Forgoing the Fossils: "E-Houses" Serve as Energy Efficiency Learning Laboratories for Technical High School Students

Rebecca A. Meyer, Connecticut Light & Power/Yankee Gas

ABSTRACT

In 2006, a K-12 energy education program launched a professional development partnership with Connecticut's technical high school system. During its first years, annual professional development workshops reviewed the scientific principles behind energy, energy efficiency and renewable energy sources. Then in 2010, the partners agreed to turn the page on textbook-based education and begin a new chapter consisting of hands-on training.

The decision resulted in the creation of the E-House, a laboratory for students and trade instructors where hands-on learning and green workforce development could flourish and bring innovative ideas to life. The 16' x 20' structure was itself an example of energy-efficient design that included high-efficiency lighting, insulation, windows, doors, siding, HVAC equipment and boilers. The facility was powered by solar photovoltaic, with solar thermal permitting its water to be heated up to 120°F.

The underlying purpose of the E-House project was to provide students with a 'green platform' for both the practical application of what they have learned and experimentation with energy-saving initiatives. Besides being the designers and builders of the facility, high school students were also responsible for installing the building's efficient and renewable energy technologies. The project would also be an education for the trade instructors involved, who went back to school in order to receive Building Performance Institute, solar thermal and solar PV certification. The state's energy efficiency and renewable energy funds agreed to sponsor the project, with utility and fund administrators providing technical expertise, networking and educational support.

So successful has been this approach that what began as a single E-House at E.C. Goodwin Technical High School in New Britain, which opened in September 2011, has now evolved into 17 of them being built at each of the state's technical high schools. The next two are scheduled to be operational in May 2012. The partnership between the technical high school system, energy funds, electric utilities and private industry is thus in the process of developing tomorrow's green workforce—one whose entry-level employees will already have practical expertise in major aspects of energy efficiency and clean energy. CTHSS administrators, Raymond Mencio and Pat Ciarleglio are the individuals who have worked long hours and put their hearts and brains into the E-House project. Its success is a tribute to their hard-working ethic and commitment to CTHSS's students and Connecticut's future 'green' job workforce.

The Design

The green energy E-House project began as an August 2006 formal training session for 17 electrician-trade instructors from Connecticut's Technical High School System. The purpose of the one-day *eesmarts* professional development workshop was to train these instructors on the pedagogy for mathematical and scientific concepts related to energy—particularly energy efficiency. The *eesmarts* program is a learning initiative on energy efficiency and clean,

renewable energy sources for K-12 classrooms in Connecticut, funded by the Connecticut Energy Efficiency Fund (Energy Efficiency Fund), and administered in partnership with Connecticut Light & Power and United Illuminating (Connecticut's electric distribution companies).

The Connecticut Technical High School System (CTHSS) has a technology exploratory program for all incoming ninth-grade students. The program introduces each student to the goals and objectives for trade/technology programs, providing an objective measure of student performance and a measure of each student's potential for success in all trades and technologies. All CTHSS students are given hands-on experience in three trade/technology areas prior to selecting the one on which they will focus for the next three years. In an effort to boost enrollment in the electrical trade program, CTHSS administrators integrated *eesmarts* lessons into its exploratory program. These lessons offered hands-on, inquiry-based activities designed to spark students' interest in energy-related topics.

For the next four years, *eesmarts* program administrators and the program's professional development provider, Wesleyan University's Project to Increase Mastery of Mathematics and Science ("PIMMS") worked with the CTHSS electrical trade program to offer classroom activities in the areas of energy conservation, energy efficiency and renewable energy technologies. The last two years of training centered on the mathematical and scientific principles of solar photovoltaic technologies and harnessing energy from the wind. The *eesmarts* program turned to the Clean Energy Finance and Investment Authority's (CEFIA) Learning for Clean Energy Innovation (LCEI) program for assistance with classroom instruction on solar and wind technologies. In August 2009, the fourth and final *eesmarts*/LCEI professional development workshop was held at the Connecticut Science Center in Hartford, Conn. The workshop entitled "A Wind-Wind Situation" focused on designing efficient windmill blade design, building a generator, convection currents and measuring kilowatt-hour consumption utilizing a Kill-A-Watt device. The workshop paired CTHSS' electrical trade instructors with their top electrical trade students.

The Blueprint

On March 11, 2008, M. Jodi Rell, Connecticut's governor at the time, announced a "Green Collar" job training program for CTHSS's 10,801 students while touring Cheney Technical High School in Manchester (CTHSS). Its purpose was to expand upon programs currently offered in construction-related fields (electrical, heating, ventilation and air conditioning, plumbing and carpentry) to incorporate training in green technologies. Such training was aimed at ensuring that Connecticut's technical high schools provided hands-on-instruction that would help lead the 3,195 students, or roughly a third of the CTHSS student population, who were enrolled in a construction-related trade area toward the clean, "green" jobs of the future.

In late 2009, CTHSS administrators began developing a plan to "green" the curriculum for construction-related trades. It was widely recognized that students would have to move beyond textbooks to actual hands-on training in green technologies. Through benchmarking of other technical high school systems across the United States, the administrators found that many different types of green technology lessons, textbooks and in-classroom activities could be made available to CTHSS students. However, their research also revealed a dearth of true hands-on training in green construction-related technologies for high school students.

One of the programs they did discover was in the neighboring state of Massachusetts where Leo Bedard, Supervisor of Construction Trades and Environmental Technology at Upper Cape Cod Regional Technical High School System had developed a high school level training on renewable energy (Weissman 2005). CTHSS administrators, CEFIA, Energy Efficiency Fund and utility personnel met with Bedard to discuss how he developed a partnership with Cape Cod Community College to install solar thermal, solar photovoltaic and biodiesel processing systems on the campus allowing high school students to utilize the equipment during the day and community college students using them at night. Cape Cod technical high school students also helped build a press box for one of the Cape Cod baseball leagues, the Bourne Braves which incorporated energy-efficient concrete blocks into its design. Students left a part of the wall exposed so future students can see the layers of energy efficiency construction. Bedard explained that the project was completely funded by manufacturers and donations, including the students' labor (Goueveia; Boyd). This model of a technical high school working with manufacturers, clean energy installers and private industry helped the Connecticut contingent realize the idea of an E-House was a home run.

These findings led the administrators to develop a blueprint for a green construction technology lab (the E-House) to be built on-site at a CTHSS school with the goals of:

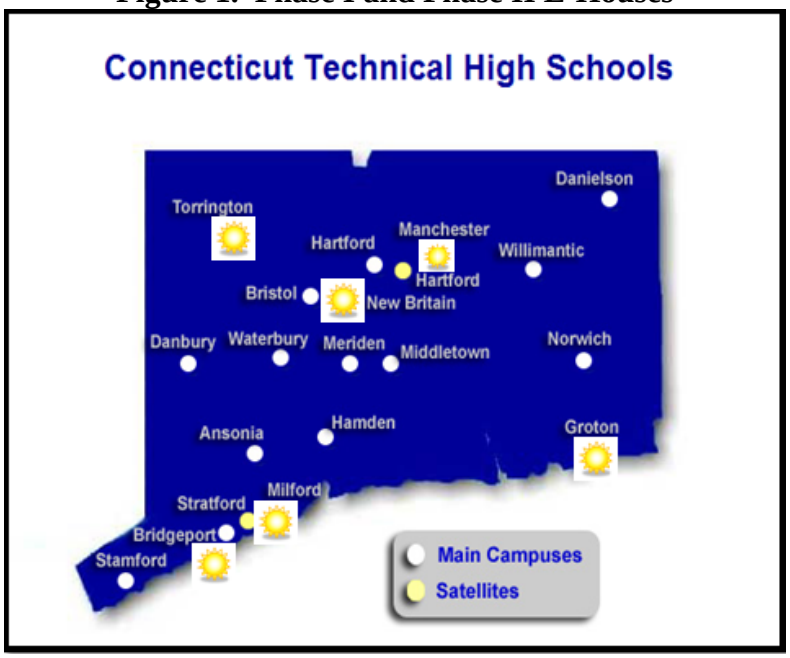
1. Increasing the CTHSS faculty's and students' knowledge and awareness of efficient and clean energy technologies and their benefits to society;
2. Enabling up to six CTHSS schools to offer their students energy-efficiency and renewable energy courses that are aligned with current curriculum standards, along with course-related hands-on equipment;
3. Expanding instructors' teaching experience in the realms of energy-efficient building design and construction, blower-door testing, weatherization and other energy-efficient technologies;
4. Providing professional development training to CTHSS trade instructors in solar photovoltaic and solar thermal renewable energy technologies;
5. Preparing students for emerging employment opportunities in energy efficiency, weatherization and clean energy fields;
6. Incorporating solar photovoltaic and solar thermal education and hands-on training into the curricula of all CTHSS schools; and
7. Equipping each such facility with high-efficiency ductless heat pumps, geothermal heat pumps and/or energy recovery ventilators that students themselves could actually help to install.

The concept was simple: a 16' x 20' structure would be erected on-site at a CTHSS school where students, under CTHSS trade-instructor supervision, would design and construct an energy efficiency, weatherization and renewable energy lab. The on-site E-House would feature green construction technologies and serve as an ongoing facility for the exploration of new energy-efficient equipment, weatherization techniques and clean energy technologies. See Figure 6 for a complete sketch of the E-House built at E.C. Goodwin Technical High School (in New Britain).

CTHSS administrators approached the Energy Efficiency Fund and CEFIA regarding funding for the E-House laboratory. A Phase I funding plan was developed for three E-Houses at E.C. Goodwin Technical High School (in New Britain), Oliver Wolcott Technical High

School (in Torrington) and Grasso Technical High School (in Groton). A Phase II funding plan was developed a few months later for three additional E-Houses at Kaynor Technical High School (in Waterbury), Norwich Technical High School (in Norwich) and O'Brien Technical High School (in Ansonia). See Figure 1 for a detailed map of Phases I and II E-Houses. The funding plan also included ongoing training and professional development for CTHSS construction trade instructors.

Figure 1. Phase I and Phase II E-Houses



The Energy Efficiency Nuts & Bolts

The six E-Houses in Phases I and II were designed by Windham Technical High School's Architectural Department's instructors and students to showcase energy-efficient construction, technologies and design. The E-Houses also will serve as weatherization and building analysis laboratories for future home-energy-assessment technicians, builders, carpenters and auditors.
Each E-House is cooled and heated via high-efficiency, ductless mini-split-system heat pumps that utilize an environmentally-friendly refrigerant (410a). CTHSS selected ductless heat pumps for Phase I and II E-Houses to showcase how mini-split systems can serve as ideal retrofit add-ons for homeowners. The ductless heat pumps have two main components: an outdoor compressor/condenser and an indoor air-handling unit. For each E-House, CTHSS students installed a conduit that houses the power cable, refrigerant and suction tubing, and a condensate drain to link the outdoor and indoor components. For future instruction of students, administrators ensured that the ductless heat-pump systems and kits contained accessories, such as extra refrigerant and line sets. The E.C. Goodwin Technical High School E-House has a 22 SEER ductless heat-pump, with plans calling for the five Phases I and II E-Houses to each be equipped with a 26 SEER (or higher efficiency) ductless mini-split heat pump. A Wi-Fi web-based accessed thermostat will allow the temperature of each E-House to be controlled and monitored via the Internet.

Each E-House is a bit like an energy-efficiency time capsule in the manner in which it demonstrates the insulation and construction practices and technologies of the past and present. Examples of the various types of insulation used in homes, for example, have been assembled by students who conducted historical surveys and research projects on the subject. The students' research revealed such diverse insulation materials as newspaper, cellulose foam, standard rolls/batts, rigid foam boards and denim. E-House visitors can view the variety of insulation methods utilized through a clear acrylic wall covering installed at several locations within the structure. Figure 2 below shows the insulation examples showcased at E.C. Goodwin Technical High School (in New Britain). Blower door and Fluke-infrared testing technologies enable CTHSS instructors and students to explore and analyze the energy efficiency of each insulation type.

Figure 2. Showcase of Insulation Technologies

An important aspect of the E-House learning experience is creating the weatherization and building analysis lab. While creating the initial facility, CTHSS carpentry instructors and students experimented with installing several different types of windows with varying energy-efficiency ratings (low/high solar heat gain coefficients, low/high U-Factor ratings, etc.) This process will be repeated in each new E-House. These same instructors and students were able to perform the blower door test, Fluke-Infrared gun and smoke stick testing to detect air leakage. Students can also practice a variety of sealing and weather-tightening methods, insulating measures and framing techniques used to make homes as energy efficient as possible. To enhance the training-lab component of the E-House, sections of the facilities' drywalls have been replaced with clear acrylic to allow students to view the internal wall cavities. This allows instructors to demonstrate various weatherization measures utilized, including non-insulated recessed lighting, attic scuttle access insulation methods, proper attic ventilating procedures, and construction/insulation techniques with weatherization as their key component.

Building analysis as well as weatherization measures has been embedded in the carpentry trade power curriculum, in conformity with Building Performance Institute standards. Specialized thermal imagers, blower-door test equipment and Combustion Area Zone (CAZ) testing equipment have been made available to facilitate such analyses.

Playing on the facility's other components; design plans include a variety of energy-efficient lighting options, from less efficient incandescent fixtures to compact fluorescent light

bulbs (CFLs) and light-emitting diodes (LEDs). Students are thus able to observe and contrast the efficiency, quality of light and lumens of each lighting-system installation.

Phases I and II E-Houses also feature low-temperature radiant floor heating generated from a 95 percent energy-efficient boiler. The boiler is connected to a two-stage heating system consisting of low-temperature Runtal radiators complete with a fan-coil unit and a low-temperature Watt's radiant heating system. Visitors may view the radiant floor-heating system in operation via clear acrylic cutaways.

Figure 3. A 95 Percent Energy-Efficient Boiler Piped to a Low Temperature Radiant Heat Flooring System

Twelve of the proposed 18 buildings will be a 16' by 20' structure with a specifically designed roof for optimum functionality of both solar thermal and photovoltaic arrays. The final six E-Houses will be larger with a 20' by 30' footprint and will incorporate geothermal technologies. These six expanded facilities will allow for Combustion Area Zone (CAZ) testing for students and instructors. These E-Houses will have two rooms, the mechanical room and main area, whose separation will allow for "real world" experiments and scenarios. In addition to the geothermal systems, these facilities will also have energy recovery ventilators. The six E-Houses that will include geothermal technologies are located at Norwich Technical High School (in Norwich), Ellis Technical High School (in Danielson), Wilcox Technical High School (in Meriden), O'Brien Technical High School (in Ansonia), Eli-Whitney Technical High School (in Hamden), and J.M. Wright Technical High School (in Stamford).

The Renewable Nuts & Bolts

The roofs of the six E-Houses in Phases I and II have been specially designed to maximize functionality of both the solar photovoltaics and solar thermal system arrays. The pitch of each roof is carefully measured to provide optimum performance based on Connecticut's latitude.

The blueprints for each E-House include specifications for a 1.7 kilowatt (kW) solar photovoltaic (Solar PV) system consisting of nine Solar PV panels. These panels are used in conjunction with a DC-AC power inverter, balance-of-systems (BOS) hardware that includes

wiring, over-current, surge protection and disconnect devices, and other power-processing equipment. CTHSS students are introduced to Solar PV technology through bench top training and then progress to mock roof-top installations that allow them to learn the correct method of adding Solar PV to a structure in a controlled safe environment. Instructors attended Solar PV seminars throughout the spring of 2011 to observe the proper techniques for installing roof brackets, solar panels, panel connections, inverters and kW meters, and grounding. Each E-House's Solar PV system and kits include such accessories as extra wires and batteries, which will give future CTHSS students the opportunity to perform upgrades and maintenance.

Figure 4. E.C. Goodwin Technical High School Students Installing Solar Photovoltaic System

E-Houses are also designed to include Boderus (Solar Thermal) flat-panel technologies. Solar Thermal instruction emulates Solar PV education, starting with bench top training, moving to mock structure installations and then to working on the functioning E-House systems themselves. Here too, CTHSS has ensured that all Solar Thermal systems and kits contain spare parts, such as extra piping, valves and fittings that can be utilized in future training sessions. The mock structure and E-House Solar Thermal installations are all fully operational, and offer the added advantage of creating domestic hot water, which is funneled to the CTHSS host school for utilization in washrooms and classrooms.

The 1.7 kW Solar PV installations are all wired back into the electrical grid, requiring an interconnection agreement with Connecticut Light & Power or United Illuminating. The output from the Solar PV and Solar Thermal installations are monitored via a web-based sun-reports module. This module gives CTHSS instructors and students across the state the opportunity to keep track of the electrical energy produced by the Solar PV system throughout the day as well as the British Thermal Units (BTUs) and kilowatts (kWs) of energy generated by both solar technology systems.

CTHSS administrators and instructors have worked together to embed Solar PV and Solar Thermal training into both the plumbing & heating and electrical curricula, respectively. The Solar PV standards utilize the North American board of Certified Energy Practioners (NABCEP) Solar PV strands, or short programs of study, which are incorporated at every level

of the electrical curriculum, with NABCEP Solar Thermal strands similarly integrated into the Plumbing & Heating curriculum.

Electric Vehicle Car Charging Stations

During the construction of the Phases I and II E-Houses, CTHSS administrators approached Connecticut Light & Power and United Illuminating seeking corporate funding to have an electric vehicle (EV) car-charging station installed outside of each E-House and powered by its Solar PV system. Both utilities agreed to fund EV car-charging stations at each of the six Phase I and II E-Houses, with instructors and students doing the work of connecting them via a conduit to each facility's electric meter. Students are also responsible for siting and prepping each station's concrete mount further enhancing their level of green technology experience and exposure.

Ongoing Training and Professional Development

A key component of the E-House project is the ongoing training and professional development it provides CTHSS construction trade instructors allowing them to introduce their classes to cutting-edge green technologies and techniques. Though the professional development is conducted for instructors, the students benefit from their increased knowledge, expertise and hands-on training. The project's funding has allowed instructors to receive training that was not afforded to them with budget reductions in the CTHSS system. Such training to date already includes:

Energy efficiency training

1. Level I Thermography Training completed by 18 electrician instructors and one plumbing/heating instructor who received four hours of Fluke hands-on infrared training in February 2011;
2. Building Performance Institute Certification obtained by five carpentry instructors in March 2010;
3. Weatherization "Train-the-Trainer" Certification obtained by five carpentry instructors in March 2010;
4. Manufacturer training for geothermal heating systems held by Florida Heat Pump in the 2011;
5. Warm air systems training held by York in the 2011;
6. Daiken manufacturer training for ductless heat pumps in 2011; and
7. Honeywell training on Red Link, energy recovery ventilator and heat recovery ventilators (HRV) in the 2012.

Renewable energy training

1. A Solar Thermal I course (residential application) completed by 12 plumbing instructors in stages of instruction during December 2010 and November 2011;
2. A Solar PV I course (residential application) completed by 11electrician instructors in two stages of instruction during December 2010 and November 2011; and

3. Solar Thermal Installer Certification completed by six plumbing instructors, who received 24 hours of intense solar thermal training at the Industrial Management & Training Institute (IMTI) in Waterbury during November 2010. All six are now fully certified by the Connecticut Department of Consumer Protection to install solar thermal technologies.

Safety training

1. OSHA 10-hour and 30-hour Construction & General Outreach Training received by 20 CTHSS instructors in 2011; and
2. An OSHA 10 Card issued by the U.S. Occupational Safety and Health Administration in May 2012 to every graduating senior in the electrical, carpentry, plumbing, masonry, and HVAC curricula that each has successfully completed 10 hours of safety training.

Future Employment Initiatives

CTHSS administrators and instructors have taken great measures to match students with Solar PV and Solar Thermal technology companies to provide them with additional real-world instruction. To this end, instructors have formed a Trade Technology Advisory Committee (TTAC) for each of the construction-related trades: 1) electrical, 2) plumbing and heating, 3) heating, ventilation and air conditioning (HVAC), and 4) plumbing, heating and cooling. Since the inception of the E-House project, instructors have been extremely proactive in recruiting vendors, manufacturers and contractors from green companies into their respective TTACs. These relationships serve to further enhance work-based-learning (WBL) opportunities that may evolve into full-time employment for CTHSS graduates.

CTHSS administrators and instructors have also worked with the Energy Efficiency Fund and CEFIA to plan for a career fair for the juniors and seniors receiving training in construction-related trades. This career fair, which is scheduled to take place in September 2012, was designed to give students an opportunity to interview with home-energy-assessment firms, builders, contractors, Solar PV and Solar Thermal installers, and other green technology enterprises. Advance networking training will be conducted with the students to ensure that the event is rewarding for both student and prospective employers.

Initial results for actual job placement for CTHSS seniors graduating in May 2012 are not yet available as of this writing. Graduating seniors were sophomores when the E-House project began in the 2009/2010 school year. This also means that statistics related to job placement, additional technical training and college admissions are unavailable at this time. Once these figures do become available, CTHSS, the Energy Efficiency Fund and CEFIA will review them in order to track the success of the E-House project and determine if further enhancements are needed.

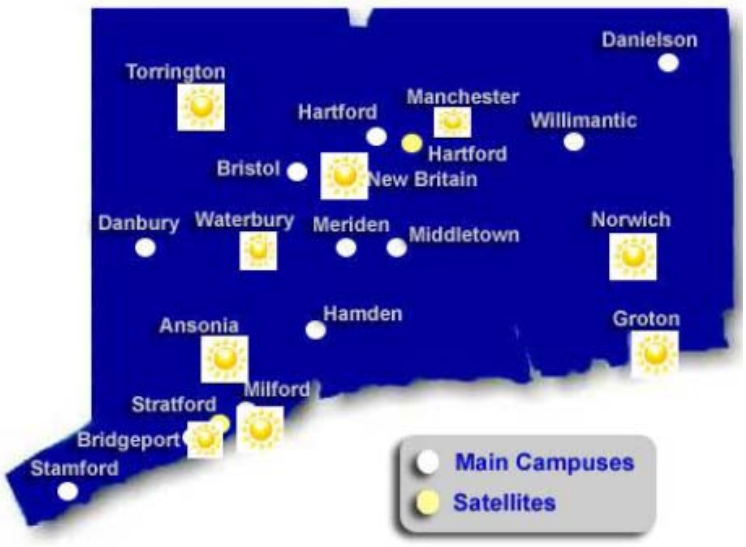
From One E-House, a Multiplier Effect

When the initial phases of the E-House projects were launched, no one could have anticipated the program's success and the overwhelming positive feedback it has received from CTHSS students, instructors and Connecticut's clean energy community of vendors, manufacturers, energy funds and utility companies. The initial idea was for one E-House that

would serve all 18 CTHSS schools. Then the concept was expanded to include five more to be placed in various parts of the state. This would allow two or three CTHSS schools to work together on a centrally-located E-House in their particular area. The plan called for all CTHSS students in construction-related disciplines to receive hands-on training and perform mock installations, and then travel to their assigned E-House for advanced training.

In 2012, the Energy Efficiency Fund and CEFIA fully committed to funding an E-House at each of the state's 18 CTHSS schools. When completed, the project will provide each school with a full equipped weatherization, energy efficiency and renewable energy laboratory at each school that will serve as a training ground for Connecticut's future clean energy workforce and further enhances the "greening" of the construction trade curriculum in the state's technical classrooms.

Figure 5. All Phases of E-House Project



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A Learning Laboratory for Others to Emulate

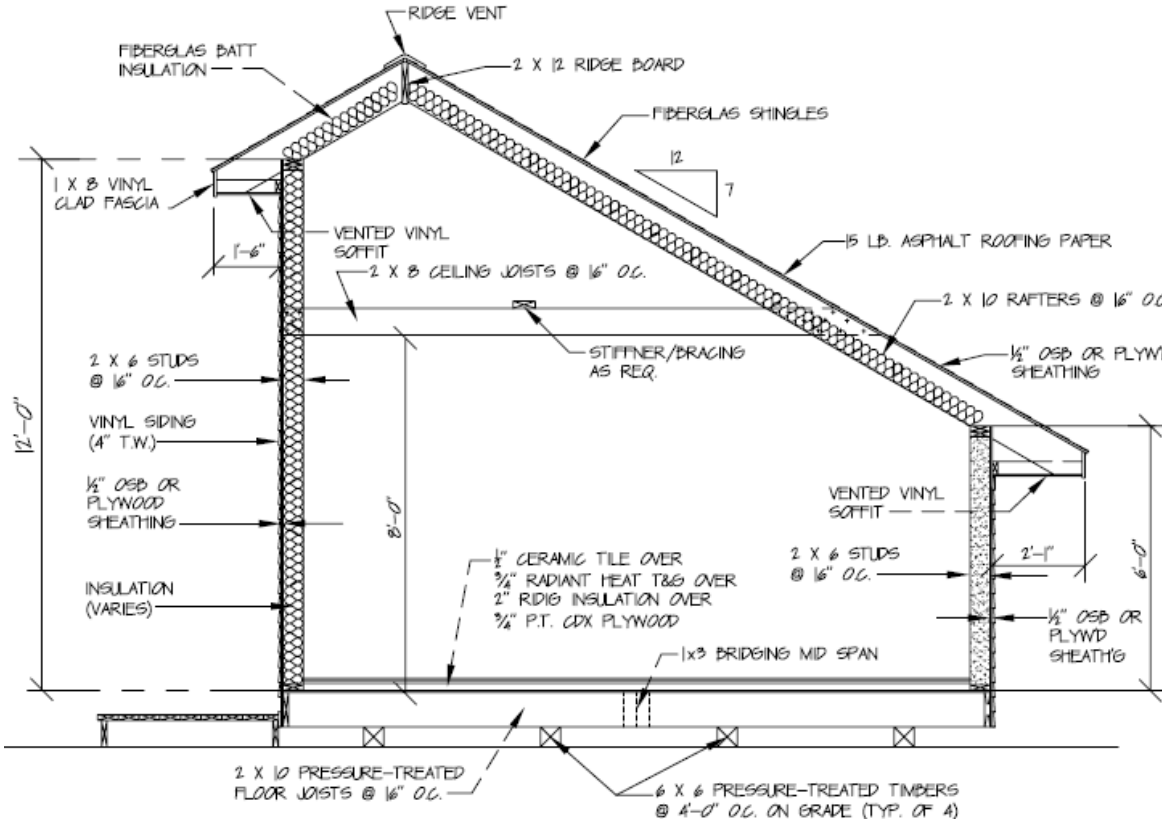
Since the first completed E-House was unveiled at New Britain's E.C. Goodwin Technical High School, CTHSS administrators, instructors and students have conducted tours of their labs, mock demonstration platforms and the E-House itself to representatives of other technical high school systems from across the country. Having an on-site training facility that demonstrates clean energy technologies in a laboratory-like setting would be enviable for any

community college or university let-alone a technical high school. From greening of curriculum standards to the hands-on BPI, OSHA, Solar Thermal, Solar PV, and weatherization experience it provides, the E-House project has consistently received an A+ across the board from these visiting school systems.

The success of the E-House project has been chronicled in the media. Connecticut's Public Television's *Empowering Connecticut* featured E.C. Goodwin Technical High School's administrators and students installing energy-efficient and renewable technologies (CPTV). The Fox Channel's *Eco-Company* also interviewed E.C. Goodwin students detailing their increased knowledge regarding installing solar thermal and photovoltaic systems (Eco-Company).

In essence, this successful and innovative partnership between CTHSS, the Energy Efficiency Fund, CEFIA, electric utilities and private industry is setting the example that is enabling Connecticut to lead the way in producing the kind of expertise that will be required to make America a more energy-efficient nation in the years to come.

Figure 6. Blueprint for E.C. Goodwin Technical High School's E-House



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