SOLAR 2013 Conference Abstract Submission **#328:**

Displaying the Benefits of a Zero Energy Home – A Monitoring Case Study

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Alfred State College is a residential comprehensive College of Technology with both two- and four-year programs. The college is part of the State University of New York (SUNY) system and its programs directly link to workforce development. Graduates typically have a 98% placement and transfer rate each year. There are two Alfred State College campuses: one located in Alfred and the other in Wellsville, New York. The Alfred campus houses the more traditional college two- and four-year programs. The Wellsville campus houses the skilled trades programs in five departments that include: Automotive Trades, Culinary Arts, Computerized Design and Manufacturing, Building Trades, and Electrical Trades. The 800 students in these programs have a unique pedagogy where students are in technical courses six hours, every day, in modular format. A typical day will include 1.5 hours of lecture and 4.5 hours of laboratory. Every department is different, but courses are modular and run from 3- to 7.5-weeks-long with few that run the full 15-week semester. This structure allows the faculty and students to concentrate on that course for the 3- to 7.5-week module. Most of the programs focus on live work such as, building homes for sale, repairing running vehicles in the automotive shops and serving prepared food for customers. The Wellsville campus is known for its "learning by doing" through this live work.

Alfred State is currently one of the largest human resource providers for the construction industry in New York State. This includes approximately 800 students in certificate, associate, and baccalaureate degrees in construction-related programs on both campuses. This includes approximately 400 students in heavy equipment operations, electrical construction and maintenance electrician, Building Trades (carpentry & masonry), and air conditioning & heating technology two-year associate degree programs on the Wellsville campus. All programs at the college have active advisory boards and, over the past few years, all programs have been integrating green technology into the course work, based on industry needs. The full implementation of green technology into the construction-related programs in Wellsville was all made possible by a series of grants. The overall goal also included developing the college's green technology educational leadership through the Center of Renewable Energy utilizing funding from these grants. Beginning in 2003, this focus on renewable energy began with a New York State Energy Research and Development Authority (NYSERDA) grant to train photovoltaic installers. This was followed by a 2007 Appalachian Regional Commission (ARC) grant to further develop the ability to teach photovoltaic systems and begin small wind instruction through the hands-on installation of such systems. In 2009, grants to develop weatherization training and a green building laboratory were funded by the Appalachian Regional Commission. In that same year, a $2.2 million Clean Energy Training grant from NYSERDA was also

awarded with the intent of developing educational modules in geothermal, solar thermal, small wind, and photovoltaic systems in a consortium of colleges, with Alfred State as the lead. All of these grants were developed to build and equip laboratories that allowed faculty to integrate these green technologies into existing programs.

Green Home Laboratory

The building trades' related programs have been building and selling homes in the Wellsville community since 1966, when the Wellsville campus was instituted. The homes are built completely by students, as part of the course work. This is a great learning laboratory where students from the Building Trades programs work on this live project. One goal of the green home, in 2008 when the grant was developed, was to construct a home where the college could showcase the high-end quality student work similar to homes the college had built since 1966. The other goal was to build a typical-looking home with green construction techniques that would be highly energy efficient and use renewable energy. This would allow the college to integrate these technologies into existing programs and have a living laboratory to showcase this technology to our students, high school students, and the public. This vision was funded by the Appalachian Regional Commission with a start date of April 2009. During the preparation year for the project, a home layout was selected and materials were determined for most components. This included working with regional suppliers of appropriate green materials. Discussions also took place with the local and state National Association of Home Builders (NAHB). The college decided to work toward a minimum of a NAHB Gold certification. This required regular meetings with the faculty involved with the project working together on decisions regarding materials and suppliers for green products and systems.

The home selected was a one-story home so we could assure the ability to showcase to all visitors and be handicapped accessible. The home is approximately 2,200 square feet with three bedrooms and master bedroom suite with master bath and walk-in closets. Both the entryway/family room and master bedroom have cathedral ceilings. The house has a full dining room, den, and kitchen with an eat-in breakfast area. There are two additional full bathrooms and a workshop. The home was designed with a fireplace and an attached garage. Since the home was to be a showcase home, some minor modifications were made to the layout. The master bedroom's walk-in closet was modified to be a handicapped restroom and a storage closet for the laboratory. The workshop was modified to be the mechanical room so all visitors could assess the mechanical space. The dining room and den are used for office space and the master bedroom is used as a conference room. Many of the renewable energy components are installed in the garage.

Most of the materials and systems selected were green in nature and of the technologies we wanted to have the students install. Since all operations were to be on the ground floor, the basement (a normal feature for homes in the area) was eliminated. A frost-protected shallow footer system was selected that includes the ability to have footers only 18" below grade; located above the frost line. The

protection includes placing insulation horizontal to the footings to prevent frost penetration. We also installed a perm-a-drain system, a hollow plastic material used to form the concrete footings. Form-a-drain is left in place to act as a drainage system and can also be used to vent the system from any radon in the soil. Since there was to be a conditioned crawl space for utilities, we used insulated concrete forms with an R value of 17. The floor system was standard engineering I-joists and was built to tight tolerance since the wall system selected was of structural insulated panels; their R value being 24.3, at 40 degrees Fahrenheit. All of these selected methods were chosen because they were energy efficient and the technologies we wanted the students to install. Since most students will be installing trusses, we selected a truss system for the home. The roof system was very complicated due to the cathedral areas and we found only one company in the area who could build the trusses.

All during the requisition of materials, we worked with local suppliers to obtain the appropriate green materials and certifications required for the NAHAB certification. The internal walls were constructed of 2x4 wood framing and were sheet rocked. The windows were high-efficiency windows with U values of 0.25. The outside building envelope was wrapped and sealed and all cracks, including windows, were sealed. Because the home was to be green and air tight, all finishes were selected to be low- to no-volatile material, including the paints and the carpeting. The oak kitchen cabinets were custom built by the Building Trades students and, again, used low volatile finishes. Colors, tiles, carpeting, and lighting fixtures were selected by the interior design students on the Alfred campus.

Renewable Energy

The original plan included adding renewable energy to the home, but with additional grants, the renewable energy systems expanded. The 8.8 Kw photovoltaic grid-tie system was installed as two arrays with two separate inverters to allow for better monitoring. The 2.1 Proven small grid-tie wind turbine was installed prior to the home's construction as part of another grant. During the home construction, a two-ton geothermal system was installed with four vertical closed-loop wells. Working with the well driller, we had four different grouts installed. Each grout had different thermal transmittance properties. Thermal couples were installed to measure the temperatures to the full depth of the wells. An eight-vacuum tube solar thermal system was installed with a storage tank. Another electric water heater was installed to act as both a surge tank and a primary heat source when there is inadequate solar energy. The geothermal heat pump and solar thermal tanks are both installed in the mechanical room. The inverters for the wind turbine and photovoltaic panels are located in the garage. An air exchange system with heat recovery is also located in the mechanical room. The whole home was wired for phone and communication systems that all terminate into one control panel in the garage as well. This is something the students do in all homes we construct, but this is the first home that we completed as operational. The goal of all the renewable energy and energy efficiency was to now be a net zero energy home. So, all of the appliances installed in

the home are electric, including the range and the clothes dryer. This will allow us to better monitor the energy usage. A Tempcast fireplace, a highly efficient word burning fireplace, was also installed that is about 97% efficient, using radiant heat.

Project Goals

The Net-Zero Energy Demonstration Home has three main goals:

1. to give students with real-world experience with renewable energy technology and green construction techniques;
2. to showcase the high-quality student work, similar to homes the college has built since 1966, and demonstrate to the public that a typical-looking home can also be green; and
3. to provide a living laboratory for educating the future workforce in green building techniques.

Timeline

This project took approximately two years from receipt of the initial ARC grant to completion of construction, as shown in the following list of project milestones:

- June 2008 - Initial ARC grant submitted
- May 2009 - ARC grant received
- August 2009 - Construction began
- May 2011 - Construction finished
- December 2011 - Monitoring system installed
- December 2011 – HERS rating: 9, 5 star plus
- January 2012 – NAHB Gold Certification received
- October 2012 – AAHE 2012 Best Campus Sustainability Award

Monitoring and Operation

The home was essentially complete and operating in the fall of 2011. We planned to build and operate a monitoring system that would allow the college to showcase the operation of the home. We also wanted to be able to operate the home with full loads to show the public the net-zero energy operation of the home. Alfred State College was introduced to IMT solar late in the summer of 2011 and, through the NYSERDA grant, a system was designed and installed in the fall of 2011. The system was essentially an expanded version of IMT Solar's REVTOS (Renewable Energy Visual Tableau Operations System) monitoring and control system that had already been used for several micro-wind and solar PV systems at numerous other schools and one industrial site. IMT Solar had never before done the monitoring for geothermal or solar thermal systems, but knew they had the scalability and flexibility in their system to include these as well. Upon inspection of the site by IMT Solar, they decided to divide the monitoring system into two control cabinets: one placed in the mechanical room and the other placed in the garage. This saved an enormous amount of wire runs from the various sensors and power monitors that were utilized in each system. In

addition to the dedicated touch screens located in the front door of each control cabinet, IMT Solar also mounted a 23" touch screen PC in the living room of the home. All three screens have highly effective graphic displays to show both real time and historical data being monitored from all four renewable energy platforms. Additionally, there are temperature sensors located in the ceilings and walls in two locations, each to measure the temperature differential between the inside of the drywall and just below the surface of the insulation. An outside temperature sensor in a radiation shield gives the outdoor ambient temperature at all times. An iPad, supplied as part of the system, also allows us to show the highly graphical data as we give tours throughout the entire house and even outside.

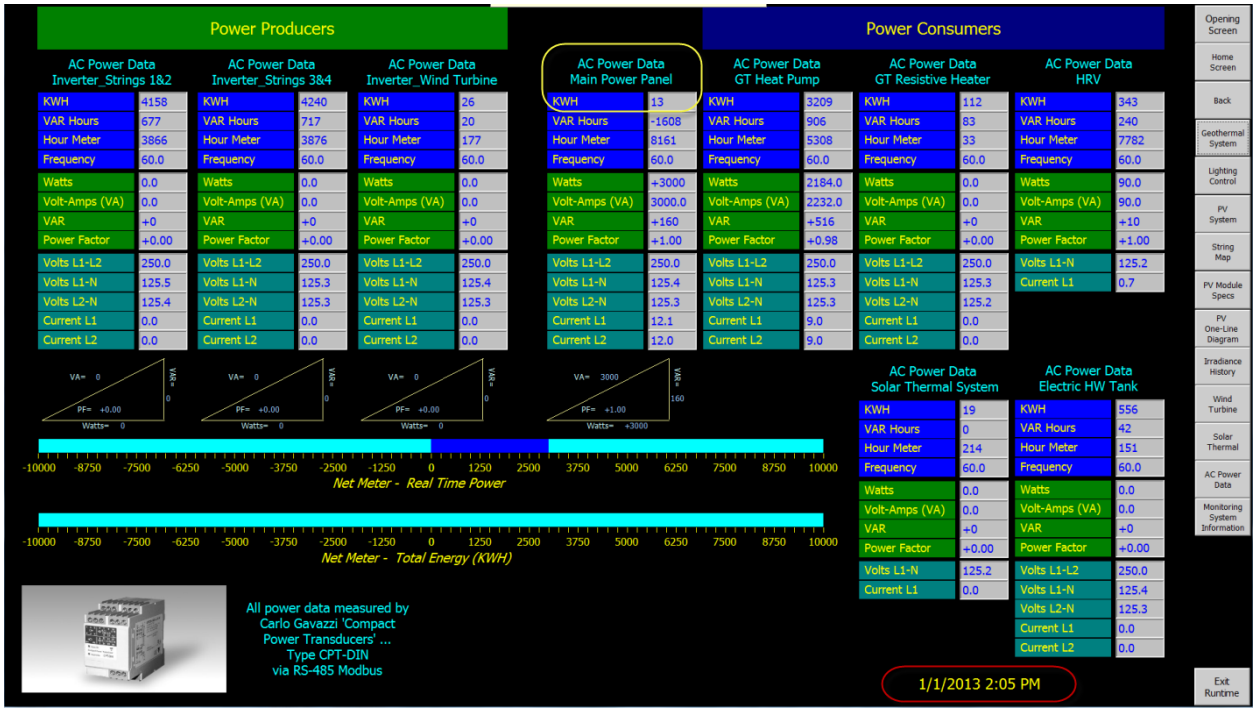
IMT Solar installed power meters on each of the power production platforms (the two PV and one wind inverters), on the major power consumers (the geothermal heat pump system, backup resistive heating unit, heat recovery ventilator, solar thermal pumps, and electric backup hot water heater), and on the main power distribution panel. This allows us to see exactly what is going on, electrically, within the entire house. They also used a very visual method to show the "net meter" on their touch screens to display the total energy (KWH) used or produced by the home, over time.

The 16 temperature sensors which were installed during the installation of the four geothermal wells are also brought into the IMT REVTOS system. Doing so allows us to study the thermal transfer characteristics of the four different grout systems.

Built-in web servers in the IMT REVTOS system allow the visualization system to be brought into any classroom where the data may be relevant to the curriculum. The same data can also be seen via the internet by visitors to our website.

Screen captures of the real time data, as well as the historical data files (stored in Microsoft Excel file format), will allow us to study all aspects of the renewable energy systems in the home, today and into the future.

The graph below shows our net meter data for January 1, 2013…a year after our monitoring system went online. Our total grid usage for the house for the year was 13 kWH, about as close to zero-energy as you can get.


Power Producers
Power Consumers
AC Power Data Inverter_Strings 1&2
KWH 4158
VAR Hours 677
Hour Meter 3866
Frequency 60.0
Watts 0.0
Volt-Amps (VA) 0.0
VAR +0
Power Factor +0.00
Volts L1-L2 250.0
Volts L1-N 125.5
Volts L2-N 125.4
Current L1 0.0
Current L2 0.0
AC Power Data Inverter_Strings 3&4
KWH 4240
VAR Hours 717
Hour Meter 3876
Frequency 60.0
Watts 0.0
Volt-Amps (VA) 0.0
VAR +0
Power Factor +0.00
Volts L1-L2 250.0
Volts L1-N 125.3
Volts L2-N 125.3
Current L1 0.0
Current L2 0.0
AC Power Data Inverter_Wind Turbine
KWH 26
VAR Hours 20
Hour Meter 177
Frequency 60.0
Watts 0.0
Volt-Amps (VA) 0.0
VAR +0
Power Factor +0.00
Volts L1-L2 250.0
Volts L1-N 125.4
Volts L2-N 125.3
Current L1 0.0
Current L2 0.0
AC Power Data Main Power Panel
KWH 13
VAR Hours -1608
Hour Meter 8161
Frequency 60.0
Watts +3000
Volt-Amps (VA) 3000.0
VAR +160
Power Factor +1.00
Volts L1-L2 250.0
Volts L1-N 125.4
Volts L2-N 125.3
Current L1 12.1
Current L2 12.0
AC Power Data GT Heat Pump
KWH 3209
VAR Hours 906
Hour Meter 5308
Frequency 60.0
Watts 2184.0
Volt-Amps (VA) 2232.0
VAR +516
Power Factor +0.98
Volts L1-L2 250.0
Volts L1-N 125.3
Volts L2-N 125.3
Current L1 9.0
Current L2 9.0
AC Power Data GT Resistive Heater
KWH 112
VAR Hours 83
Hour Meter 33
Frequency 60.0
Watts 0.0
Volt-Amps (VA) 0.0
VAR +0
Power Factor +0.00
Volts L1-L2 250.0
Volts L1-N 125.3
Volts L2-N 125.2
Current L1 0.0
Current L2 0.0
AC Power Data HRV
KWH 343
VAR Hours 240
Hour Meter 7782
Frequency 60.0
Watts 90.0
Volt-Amps (VA) 90.0
VAR +10
Power Factor +1.00
Volts L1-N 125.2
Current L1 0.7
AC Power Data Solar Thermal System
KWH 19
VAR Hours 0
Hour Meter 214
Frequency 60.0
Watts 0.0
Volt-Amps (VA) 0.0
VAR +0
Power Factor +0.00
Volts L1-N 125.2
Current L1 0.0
AC Power Data Electric HW Tank
KWH 556
VAR Hours 42
Hour Meter 151
Frequency 60.0
Watts 0.0
Volt-Amps (VA) 0.0
VAR +0
Power Factor +0.00
Volts L1-L2 250.0
Volts L1-N 125.4
Volts L2-N 125.3
Current L1 0.0
Current L2 0.0
VA= 0 PF= +0.00 Watts= 0 VAR= 0
VA= 0 PF= +0.00 Watts= 0 VAR= 0
VA= 0 PF= +0.00 Watts= 0 VAR= 0
VA= 3000 PF= +1.00 Watts= +3000 VAR= 160
-10000 -8750 -7500 -6250 -5000 -3750 -2500 -1250 0 1250 2500 3750 5000 6250 7500 8750 10000
Net Meter - Real Time Power
-10000 -8750 -7500 -6250 -5000 -3750 -2500 -1250 0 1250 2500 3750 5000 6250 7500 8750 10000
Net Meter - Total Energy (KWH)
All power data measured by Carlo Gavazzi 'Compact Power Transducers' ... Type CPT-DIN via RS-485 Modbus
1/1/2013 2:05 PM
Opening Screen
Home Screen
Back
Geothermal System
Lighting Control
PV System
String Map
PV Module Specs
PV One-Line Diagram
Irradiance History
Wind Turbine
Solar Thermal
AC Power Data
Monitoring System Information
Exit Runtime