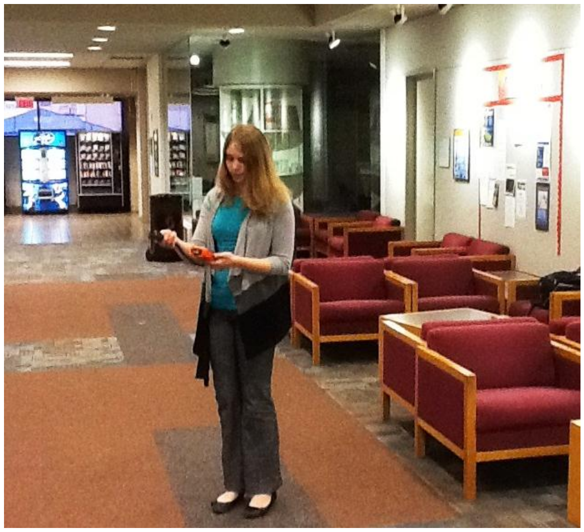


Student Installing Data Logging Equipment

Commercial buildings have motors attached to blowers, chilled water pumps and hot water pumps. In the majority of existing buildings these blowers and pumps operate at a constant speed regardless of the heating or cooling loads. The energy required and therefore the cost of operation is a function of the third power of the flow rate of the air, chilled or hot water. Therefore reducing the speed of the motor to correspond with the load requirements reduces energy use and costs. This requires data logging the supply and return water or air temperature along with the amperage to the motors. The same data loggers and temperature sensors as used for ventilation service with the addition of the sensors for amperage. While it is not practical to replicate the HVAC system, it is practical to have a mock-up of a motor with a variable frequency drive driving a water pump supplying water to coils with both two-way and three-way valves to monitor and compare the energy use of constant speed motors to variable speed motors.

VFD and Motor and Coil Ready for Assembly

Lighting and electrical equipment are a large source of energy use in commercial buildings. In existing buildings lighting system are retrofitted with more efficient lighting and fixtures. Lighting levels also need to be measured to adjust the levels recommended for the areas and activities. A luxmeter is required to measure the lighting levels. Lighting and equipment are not always turned off when not in use. Therefore it is necessary to data log the lighting levels and/or the amperage to the lighting and/or equipment electrical circuit. The same data loggers and sensors for amperage can be used as before and an additional light sensor can be added. This light level monitoring and circuit logging can be accomplished in the campus buildings. The campus buildings then become a part of the laboratory.



Student Measuring Lighting Levels

Commercial buildings have complex HVAC system consisting of multiple zones meaning there is more than one thermostat for each air handling unit. Therefore there are zone controls which can come out of adjustment. To determine the need for recommissioning of the HVAC system, the temperatures are data logged throughout the building zones. Also, the temperatures in unoccupied areas, or the whole building when unoccupied, can be adjusted to an unoccupied temperature. As this situation cannot be practically replicated in the formal laboratory, the campus building can again be used to teach the students. The data loggers and temperature sensors are already required for other operations.

To collect and organize the equipment and facility requirements for the laboratory to support commercial assessment a listing is given below. The University of Dayton Industrial Assessment Center [2] has free software available which explicitly lists required equipment and instrumentation to design a laboratory to support training of commercial assessment.

1. data loggers and sensors for measuring temperature, carbon dioxide and humidity
2. amperage sensors
3. mock-up of a motor with a variable frequency drive driving a water pump supplying water to coils with both two-way and three-way valves
4. luxmeter

5. light sensor
6. commercial community partners to provide access the systems which are not practical to have in the laboratory

Laboratory for Industrial Applications

Industrial processes include lighting, motors, fluid flow, air compressors, process heating, process cooling, HVAC and steam. Lighting requires the same equipment and skills as for commercial buildings and therefore the requirements for commercial buildings are transferable to industrial facilities. Motors and resulting fluid flow in industrial facilities require the data logging of fluid supply and return temperatures and amperage to the motors as in commercial buildings. Therefore the equipment and skills required in commercial buildings are again transferable to industrial facilities.

Large scale air compressors are usually unique to industrial facilities as compressed air is used for many industrial operations. The energy consumed by these air compressors is a large portion of industrial energy use. The Department of Energy estimates, on the average, 20% of compressed air is lost through leaks. Therefore an ultrasonic compressed air leak detector is a necessary requirement for the laboratory. As it is not practical to install a compressed air distribution system in the laboratory, it is necessary to establish industrial community partners to fill this portion of the student's laboratory experience. The compressor control methods and volume of storage affect the energy use of these systems. A small scale air compressor with a load/unload control system and with auto shutoff and connected to a variable volume storage system allows the student the opportunity to monitor the energy use of the compressor as the different control strategies are activated and the volume of the storage is changed. The data logger with the amperage sensor is used to monitor the energy use with the different strategies and volumes.

Process heating and cooling requires the data logging of temperatures and the equipment and skills taught in the commercial HVAC systems are transferable. Industrial HVAC systems are similar to commercial HVAC system with the exception that many industrial facilities have exhaust air system and make-up air systems to maintain indoor air quality. Many industrial facilities have processes that produce undesirable fumes or humidity which must be exhausted. The commercial HVAC equipment and skills are transferable to the industrial facilities. As lighting systems in industrial facilities have enough similarity to commercial building lighting systems, the equipment and skills are also transferable.

Student on an Industrial Assessment

To collect and organize the additional equipment and facilities requirements for the laboratory to support commercial assessment a listing is given below. The University of Dayton Industrial Assessment Center [2] has free software available which explicitly lists required equipment and instrumentation to design a laboratory to support training of industrial assessment.

1. ultrasonic compressed air leak detector
2. small scale air compressor with a load/unload control system and with auto shutoff and connected to a variable volume storage system
3. industrial community partner to provide access to processes that are not practical to have the laboratory

Laboratory for Renewable Energy Applications

The laboratory requirements for renewable energy are relatively will defined. M. Al-Addous, C. B. Class [3] provide a list of solar thermal equipment to support a portion of a renewable energy laboratory. The North American Board of Certified Energy Practitioners [4] lists implicitly in their PV Installer Task Analysis the required equipment and instrumentation for a laboratory to support solar photovoltaic training. The North American Board of Certified Energy Practitioners [5] also provides a Solar Heating Entry Level Learning Objectives which explicitly lists the required equipment and instrumentation for solar thermal training. The equipment includes an active solar photovoltaic system, an active solar thermal system, an active wind turbine, a biodiesel processor and an ethanol still. The solar photovoltaic system is grid connected with battery backup. This gives the students the advantage of learning both stand alone and grid connected systems. The solar photovoltaic system requires a roof mock-up to properly mount the system in a water tight method. The remaining components for the photovoltaic system are a combiner box and breakers, charge controller, battery bank, an inverter, and miscellaneous breakers, disconnects, panel box, and wiring of different sizes. The solar thermal system requires solar thermal panels and another roof mock-up and mounting system, a solar storage tank with an internal heat exchanger, an expansion tank, a differential temperature controller, a circulating pump and miscellaneous piping and insulation. The active wind turbine requires in addition to the already required equipment, the wind turbine with the factory mounting pole and tie down system, its own charge controller, lightning arresters and miscellaneous wiring and disconnects. The biodiesel processor and the ethanol still are two items that can be purchased as a completed unit. However, the biodiesel processor requires a containment vessel for leaks and spillage containment and a fume hood. If the biodiesel is to be used, test equipment is necessary to insure that the biodiesel meets ASTM standards. There is also personal safety equipment required when working with the chemicals to process the biodiesel and all MSDS information is to be properly displayed and available.

Students with Solar Pathfinder

Students Collecting Data from Solar PV System

Students Moving Solar Thermal System from Lab to Outdoors

Students Collecting Data from Wind Turbine

To collect and organize the equipment and facility requirements for the laboratory to support renewable energy a listing is given below.

1. roof mock-up and mounting system for solar photovoltaic panels
2. combiner box and breakers
3. charge controller
4. battery bank
5. inverter
6. panel box and breakers
7. miscellaneous breakers, disconnects and wiring
8. solar thermal panels
9. another roof mock-up and mounting system
10. differential temperature controller
11. circulating pump
12. solar storage tank
13. expansion tank
14. miscellaneous piping and insulation and fittings
15. biodiesel processor
16. containment vessel
17. fume hood
18. test equipment
19. personal safety equipment
20. required chemicals
21. ethanol still

Summary

Colleges or universities may not wish to develop a complete energy management program addressing residential, commercial and industrial facilities and renewable and alternative energy. Therefore, the information is given to facilitate the design and development of the laboratory to support each portion of the program. Before each piece of equipment or facility required for that supporting laboratory was presented, a clear understanding of its use and need was also given.

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