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# ETSU GearUp: The Design and Development of an Alternative Energy Greenhouse.

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ETSU GearUp:

The Design and Development of an Alternative Energy Greenhouse

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Masters of Science in Engineering Technology

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by

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# ABSTRACT

ETSU GearUp:

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East Tennessee State has partnered with David Crockett High School through the Federal Gaining Early Awareness and Readiness for Undergraduate Programs. This year's project is an alternative energy greenhouse, which incorporates solar panels and a wind turbine. The focus is on familiarizing students with control systems including programmable logic controllers and power management. There is also an emphasis on the importance of green engineering.

The high school's students have been involved in the design and development of every aspect of the system. The development of the system is ongoing and will be further integrated into classes in the fall semester. This unique project requires the students to use classroom skills in real world circumstances. The hope is that allowing the students to be involved with projects such as this will encourage them to take higher math and science courses and pursue a college degree in the science and engineering fields.

# DEDICATION

This is dedicated to my three sons, Drew, Zefram, and Kepler, with hope that they may have a hand in bettering their world.

"No sensible decision can be made any longer without taking into account not only the world as it is, but the world as it will be."

-Isaac Asimov

# ACKNOWLEDGEMENTS

The ETSU GearUp alternative energy greenhouse project was the brainchild of Dr. J. Paul Sims. It would not exist if not for his work in developing the grant and leading all of the work involved in the project's design and development.

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# CHAPTER 1

## INTRODUCTION

This year's ETSU Gaining Early Awareness and Readiness for Undergraduate Programs (GearUp) project is an alternative energy greenhouse at David Crockett High School. It has a wind turbine and two solar panels. The children are involved in the design and development of every aspect of the system. The focus is on familiarizing the students with control systems including programmable logic controllers and power management. There is also an emphasis on the importance of "green" engineering. There are plans for on-site ethanol production as well.

There are sensors that monitor the temperature, humidity, UV radiation, carbon dioxide levels, soil moisture, soil temperature, soil conductivity, and leaf wetness inside the greenhouse as well as a complete weather station on the outside. These sensors are routed through a wireless system to link with the school's network. The students will be able to monitor all of these conditions from a website. This website will also monitor the power systems of the wind turbine and solar panels.

This arrangement requires the students to learn higher mathematics and engineering to set up the programmable logic controllers and control circuits. They are also learning about agriculture, communications, programming, and environmental controls. There is no other educational alternative energy system like this in the area. The students and faculty are excited about the possibilities that the project will bring to the school as it is further integrated into classes in the fall semester.

# CHAPTER 2

# BACKGROUND INFORMATION

## Education

Ignorance is dangerous. Eugenie Scott, director of the National Center for Science Education, told the New York Times that "we ignore public understanding of science at our peril." (Dean, 2005, 5) In a democratic society, the public will is meant to form the country's mores and decide its future. However, ignorance of the facts of an issue doesn't keep people from having opinions about it. It may be unwise to listen to public opinion about building new nuclear power facilities because a study shows about 10% of U.S. adults know what radiation is. The decrease in NASA funding might be related to the finding that one in five U.S. adults thinks the Sun revolves around the Earth.

As shown in Table 1, the further U.S. students progress in school, the further behind they fall in relation to the rest of the world's students. U.S. 10$^{th}$ graders are ranked 28$^{th}$ out of 39 industrial nations in math scores and 22$^{nd}$ in science. (Kolawole, Henig, & Robertson, 2007) Figure 1 shows that most American students get through high school without taking higher mathematics and sciences. Less than a third takes physics. Fewer than 8% take trigonometry. More than 30% don't even finish Algebra II. (U.S. Department of Education, 2004) We must change the students' attitudes towards higher math and science in order to resolve these deficiencies.

Table 1

*U.S. Math and Science Rankings Worldwide in 2003*

| U.S. Worldwide Math and Science Rankings in 2003 | | | | |
|---|---|---|---|---|
| Study | Age/Grade | Subject | Ranking | Total # of Countries |
| TIMMS 2003 | 9 / 4th | Math | 12 | 25 |
| | | Science | 6 | |
| TIMMS 2003 | 13 / 8th | Math | 15 | 45 |
| | | Science | 9 | |
| OECD 2003 | 15 / 10th | Math | 28 | 39 |
| | | Science | 22 | |

(adapted from Kolawole, Henig, & Robertson, 2007)

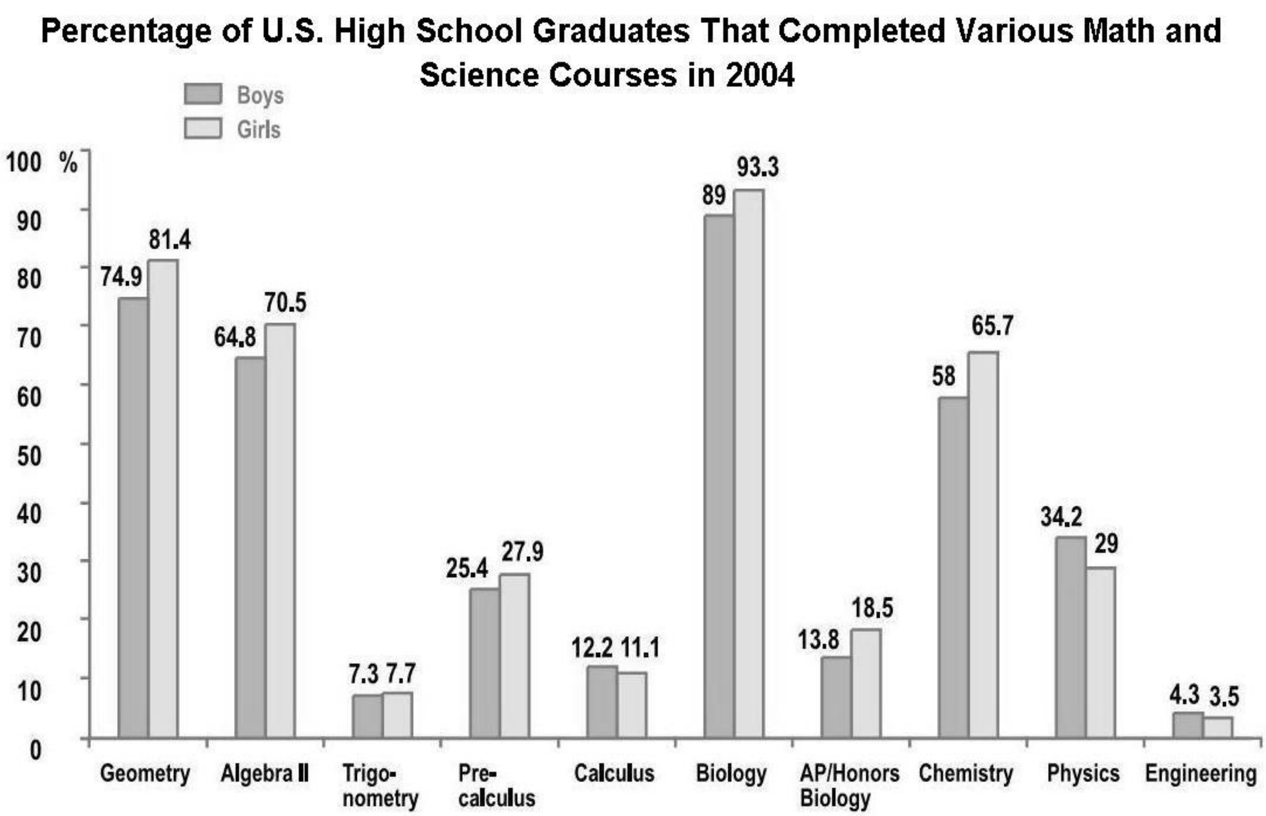


*Figure 1*. Percent of U.S. High School Graduates Completing Various Courses in 2004 (U.S. Department of Education, 2004)(PD-USGov-Education)

Nationwide around 55% of graduating seniors go on to attend college. Of those who do go on to attend college and take at least 10 credit hours of classes, about half fails to receive a bachelor's degree. (Burd, 2004) Tennessee is well below the national average in most education statistics, as shown in Figure 28 in Appendix B. In nationwide rankings, Tennessee is 43rd in percentage of adults who have at least a bachelor's degree. In 16 Tennessee counties, more than 20% of the adult population has less than a 9th grade education, according to the 2000 census.

Mentoring programs are attempting to remedy this deficiency. Students need encouragement. Students are more likely to further their education when they have support and encouragement from a mentor. Teachers at the elementary and high school level are more effective when they are paired with their colleagues from colleges and universities. (National Science Foundation, 2007)

Several mentoring programs have been started by the federal government in the past several years. The National Science Foundation's Math and Science Partnership program started in 2002 and has placed qualified mentors from higher education in more than 3,300 classrooms around the country. Studies following the schools in the program have shown significant improvement on annual math and science assessments across almost every age group. (Dean, 2005) The TRiO program has been shown to increase completed bachelor's degrees by 8% to 15%. (ExpectMore.gov, 2008)

The education system in this country needs to be revamped from within by the students adjusting their attitudes towards school and raising the bar for the educational standard. Mentoring our youth will help to encourage them to take the higher math and science classes that will prepare them for college. These more advanced classes will better prepare them to participate in the new world of pollution, climate change, stem cells, and other social issues that require higher education to understand. They can then intelligently debate and decide our future.

## GearUp

One program that seems to be especially fitted to Tennessee's educational issues is the federally funded Gaining Early Awareness and Readiness for Undergraduate Programs (GearUp). Developed in 1998, GearUp aims to help encourage more middle and high school students to participate in college tract classes. The program focuses on lower income areas in which students may have lower expectations for their educational future.

GearUp is very similar to older programs, such as TRiO, in that it targets lower income children and provides mentoring support from secondary educational professionals in elementary school and follows the students through to college. The primary difference between TRiO and GearUp is that TRiO focuses on individual students with parents who didn't attend college and earn less than $25,000, while GearUp targets entire school systems that have lower income families. This makes GearUp especially suited to accommodate Tennessee's dramatic disparities between educational attainment based on geographical and economical differences. This disparity is shown in the chart showing adults' levels of education broken down by Tennessee county in both Table 2 and Figure 27 in Appendix A.

ETSU's GearUp program was started 2 years ago and is partnered with the Jonesborough area schools. The program started out introducing a group of junior high school children to the mathematics of model rocketry. Each child built and decorated a rocket. Next, they each got a chance to set off a rocket engine in a specially built force gauge in order to understand the function and physics of the different stages of rocket flight. The students compared their data with the manufacturer's expected thrust over time curves. They calculated the projected altitude of their rockets using the data collected.

The students used sextants to calculate the actual altitude achieved by each rocket. They measured the distance from the landing area and used stopwatches to find the time between liftoff and landing. Awards were given for highest rocket flight, closest approximation of individual altitudes, and the rocket that landed closest to the target area. Many of the students seemed quite excited about the prospects for learning more about the science of rocketry in class. This style of summer program is typical of the national GearUp system.

The problem with most systems is that there are not enough hands-on, exciting, scientific projects like this. There are field trips, college campus weekends, and other postsecondary education awareness programs. The vast majority of programs focus on college scholarships, test preparation, mentoring, and tutoring services. In preparing the students for college, the focus is more on encouragement, awareness, and financial assistance and less on mentorship and actual academic education. The following excerpt from the Montana GearUp program's website is typical of the many state programs.

> ***Mission Statement**: Montana GEAR UP believes that postsecondary education is possible for all Montana students, regardless of economic background, and strives to empower them to realize that ambition. Montana GEAR UP brings this message to middle and high schools, students, their parents, and the community through early college and career awareness activities, scholarships, financial aid information, and improved academic support to help raise the expectations and achievement of all.*
>
> ***Goals & Objectives:***
>
> *I.* ***To establish the importance of postsecondary education throughout the GEAR UP demonstration program and provide early college and career awareness activities.***
>
> *i.* *Increase student and family knowledge of postsecondary education preparation.*
>
> *ii.* *Improve teacher, counselor and administrator expectations of students*
>
> *iii.* *Increase student level of college and career awareness.*
>
> *II.* ***To provide financial aid awareness, planning and scholarships to GEAR UP students.***
>
> *i.* *Increase student and family knowledge of postsecondary education financing.*

ii. *Increase scholarship participation and qualification.*

III. ***To provide GEAR UP schools with the tools necessary to strengthen academic rigor and support in order to improve student opportunities and enrichment***

i. *Increase the academic performance and preparation for postsecondary education for GEAR UP students.*

ii. *Increase the rate of high school graduation and participation in postsecondary education for GEAR UP students.* (Montana GEAR UP Program, 2008, 4)

## Alternative Energy Greenhouse

There is a pressing need to encourage our youth to participate in higher math and science courses in order to prepare them for higher education and careers in the science and engineering fields. The ETSU GearUp alternative energy greenhouse project is an original and timely way of answering this need. The students are being involved in every area of the design and implementation of this major engineering project.

The alternative energy greenhouse project allows for the students to get real world experience using the skills they learn in class. This helps them to see the importance of their education as they receive it. The old question of “When am I going to use this?” can be answered emphatically, “As soon as you can.” The students are using drafting, design, mathematics, agriculture, communications, programming, engineering, and other skills learned through their coursework in order to create a new learning environment with tangible and rewarding benefits for themselves and future students of the high school.

# CHAPTER 3

## PROBLEM STATEMENT

The need for expanding the world's alternative energy resources is critical due to environmental and economical forces. The need for increasing the number of scientists and engineers who are focused on this expansion is inalienable. While the total number of college graduates has increased by 40 % from 1993 to 2003, the percentage of these that are working in the science and engineering fields has increased only 1 %, from 11 % in 1993 to 12 % in 2003.

The U.S. Department of Energy's Wind Powering America program and National Renewable Energy Laboratory started the Wind for Schools project in 2005. The program helps schools find funding and suppliers for installing small 400 watt wind turbines on their campuses. The schools are encouraged to use the turbines as teaching aids in the classes. There are engineering, environmental, economic, and other aspects that could be worked into the curriculum.

To date, there are 23 states with installed school wind projects in the program. Six more states have projects planned or under development. The Southeast, as shown in Figure 2, has just two projects; both of which are located on North Carolina college campuses.

The map of participation in Wind for Schools, Figure 2, for the most part corresponds with the map of the potential for wind power, Figure 3. One of the few differences between the maps is that the southern Appalachian states other than North

Carolina, while they have significant wind power potential, have no Wind for School projects planned. Kentucky, West Virginia, Virginia, and Tennessee should be participating in wind power projects. A factor in the lack of wind power interest may be that these areas' economies are closely tied to the coal industry.

Tennessee has a need to encourage young people to participate in more mathematics and science classes. Tennessee severely underutilizes its wind resources. These problems call for action at the elementary and high school levels. The scientists and engineers of tomorrow must be instructed and inspired as today's children.

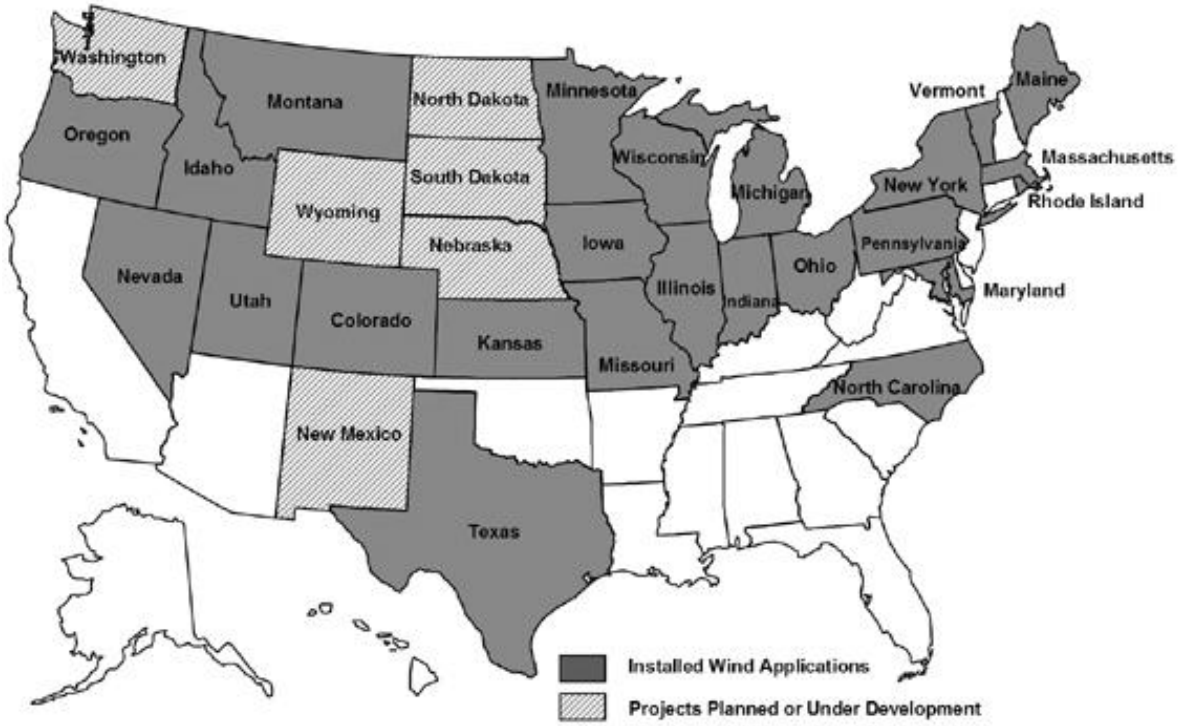


*Figure 2*. Wind for Schools Project Locations (U.S. Department of Energy, 2008)(PD-USGov-DOE)

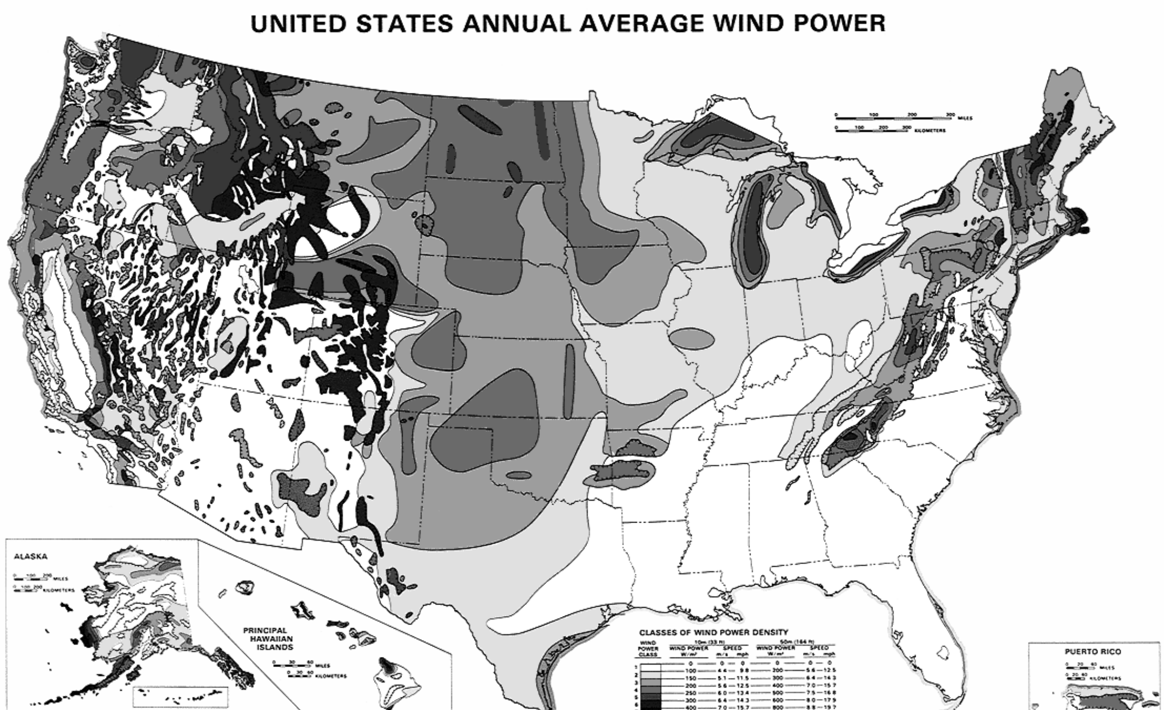


*Figure 3.* Average Annual U.S. Wind Power (U.S. Department of Energy, 2002) (PD-USGov-DOE)

# CHAPTER 4

# SOLUTION

## GearUp Collaboration

The ETSU GearUp partnership program with Davy Crockett High School (DCHS) is helping the next generation of energy engineers find their place. It is not only increasing the students' knowledge and awareness of working with alternative energies, it is teaching them skills that they will use along their paths through higher education.

The collaboration involves students and faculty from both ETSU and DCHS. An ETSU professor, Dr. Paul Sims, instigated the grant from the Federal GearUp system and has been integral in almost every decision since then. Teachers from the engineering and agriculture departments at DCHS have been on the site working to design and set up many of the systems. The high school students have set up and programmed some of the weather monitoring gear, built some of the structural components, and wired some of the components, as shown in Figure 29 in Appendix C. Graduate students from ETSU have been working both independently and with the other contributors to bring the project to completion.

The high school students are learning about energy management, control systems, sensors, communications, project management, communications, programming, and other useful engineering areas. The project will be used by biology, agriculture, business, and other classes as well. The students who have participated in the development process have called on the skills learned in their mathematics, drafting, design, electrical, mechanical, programming, structural, and other classes.

The greenhouse is being designed with future students in mind as well. There is room being left for expansion into other projects, such as further implementation of sensors, a more complex automation system, and the possible production of ethanol. The power being generated will probably be enough to expand the alternative energy project well beyond the greenhouse stage and incorporate the entire school and its varied curriculums.

The GearUp model of helping entire districts with college preparedness rather than focusing on individual children in need, fits Tennessee's needs. As shown in Table 2 and Figure 27 found in Appendix A, Tennessee's counties are dramatically varied in their levels of educational attainment. A project such as David Crockett High School's alternative energy greenhouse can help an entire community's children to better understand and appreciate the need for furthering their scientific education.

## Technical Details

The greenhouse has a semi-automated environmental control system. This is entirely powered by the energy produced by the wind turbine and the solar panels. The existing electric heaters are the only parts of the system that will be using grid power. There should even be enough excess power from the alternative energy system to handle the school's outdoor water fountain and some other superfluous power requirements.

There are a variety of sensors, valves, and controls throughout the system. These are all connected centrally in a control box on the West side of the greenhouse. There are nine smaller junction boxes in the system for the tables in the greenhouse and one outside at the tower.

## Sensors

There are several different types of sensors that will be used to monitor the plants' environment and health. The measurements from the sensors described in this section are sent wirelessly to the school's network. All of these measurements will be able to be viewed by students on a website hosted by the school.

Air Quality. Air quality will be continuously monitored using an Elektronik EE80 HVAC room monitor. The EE80, shown in Figure 4, will monitor the greenhouse air's relative humidity, temperature, and carbon dioxide levels. These readings are provided as analog outputs and will be recorded using the Keithley programmable multimeter housed in the control box for the greenhouse as shown in Appendix C in Figure 33. The EE80 uses infrared beams to measure the spectral aspects of the air and determine the qualities needed. This model has two infrared beams that allow it to self calibrate without having to be exposed to ambient carbon dioxide levels to find a baseline. This form of self calibration is crucial in the greenhouse environment because it will be an interminable working environment. (Elektronik Ges.m.b.H., 2007) This model has a liquid crystal display for reading the measurements on the site as well.

*Figure 4.* Elektronik EE80 HVAC Room Monitor

Leaf Wetness. The moisture collected on the plants leaves will be measured using Decagon dielectric leaf wetness sensors, shown in Figure 5. These sensors mimic the size shape and thermodynamic properties of real leaves. The dielectric constant of the zone above the surface of the senor is measured. Air has a dielectric constant of 1 whereas ice’s is 5 and water is 80. The measured constant should give a value proportional to the amount of ice or water on the leaves surfaces. (Decagon Devices, Inc., 2007)

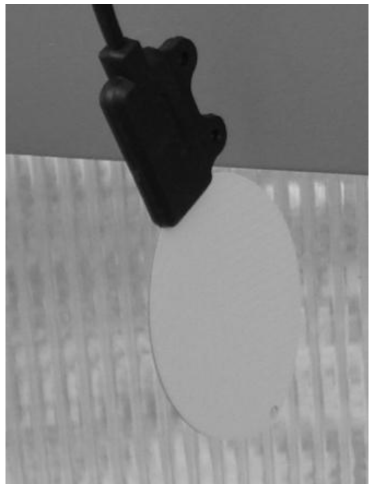

*Figure 5*. Leaf Wetness Sensor

Solar Radiation*.* Solar radiation flux density will be monitored using a Decagon pyranometer, shown in Figure 6. It measures the ultraviolet radiation levels in watts per square meter using specially calibrated photoreactive cells. Both the pyranometer and the leaf wetness sensors return analog signals that will be recorded using the Keithley programmable multimeter.

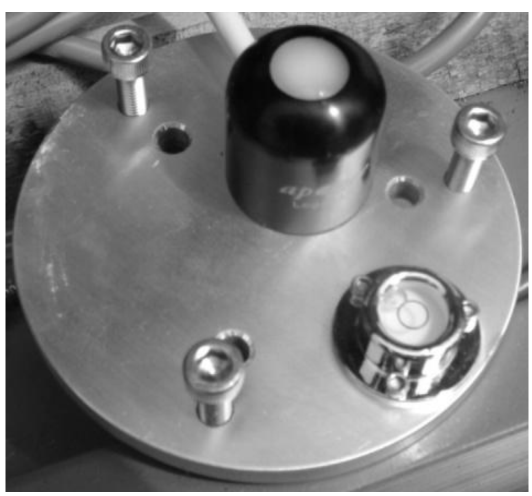

*Figure 6.* Pyranometer

Soil Properties. There are two different types of sensors that will be used to monitor the soil qualities. There are five soil sensors. Two Decagon ECH2O-TM probes measure the soil's water content and temperature. Three Decagon ECH2O-TE probes, shown in Figure 7, measure the soil's water content, temperature, and electrical conductivity. The volumetric water content is measured using the same dielectric method as the leaf wetness sensors. Soil temperature is measured using a surface mounted thermistor that reads an average temperature across the probes three prongs. The electrical conductivity of the soil indicates the amount of fertilizer that is present. The ECH2O-TE measures electrical conductivity by sending an alternating electrical current from the two outside prongs and measuring the voltage and current received by the inner prong. (Decagon Devices, Inc., 2007)

*Figure 7*. ECH2O-TE Soil Sensor

Weather. The external weather station is mounted on the wind turbine's tower as seen in Figure 8. The weather station includes an anemometer, wind vane, rain gauge, barometer, thermometer, and ultraviolet light sensor. The station has its own small solar panel for daylight operation in order to preserve the batteries. This is especially helpful because it is high on the turbine tower and would be hard to reach in order to change the batteries. The measurements are transmitted wirelessly to a substation that uploads the data to the high school's computer network.

*Figure 8.* Outdoor Weather Station

## Environmental Controls

A greenhouse environment intrinsically needs to be regulated. The greenhouse walls are made to allow light in and hold the resulting heat. This is an imperfect system and requires ventilation for cooling and allowing in fresh carbon dioxide. Auxiliary heating in the colder months is also required. The plants need to be exclusively manually watered, as they are not exposed to rain. The soil in the plant beds is also detached from the natural system of nutrient replenishment so that fertilizer is required.

Temperature. The temperature in the greenhouse is monitored though the Elektronik EE80 HVAC room monitor as mentioned in the section about the sensors. There are also traditional thermostats in the greenhouse. Some of these thermostats control the heaters and others control the exhaust fan and louvers. The electric heaters, shown in Figure 9, are the only components in the control or environmental systems that will not be powered by the wind and solar resources. This is because they were purchased ahead of time and are thusly not appropriately sized for the project.

*Figure 9*. Electric Heater

The fan, in Figure 10, is turned on when the internal temperature reaches a given temperature. At the same time, the louvers, one is shown in Figure 11, are opened with rotary actuators that pull on chains connected to the louver control bars, shown in Figure 12. The exhaust fan is centered over the West door of the greenhouse. There two louvers are smaller and located on the East wall on each side of the door.

*Figure 10.* Exhaust Fan

*Figure 11.* North Louver

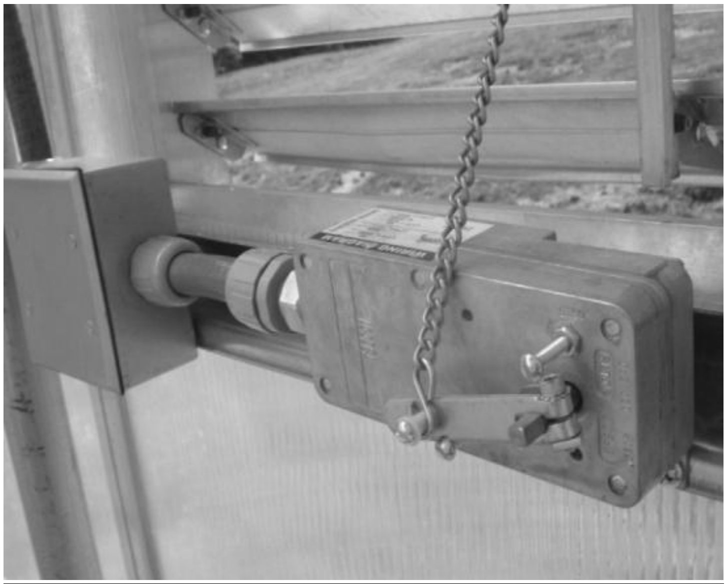

*Figure 12.* Louver Control

Water and Fertilizer**.** The watering system is combined with the fertilizer system. The fertilizer is automatically mixed with the water at the supply valves shown in Figure 13 before it is distributed through the pipes and sprayers. The water controls are not fully automated. The front panel of the control box shown in Figure 14 has switches that allow an operator to set the tables that will receive watering and the amount of time that the water will be applied. Above the switches is a TL20 control panel and display for the programmable logic controllers.

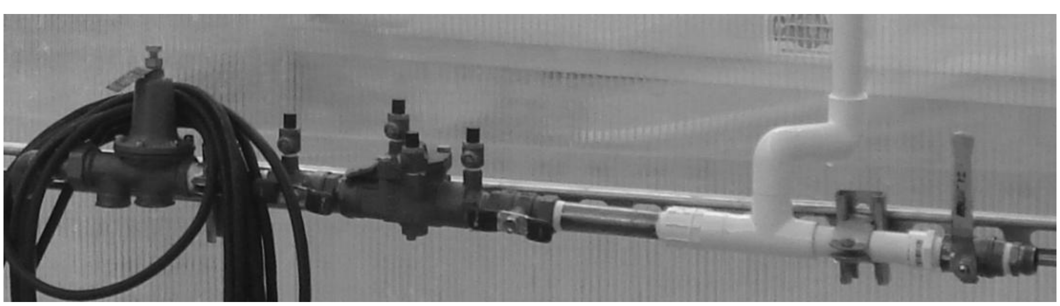

*Figure 13.* Water and Fertilizer Blending Valves

*Figure 14*. Control Panel

There are two knobs for controlling the watering time. One lets the operator select 0, 20, or 40 minutes, the other lets them select 0, 1, or 2 hours. A momentary push switch is used to start the watering process. When the start button is pressed, the programmable logic controller in the control box opens the solenoid valves, Figure 15, that correspond to the switches for the corresponding tables. The controller then closes the solenoid valves after the time set for the given tables. The emergency stop switch on the panel cuts power to all control systems and thereby closes the solenoid valves and stops the water.

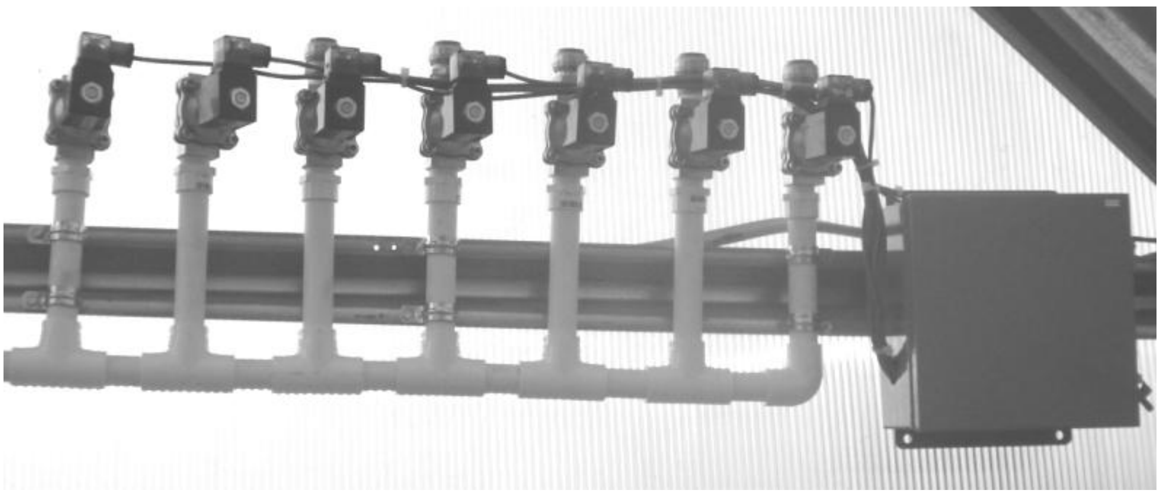

*Figure 15.* South Solenoid Valves and Junction Box

The program can be updated or expanded by the students in the future. As more projects are developed that could be added to the existing system, the students will be able to connect a laptop computer to the programmable logic controllers, located in the control box as shown in Figure 16, and add new functions or adjust the existing functions to better fit their needs. At present, these controllers will be used only for controlling the watering system, but they have room for expansion.

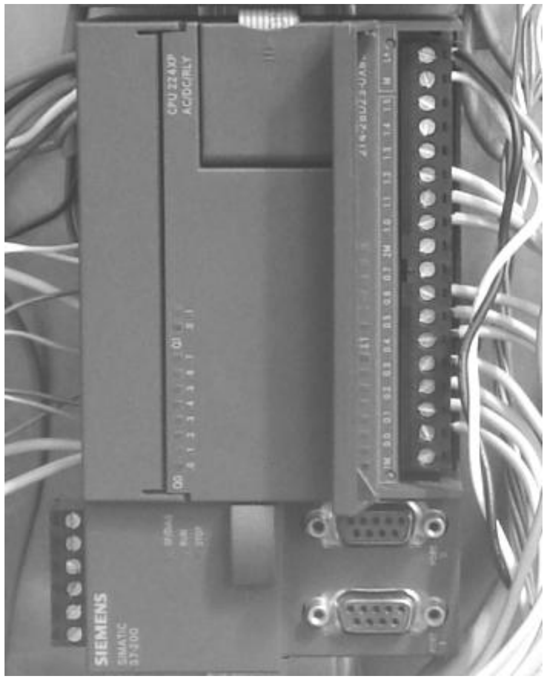


*Figure 16.* Programmable Logic Controllers

There are presently two programmable logic controllers in use to control the watering system. These are wired to the control panel's switches and to the solenoid valves as shown in Appendix C in Figure 35 and Figure 36. Each controller manages one side of the greenhouses tables and solenoid valves. As seen in Figure 34 in Appendix C, the odd numbered tables are on the South side of the greenhouse and the even numbered tables are on the North side.

The wiring for each is an identical mirror image of the other. This simplifies troubleshooting issues later. The program is identical for each side and each controller as well. Figure 17 shows the ladder logic program that is loaded in each controller. The inputs that are the labeled I0.0 through I0.6 represent the table selection switches. Input I1.0 corresponds to the cycle start button. Inputs I1.1, I1.2, I1.3, and I1.4 represents the timer settings for the 20 minute, 40 minute, 1 hour, and 2 hour switches, respectively. The program uses these inputs to determine a watering time anywhere from 20 minutes to 2 hours and 40 minutes in increments of 20 minutes.

This allows the operator to select which tables will receive water and fertilizer, how much time they will be watered, and press start. The system will activate the proper solenoid valves and only water the tables selected for the time selected. Eventually, the high school plans to have the students write programs that will more fully automate the process. The controller could be made to monitor the soil moisture in certain tables and automatically water those tables as required.

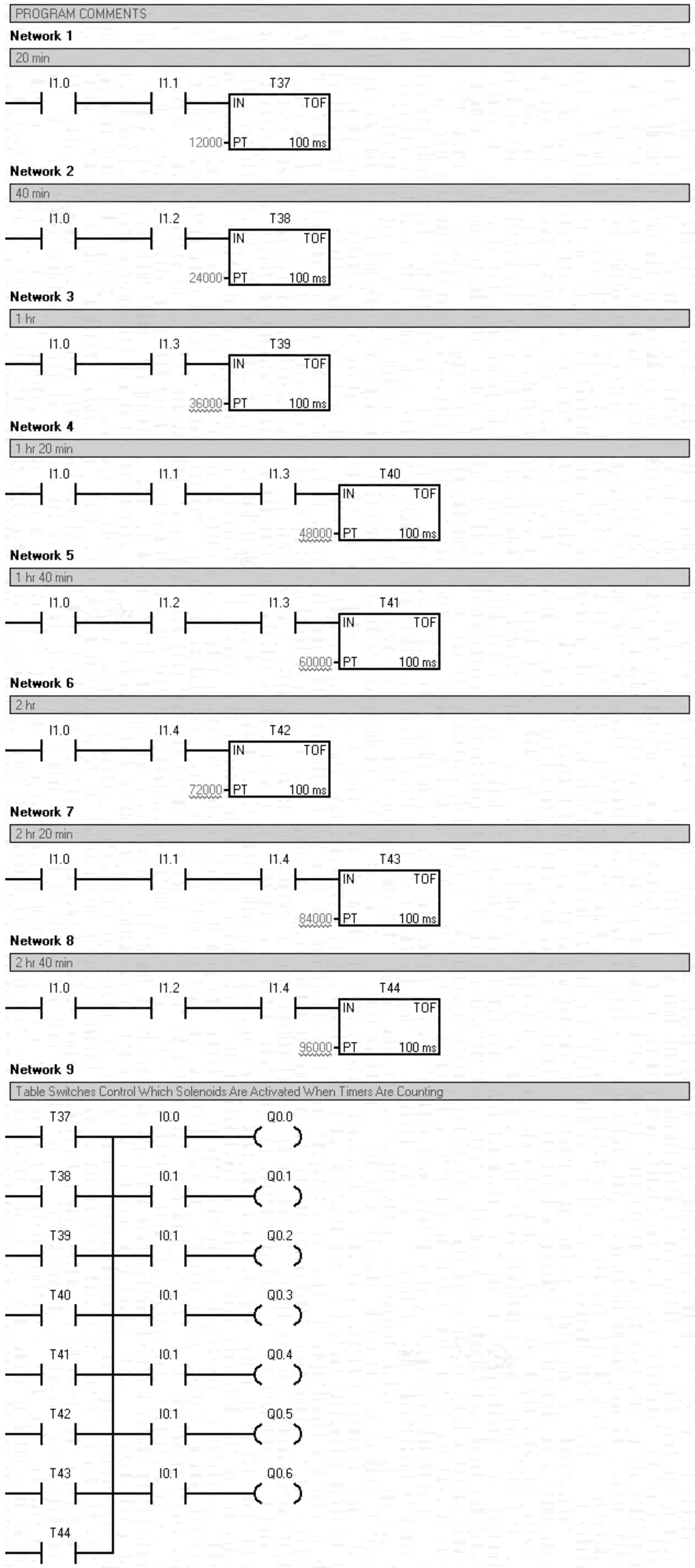


*Figure 17.* Watering System Program

Power Generation

The power for the sensors and control systems in the greenhouse is generated on-site. The power comes from a wind turbine and two solar panels. These are both located just outside the greenhouse to the East, as seen in Figure 32 in Appendix C. Each system has its own breaker at the tower. They are grounded at the base of the tower and connected to a lightning arrester as shown in Figure 30 in Appendix C.

Wind Turbine*.* The wind turbine used in the project is an AirX 400 watt turbine, as shown in Figure 18. It has a 46 inch rotor diameter and is mounted on a 30 foot EZ-Tower as seen in Figure 31 in Appendix C. The turbine has a start-up wind speed of 8 miles per hour and is rated to survive up to 110 miles per hour. There is an internal microprocessor that regulates power production and overspeed control. This works by automatically switching one of the dual armature windings to brake the turbine in high winds in order to prevent damage.

*Figure 18.* AirX 400 Watt Wind Turbine

The turbine's power output is dependent on the wind speed available. This relationship is graphed in Figure 19. The amount of energy produced each month by the turbine is compared to the annual average wind speed in Figure 20. These charts can be used by the students in statistics classes. They can compare actual wind speeds and actual power generated to the expected values from the charts.

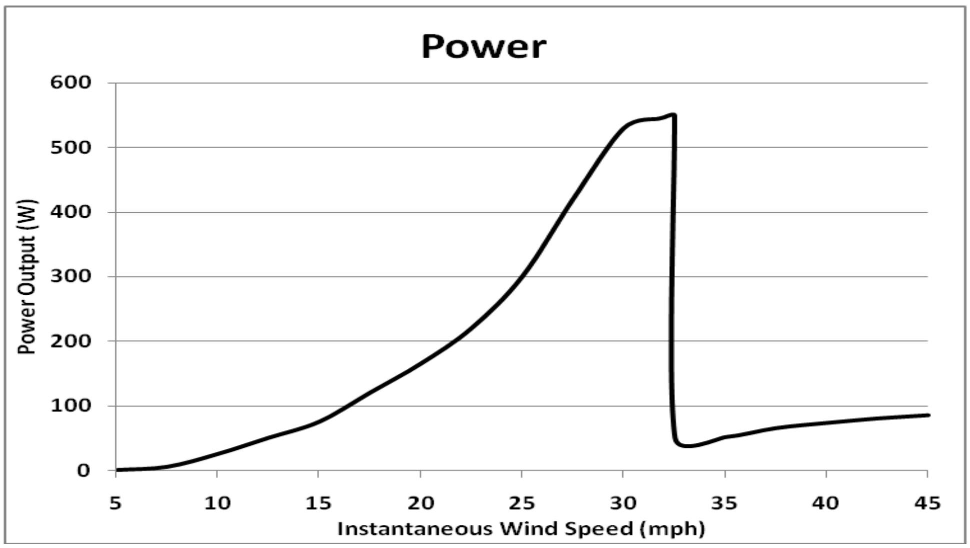


*Figure 19.* AirX Turbine Power Output vs. Wind Speed (adapted from Southwest Windpower, 2008)

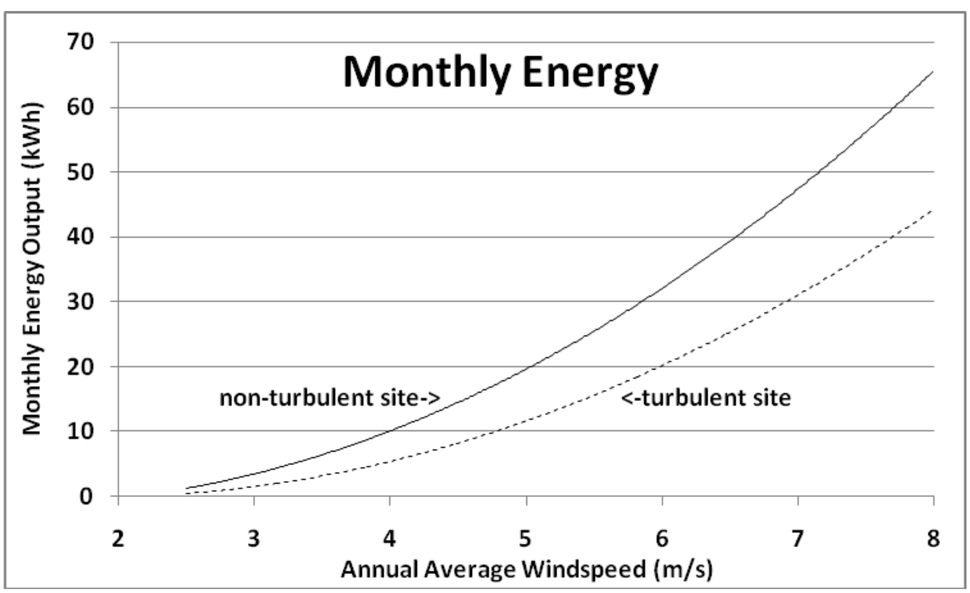


*Figure 20.* AirX Turbine Monthly Energy Output vs. Average Annual Wind Speed (adapted from Southwest Windpower, 2008)

Solar Panels. The solar panels are two matching Kyocera multicrystal 130 watt 17.6 volt photovoltaic modules. They each measure 56.1 inches by 25.7 inches. These are wired in parallel to provide a maximum current of 14.78 amps. The panels are mounted on an aluminum frame that is attached to wooden posts, as shown in Figure 21. The frame is adjustable from 21 degrees to 35 degrees from the horizontal. This is in order to maximize the panels' exposure to sunlight during different seasons. It is set for 21 degrees during the summer months and 35 degrees during the winter.

*Figure 21.* Adjustable Solar Panel Frame

Solar Controller*.* The power from the solar panels is regulated by a ProStar-30 solar controller, Figure 22, found in the greenhouse's control box. The photovoltaic cells need a controller to regulate the voltage produced or they can burn themselves out without a load. The ProStar solar controller can monitor the power produced, the battery levels, and the load demands. The controller can manage the charging of the batteries and prevent overcharging as well.


*Figure 22.* ProStar-30 Solar Charge Controller

Battery Bank*.* The power from the turbine and photovoltaic cells is stored in the battery bank shown in Figure 23. This consists of 10 sealed Exide marine rated batteries. They are wired in parallel in two separate groups of five each. Each group has its own individual breaker to prevent shorting issues. The batteries charge more evenly and are safer in this dual section configuration.

*Figure 23*. Battery Bank

<u>GreenMeter</u>*.* The true heart of the entire greenhouse is the GreenMeter hybrid energy management system shown in Figure 24. This acts like the solar controller in that it regulates the power coming from the solar panels, charges the battery bank, and monitors the power loads. The GreenMeter also manages the power from the wind turbine, provides power to the power inverter, and interfaces with the network through software. The maximum current that it can carry is 500 amps and is rated to handle nominal 12 to 24 volts with a peak of 58 volts. (WES PowerTechnology Inc., 2006)


*Figure 24.* GreenMeter Power Management System

Power Inverter. The power being generated and coming from the GreenMeter is direct current. In order to power some of the control systems, fans, and supplementary systems, the power must be converted to alternating current. The power inverter, shown in Appendix C in Figure 33, takes the direct current power and supply up to 1500 watts of alternating current power for the systems that require it. This is more than enough wattage in that the wind turbine and the solar panels together should produce less than 1000 watts at their peak performance.

Safety is a concern when dealing with this much power, especially because the project will primarily be worked on by the high school students once the fall semester starts. The system is designed using direct current wherever feasible because it is much safer than alternating current. The 12 volt direct current lines are not going to seriously injure a student in the event of an accident. Even with this precaution, there have been redundant breakers installed on all lines carrying significant voltage or current.

## Data Systems

*EM50 Data Logger.* The ECH2O soil sensors are all connected to the Decagon EM50 data logger as shown in Figure 25. This receives and transposes the signals from the soil sensors for collection on a computer system. The soil sensors must be run through the data logger because they require specially timed excitation for the readings to be made.

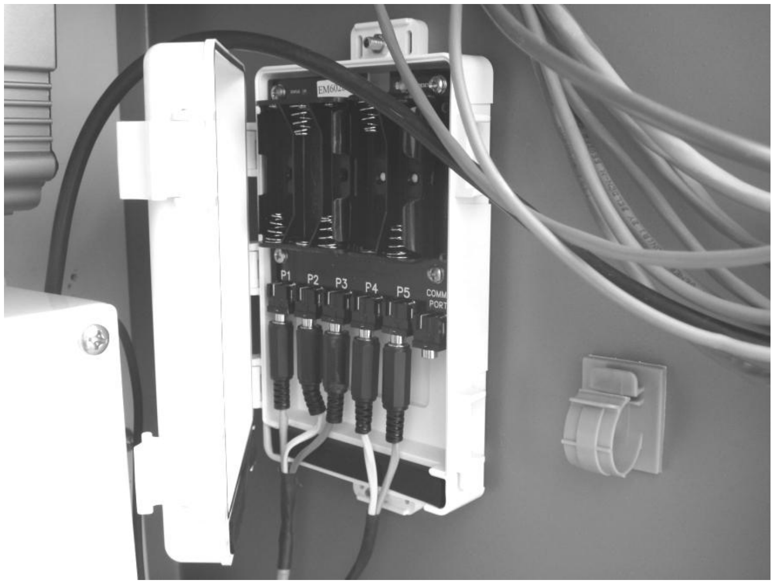

*Figure 25.* EM50 Data Logger

Keithley Programmable Meter. The leaf wetness, air quality, and solar radiation sensors are all routed through the Keithley programmable meter. This is an advanced multimeter that allows for the programmer to define the input and output parameters. This is set up to record the data from the sensors and output them to the network bridge.

Wireless Bridge. The data collected by the GreenMeter, EM50 data logger, and the Keithley programmable meter are routed through a wireless transceiver. The receiver for the data is in one of the engineering laboratories. Here, it is collected on a desktop computer and entered into the database on the school's network. The high school students will maintain a website where they can access live data streaming from the greenhouse.

The students will be able to monitor all of the sensor and power data on the school's network. They will use the weather and greenhouse data to create time lapse projections and statistical analyses. The power and weather data will be accessible through a website interface. There are plans to install cameras for real-time viewing of the greenhouse, turbine, weather, and plants. These may eventually be broadcast as webcams through the internet website along with senor data from within the greenhouse as well.

# CHAPTER 5

## CONCLUSIONS AND RECCOMENDATIONS

The East Tennessee State University and David Crockett High School  GearUp alternative greenhouse project is almost complete. The sensors and control systems are in place. The wind turbine and solar panels are wired and almost ready to begin powering the systems. The children will be moving the plants from their old greenhouse into the new one as soon as the water pipes are finished being run from the fertilizer mixing valves to the sprayers.

Surveys and studies should be performed to determine the success rate of the GearUp program. There should be follow-up surveys with the students who have been involved with the program. The program has a lot of potential for fulfilling the GearUp ideals and furthering the area’s alternative energy awareness. The control systems and the infrastructure of the greenhouse have been set up with plenty of room for expansion and new projects. There are plans for future projects on which the high school students can take the lead. The more complicated and dangerous wiring has been finished so that the high school students can safely work on their own projects in order to expand the scope of the greenhouse systems.

The possibilities for expansion into other areas of the school’s curriculum and into other areas of alternative energies make this an ongoing project. The teachers will use the programming, engineering, environmental, mathematical, biological, and agricultural aspects of the project in their curriculum. The plans for the production of ethanol have just begun, but look promising. There are possibilities that other energy options could be incorporated as well. Methane gas could be harvested from composting the cafeteria waste. The spent compost can be used as fertilizer. The project should continue to grow as long as teachers and students continue to reach for higher goals.

Other school systems have developed alternative energy programs with incredible results. In 1992, the Spirit Lake Community School District, in Spirit Lake, Iowa, purchased a 250kW wind turbine using a grant from the Department of Energy and a low interest loan from the Energy Council of Iowa Department of Natural Resources. The turbine provided enough revenue to pay off the loan in 1998 and has earned the district around $25,000. The district used this money along with another loan to purchase a larger 750kW wind turbine in 2003. The smaller turbine now generates enough power to supply the entire district's energy needs. The 750kW turbine, shown to the right of its 250kW predecessor in Figure 26, was paid off last year and will provide $120,000 tax-free yearly revenue from selling the excess power to the power company. (U.S. Department of Energy, 2003)

*Figure 26.* Spring Lake Elementary School Playground and Wind Farm (U.S. Department of Energy, 2003)(PD-USGov-DOE)

Projects such as the alternative energy greenhouse and the Spring Lake wind farm should not be as exceptional as they are. They need to be emulated and expanded. The future for the ETSU GearUp greenhouse project should be continued cooperation between the students and faculty of both ETSU and David Crockett High School. There should be increased involvement in the school's science, technology, engineering, and mathematics education programs. The future depends upon our children and schools working to better themselves and our environment.

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APPENDICES

## Appendix A: Stages of Education in Tennessee Counties

Table 2

*Percent of Adults in Tennessee Counties with Various Stages of Education*

| County | Less Than a 9th Grade Education | Without a High School Diploma | With a High School Diploma | With an Associate's or Bachelor's Degree | With a Professional or Graduate Degree |
|---|---|---|---|---|---|
| Anderson | 9.48% | 11.66% | 52.80% | 17.21% | 8.85% |
| Bedford | 13.61% | 16.69% | 54.96% | 11.16% | 3.58% |
| Benton | 13.88% | 20.34% | 57.19% | 5.83% | 2.76% |
| Bledsoe | 16.92% | 17.05% | 55.85% | 8.05% | 2.13% |
| Blount | 8.34% | 13.22% | 54.94% | 17.02% | 6.48% |
| Bradley | 11.62% | 15.07% | 51.69% | 16.17% | 5.45% |
| Campbell | 21.29% | 20.01% | 49.19% | 6.66% | 2.85% |
| Cannon | 12.79% | 20.02% | 56.71% | 7.48% | 3.00% |
| Carroll | 14.56% | 17.55% | 54.38% | 10.01% | 3.50% |
| Carter | 14.11% | 16.79% | 52.10% | 12.72% | 4.28% |
| Cheatham | 7.12% | 17.48% | 55.38% | 15.51% | 4.51% |
| Chester | 12.25% | 19.97% | 53.10% | 11.37% | 3.31% |
| Claiborne | 21.69% | 18.06% | 48.45% | 8.42% | 3.38% |
| Clay | 23.80% | 17.80% | 50.34% | 5.77% | 2.29% |
| Cocke | 19.66% | 19.12% | 51.91% | 7.22% | 2.09% |
| Coffee | 10.34% | 16.00% | 51.80% | 15.85% | 6.01% |
| Crockett | 14.48% | 20.39% | 53.06% | 9.29% | 2.78% |
| Cumberland | 13.38% | 14.13% | 54.83% | 12.35% | 5.31% |
| Davidson | 5.73% | 12.75% | 46.18% | 24.96% | 10.38% |
| Decatur | 16.81% | 19.55% | 53.50% | 7.59% | 2.55% |
| DeKalb | 17.90% | 17.52% | 50.90% | 8.89% | 4.79% |
| Dickson | 10.17% | 17.19% | 56.73% | 11.78% | 4.13% |
| Dyer | 14.78% | 18.93% | 50.22% | 11.93% | 4.14% |
| Fayette | 10.40% | 18.99% | 54.30% | 12.02% | 4.29% |
| Fentress | 25.86% | 16.88% | 47.12% | 6.71% | 3.43% |
| Franklin | 11.96% | 14.21% | 53.52% | 13.02% | 7.29% |
| Gibson | 11.73% | 17.42% | 57.79% | 9.95% | 3.11% |
| Giles | 10.96% | 16.50% | 57.98% | 10.74% | 3.82% |

(2003 U.S. Census)

Table 2

*Percent ofAdults in Tennessee Counties with Various Stages of Education*

| County | Less Than a 9th Grade Education | Without a High School Diploma | With a High School Diploma | With an Associate's or Bachelor's Degree | With a Professional or Graduate Degree |
|---|---|---|---|---|---|
| Grainger | 23.34% | 16.59% | 49.29% | 7.97% | 2.81% |
| Greene | 15.04% | 15.34% | 53.17% | 11.65% | 4.80% |
| Grundy | 24.57% | 20.28% | 46.30% | 6.29% | 2.56% |
| Hamblen | 13.72% | 16.94% | 51.48% | 13.02% | 4.84% |
| Hamilton | 6.00% | 13.29% | 50.67% | 21.99% | 8.05% |
| Hancock | 26.42% | 17.63% | 43.11% | 7.88% | 4.96% |
| Hardeman | 12.83% | 20.52% | 54.63% | 8.72% | 3.30% |
| Hardin | 15.42% | 17.66% | 54.36% | 8.94% | 3.62% |
| Hawkins | 14.11% | 15.53% | 56.05% | 10.74% | 3.57% |
| Haywood | 14.73% | 19.62% | 51.96% | 9.40% | 4.29% |
| Henderson | 12.82% | 17.86% | 55.52% | 10.84% | 2.96% |
| Henry | 11.79% | 17.73% | 55.99% | 10.15% | 4.34% |
| Hickman | 14.50% | 21.23% | 53.47% | 8.33% | 2.47% |
| Houston | 12.67% | 17.19% | 56.20% | 11.02% | 2.92% |
| Humphreys | 9.05% | 18.98% | 59.10% | 9.58% | 3.29% |
| Jackson | 21.91% | 16.46% | 50.90% | 7.93% | 2.80% |
| Jefferson | 12.82% | 16.14% | 53.63% | 12.83% | 4.58% |
| Johnson | 20.58% | 21.05% | 47.67% | 8.56% | 2.14% |
| Knox | 5.82% | 11.63% | 48.06% | 23.71% | 10.78% |
| Lake | 20.54% | 23.41% | 48.78% | 5.54% | 1.73% |
| Lauderdale | 15.14% | 22.60% | 51.92% | 7.28% | 3.06% |
| Lawrence | 17.50% | 16.99% | 53.13% | 8.87% | 3.51% |
| Lewis | 14.48% | 15.98% | 57.16% | 9.58% | 2.80% |
| Lincoln | 12.03% | 18.37% | 53.44% | 12.60% | 3.56% |
| Loudon | 10.61% | 13.80% | 52.62% | 17.10% | 5.87% |
| Macon | 20.01% | 19.81% | 51.14% | 6.82% | 2.22% |
| Madison | 7.24% | 14.00% | 52.19% | 19.02% | 7.55% |
| Marion | 15.43% | 20.01% | 50.24% | 10.33% | 3.99% |
| Marshall | 10.00% | 16.43% | 58.75% | 11.54% | 3.28% |
| Maury | 8.19% | 13.89% | 58.08% | 15.02% | 4.82% |
| McMinn | 13.47% | 17.25% | 53.83% | 11.45% | 4.00% |
| McNairy | 13.68% | 17.78% | 56.38% | 8.69% | 3.47% |
| Meigs | 14.95% | 21.51% | 54.17% | 7.56% | 1.81% |
| Monroe | 17.75% | 15.52% | 52.23% | 10.71% | 3.79% |

(2003 U.S. Census) (continued)

Table 2

*Percent of Adults in Tennessee Counties with Various Stages of Education*

| County | Less Than a 9th Grade Education | Without a High School Diploma | With a High School Diploma | With an Associate's or Bachelor's Degree | With a Professional or Graduate Degree |
|---|---|---|---|---|---|
| Montgomery | 4.81% | 10.86% | 58.20% | 19.47% | 6.66% |
| Moore | 8.76% | 14.65% | 59.20% | 13.23% | 4.16% |
| Morgan | 13.36% | 22.88% | 54.43% | 6.76% | 2.57% |
| Obion | 10.96% | 18.03% | 58.19% | 9.50% | 3.32% |
| Overton | 23.31% | 17.73% | 48.79% | 7.75% | 2.42% |
| Perry | 15.20% | 21.04% | 53.91% | 6.74% | 3.11% |
| Pickett | 21.18% | 15.92% | 50.87% | 7.50% | 4.53% |
| Polk | 20.30% | 17.46% | 50.87% | 7.80% | 3.57% |
| Putnam | 14.16% | 13.28% | 49.92% | 14.89% | 7.75% |
| Rhea | 14.58% | 20.15% | 51.62% | 10.74% | 2.91% |
| Roane | 11.69% | 13.55% | 54.80% | 13.99% | 5.97% |
| Robertson | 8.87% | 16.30% | 58.50% | 13.29% | 3.04% |
| Rutherford | 5.73% | 12.50% | 53.64% | 21.47% | 6.66% |
| Scott | 19.07% | 20.27% | 50.32% | 6.94% | 3.40% |
| Sequatchie | 14.30% | 19.01% | 53.14% | 10.78% | 2.77% |
| Sevier | 10.81% | 14.60% | 56.55% | 13.51% | 4.53% |
| Shelby | 5.93% | 13.29% | 50.27% | 21.62% | 8.89% |
| Smith | 16.60% | 15.91% | 55.51% | 8.50% | 3.48% |
| Stewart | 13.17% | 12.53% | 60.71% | 9.42% | 4.17% |
| Sullivan | 10.71% | 13.54% | 51.94% | 17.81% | 6.00% |
| Sumner | 7.66% | 12.63% | 54.99% | 19.51% | 5.21% |
| Tipton | 9.03% | 16.40% | 58.21% | 12.99% | 3.37% |
| Trousdale | 19.33% | 19.29% | 49.84% | 8.88% | 2.66% |
| Unicoi | 15.25% | 17.09% | 52.99% | 10.56% | 4.11% |
| Union | 21.91% | 21.80% | 47.11% | 7.11% | 2.07% |
| Van Buren | 21.32% | 16.64% | 53.13% | 6.23% | 2.68% |
| Warren | 12.89% | 19.87% | 55.56% | 8.46% | 3.22% |
| Washington | 9.51% | 13.28% | 49.52% | 19.52% | 8.17% |
| Wayne | 17.93% | 20.77% | 50.25% | 7.32% | 3.73% |
| Weakley | 12.27% | 17.48% | 52.60% | 10.94% | 6.71% |
| White | 18.56% | 16.68% | 54.76% | 6.79% | 3.21% |
| Williamson | 3.91% | 6.03% | 40.71% | 35.11% | 14.24% |
| Wilson | 6.85% | 12.26% | 55.60% | 19.87% | 5.42% |

(2003 U.S. Census) (continued)

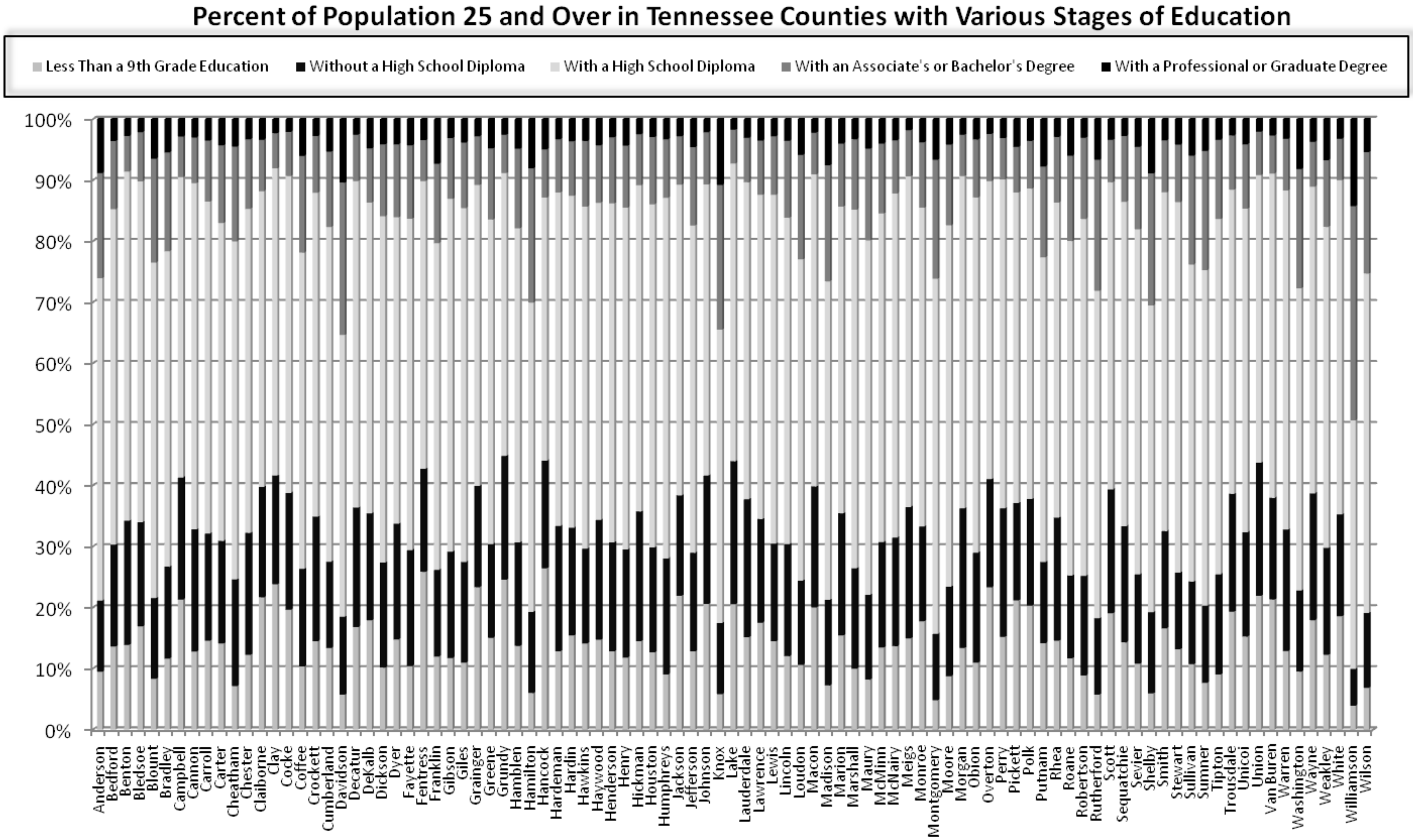


*Figure 27.* Percent of Adults in Tennessee Counties with Various Stages of Education (2003 U.S. Census)

Appendix B: 2005 Educational Attainment of Adults for the U.S. and Tennessee

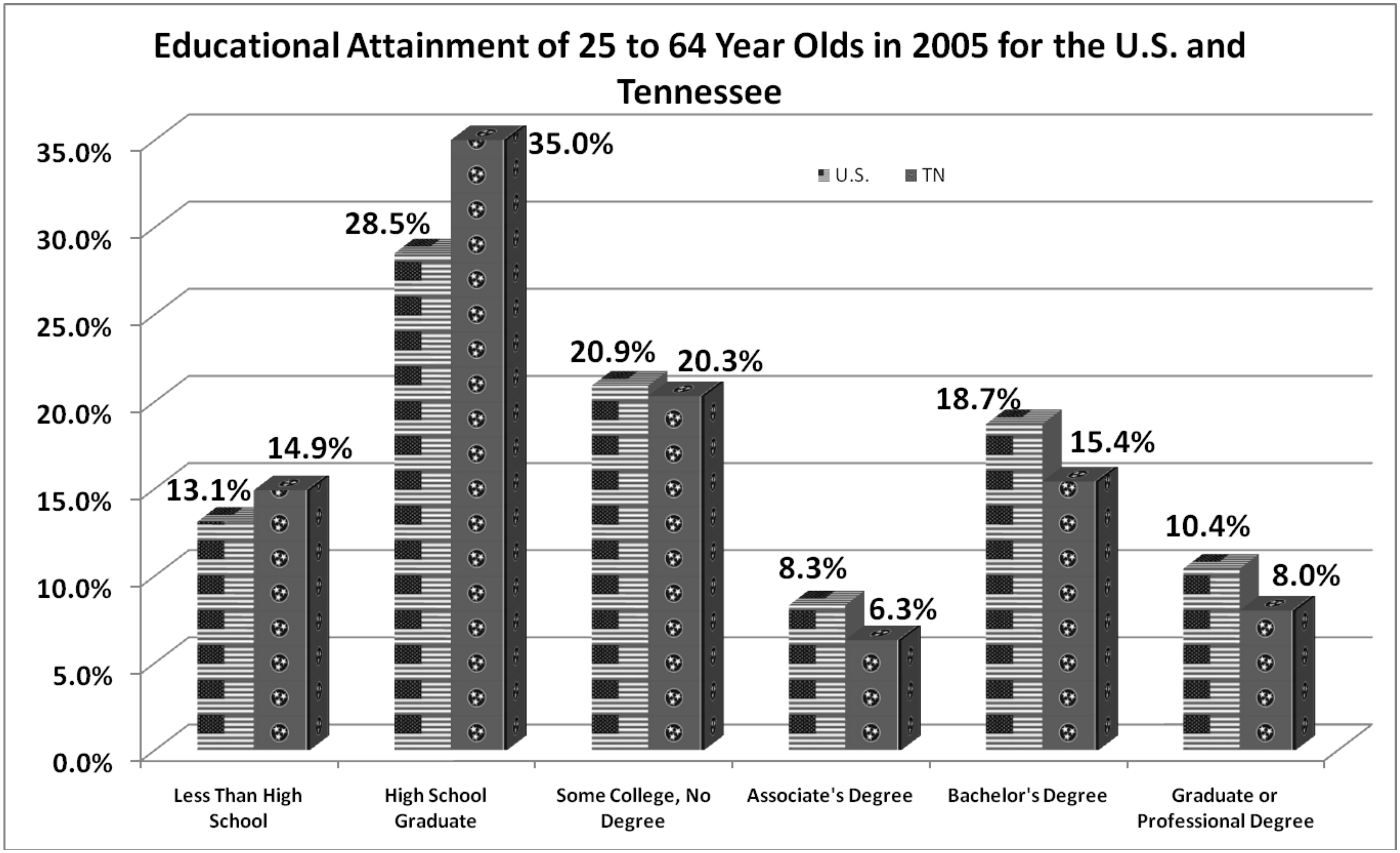


*Figure 28.* 2005 Educational Attainment of Adults for the U.S. and Tennessee (2003 U.S. Census)

Appendix C: Greenhouse Images

*Figure 29.* Students Assist Dr. Paul Sims and Guy McCamis in Wiring the Turbine

*Figure 30.* Grounding the Turbine

*Figure 31.* Students and Faculty Erect the Turbine

*Figure 32.* Greenhouse, Turbine, and Solar Panels

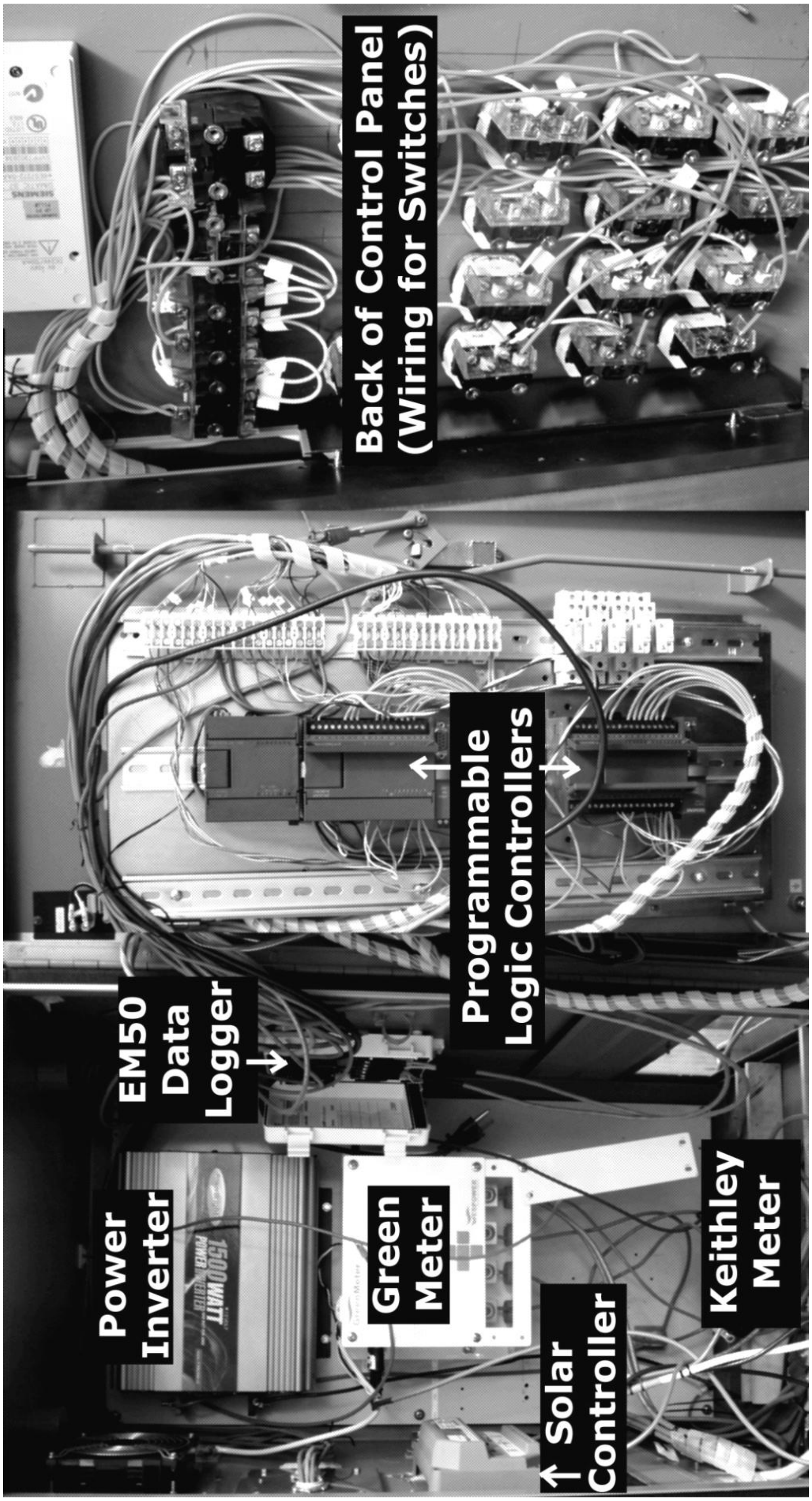


*Figure 33.* Control Box Layout

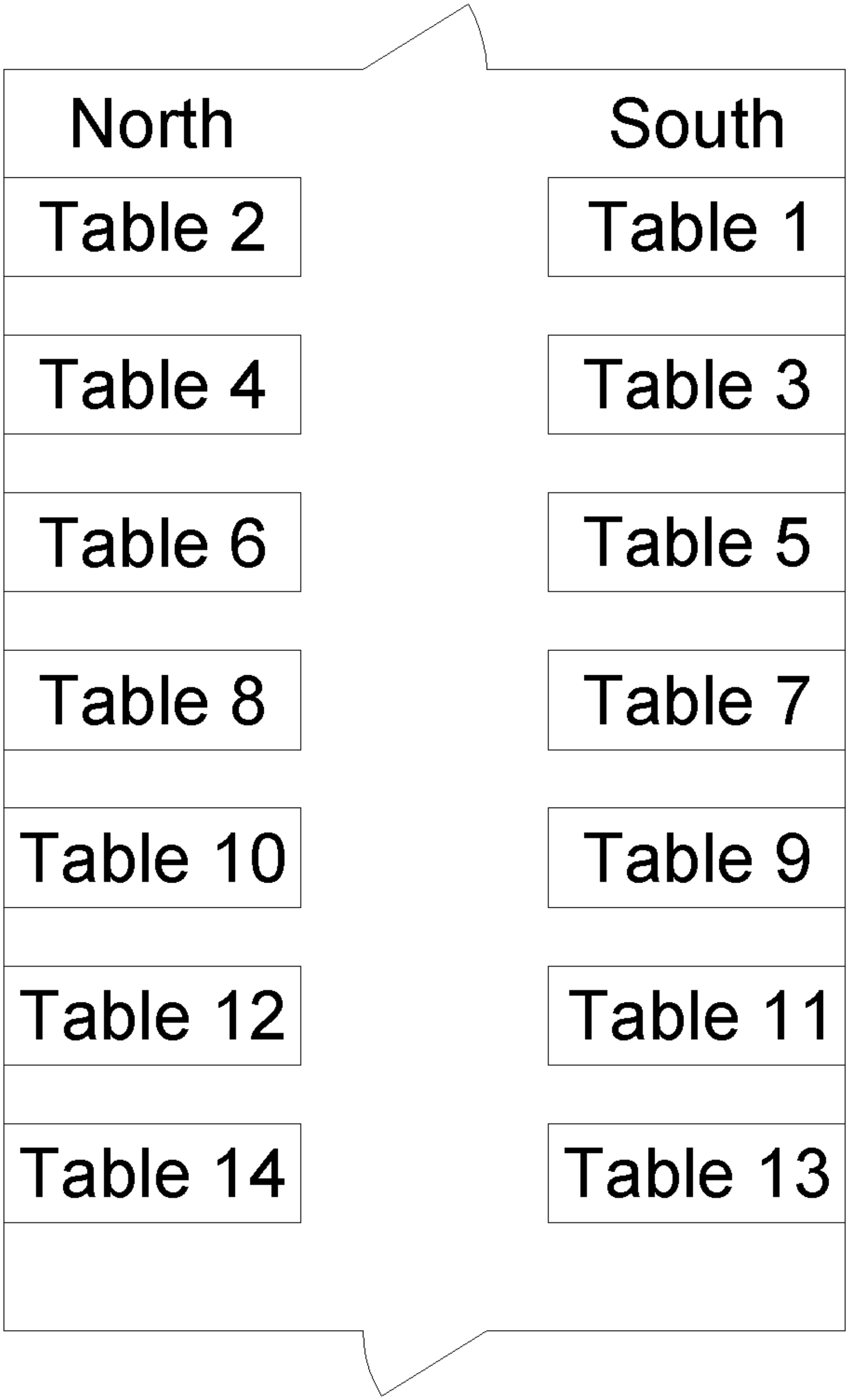


*Figure 34.* Greenhouse Table Layout

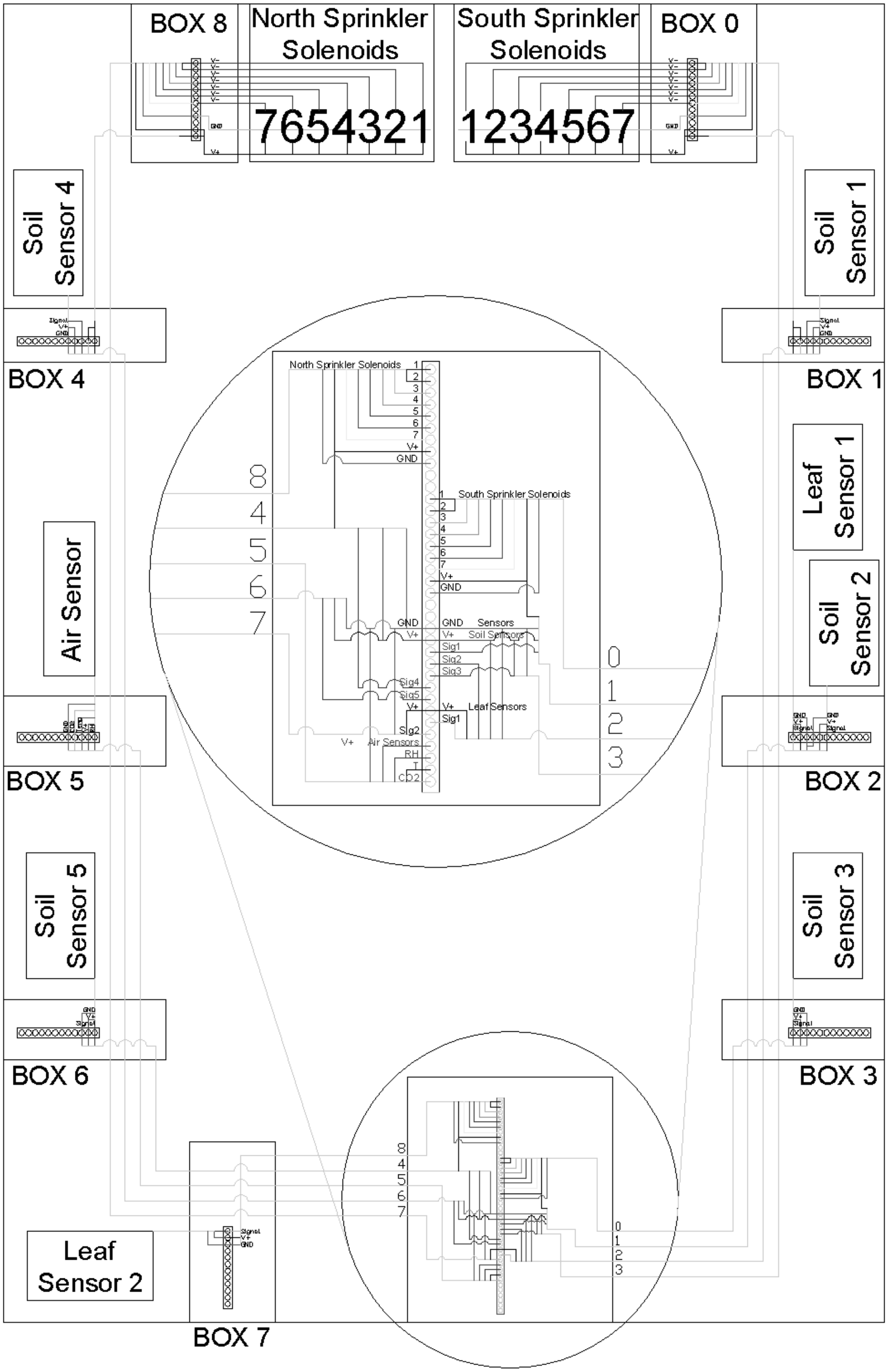


*Figure 35.* External Wiring Diagram for Sensors and Solenoids

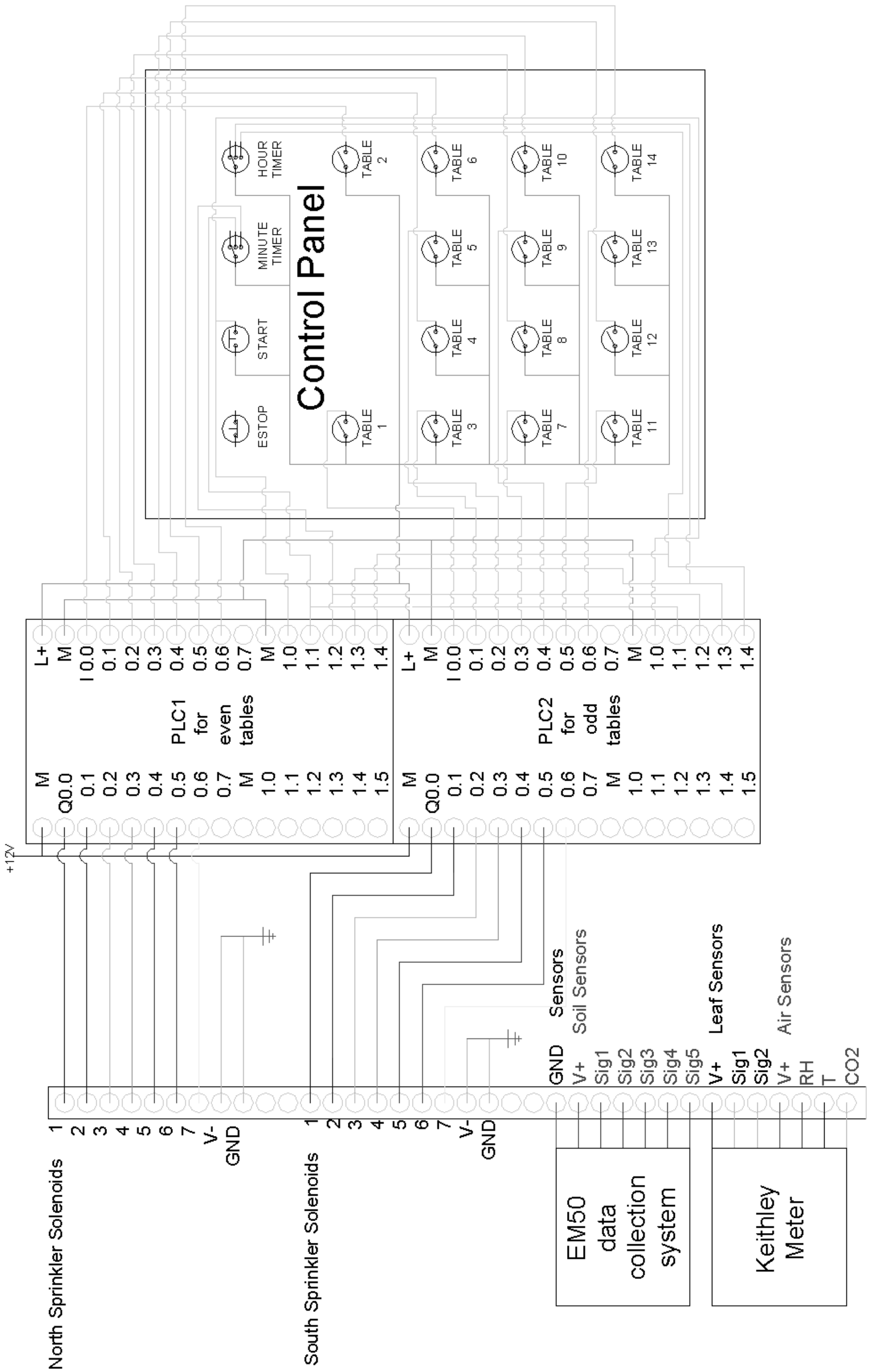


*Figure 36.* Internal Wiring Diagram for Sensors and Solenoids

# VITA

## GARTH GHEARING

Personal Data: Date of Birth: March 10th, 1977

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Gold Award for *Pick and Place* at National Robotics Challenge 2008