Paper ID #18960

Sustainable Development and Engineering Technology

Mr. Jesse Gilmore, University of Houston, Downtown

Jesse Gilmore is an undergraduate at the University of Houston-Downtown, pursuing a Bachelor of Science degree in Control and Instrumentation Engineering Technology with the hope of gaining employment as an EIT in the field of process control or renewable energy.

Mr. Scott Patterson, University of Houston, Downtown

Scott Patterson was born in Lexington, KY, in 1986. He received a B.S. degree in Controls and Instrumentation Engineering Technology from the University of Houston-Downtown, Houston, TX, in 2016. In 2009 he joined the Houston Fire Department as a firefighter and is currently an active firefighter. He was an engineering tutor with a focus on Introduction to Circuits, Electronic Devices, and PC Applications in Engineering. He was a member of the Scholars Academy, an honors program for high achieving students. He has been a member of the International Society of Automation since 2012.

Dr. Lisa Deane Morano
Dr. Vassilios Tzouanas, University of Houston, Downtown

Vassilios Tzouanas is an Associate Professor of Computer Science and Engineering Technology at the University of Houston – Downtown, in Houston, Texas. He also serves as assistant department chairman. He received all his degrees in chemical engineering and obtained his Ph.D. from Lehigh University. He has worked in the industry for 19 years where he held technical and management positions with major operating companies as well as process control technology development companies. Since 2010, he has been with UHD where he teaches university courses in process control, modeling and simulation, process design and operation, applied thermodynamics and heat transfer, and numerical methods. Dr. Tzouanas research interests include process modeling, simulation and design, process control, and renewable energy systems. Dr. Tzouanas is an ABET Program Evaluator (PEV) for Engineering and Engineering Technology programs. He is also member of AIChE and ASEE.

Sustainable Development and Engineering Technology

I. Introduction

There are different definitions of sustainable development but according to Geir Asheim[1] "Sustainability is defined as a requirement of our generation to manage the resource base such that the average quality of life that we ensure ourselves can potentially be shared by all future generations…. Development is sustainable if it involves a non-decreasing average quality of life." According to a United Nations 2016 report[2], for the first time countries around the world have added sustainable development plans and a record number have agreed to make positive steps to address climate change. As such, we are living at a unique time in history where citizens of the world may work together to address the question of how to improve the lives of people everywhere.

The ever-increasing world population requires a greater demand for food and an increasing pressure on our agricultural systems. Specifically, with the increasing demand for agriculture comes the increasing demand for water used in irrigation. Water is indeed a scarce commodity. The Earth's surface is about 71% water yet only about 2.5% is useable for consumption, including irrigation[3]. This 2.5% is also not reliably available or evenly distributed, as the many droughts in the agricultural areas of California and the Midwest have taught us. With what little water is available for crop irrigation, farmers must be conscious of irrigation use and techniques to efficiently use what is available. In an urban environment, sustainable community gardening is a movement that not only cultivates a garden that provides food for the neighborhood but also gives its participants a sense of community. While sustainable gardening is on a much smaller scale than the agricultural industry, water conservation is still an important component of the process. Cities use enormous amounts of water and community gardens are typically charged the city "home" rate for water use. In addition, community gardens serve as important educational centers to teach about all aspects of sustainable practices. It is here that those outside of the sustainable science field (community members, children) are most likely to learn about the practices of conservation and sustainability.

The United Nations has adopted 17 development goals to create a more sustainable planet[2]. In particular, Sustainable Development Goal 7 is to "ensure access to affordable, reliable, sustainable and modern energy for all." Sustainable Development Goal 13 is to "take urgent action to combat climate change and its impacts" while Sustainable Development Goal 12 aims to "ensure sustainable consumption and production patterns." In alignment with such noble goals, the Center for Urban Agriculture and Sustainability (CUAS) at the University of Houston-Downtown (UHD) brings together students from various disciplines and educates them on sustainability in an urban environment, teaches them about renewable energy sources and associated technologies, provides opportunities to students to produce goods and food in a sustainable manner, and engages them in community service. The inception of this program was supported by a USDA NIFA grant which has the goal of creating experiential learning for students and building new curriculum. With this funding our university's community garden and community gardens of our local partners have begun to contribute to the UN Sustainable Goals 7, 12 and 13.

This paper describes the technologies used to achieve sustainable development within an academic framework. Engineering technology students developed systems to harvest solar and wind energies, and used such energy to power a computer controlled system which automatically irrigates the university's garden based on soil water needs. The design of the solar and wind energy collection systems, instrumentation, wireless data transfer, and automation mechanisms are presented. Since such work was carried out as part of engineering technology students' senior capstone project, lessons on project management, budget and schedule development, teamwork, and technical communication are also presented.

The USDA funded summer program of the CUAS became the catalyst that enabled us to expand the impact of projects beyond engineering technology and connect to other majors at UHD. In addition, the grant created an opportunity for us to reach out to a local community garden. We duplicated the solar-powered irrigation system in a Target Hunger of Houston community garden which grows vegetables that are then distributed to homeless citizens of our community. As part of this collaborative project students from across UHD were encouraged to apply. We had a number of engineering technology students that worked on the design of the system. Biology students from our Natural Sciences department had primary responsibility for determining the types of vegetables and other crops to be produced by the garden and ran genetic analysis on the crops. A student of Social Work from the College of Public Service did research on the impact of the community garden on those served by the garden.

Details of the aspects of our hands-on, innovative and collaborative take on building sustainable irrigations systems are outlined by section. Section II presents the as built university garden. Section III provides details on the methods and materials used to build the garden with its renewable energy technologies and automated irrigation system. Section IV describes the functionality of the system, time schedule and project cost. Community outreach and duplication of the project at a community garden are discussed in section V. Lessons learned and student comments are included in section VI while section VII outlines main conclusions.

II. Project Description: Building the First System at UHD

Predictions are that by the year 2025 severe water shortages will affect ¼ of the world's population[4]. Water conservation efforts will need to be a consideration in all aspects of agricultural and city operations. Education of water conservation mechanisms using green energy for community gardens is both practically and pedagogically valuable. Water consumption can be reduced with the use of an automated irrigation system which utilizes information about the actual water needs of a plant. On the other hand, carbon footprint can be minimized by using renewable energy sources such as solar and wind to generate electricity. This project provides a proof of concept that can be implemented to develop a sustainable garden/farm that minimizes water and is self-sufficient in terms of energy requirements.

The first implementation of the project took place at the university's community garden in collaboration with UHD's Garden Club. The as built-system is shown in Figure 1. A computer based control system monitors soil water availability and turns on/off water valves as the plant needs dictate using water potential thresholds. The energy required to power the computer system and sprinkler valves is generated using a combination of solar and wind power.

LabVIEW[5] is used for data acquisition and control. In order to increase the usability of the garden and enhance it aesthetically during night time hours, lights were installed along its perimeter. The lights are powered via a battery bank that is constantly recharged with renewable energy by photovoltaic cells in conjunction with a wind turbine. The battery also supplies the required power to operate the control system.

This sustainable garden has allowed for a number of student projects. Biology students can perform a number of research studies and better understand and control water conditions which contribute to optimal plant growth. Some biology students are using the garden to grow plants for plant genetic and nutrition studies and future students will be able to run more precise student studies of water use by native prairie grasses. Engineering Technology students can use the system to study key variables affecting system operation and thus be able to optimize energy generation. Also, users of the irrigation system have the capability of monitoring, recording and manipulating variables from a station computer or handheld device. The system allows for wireless data transfer and storing in a real time data base. In short, this sustainability garden will continue to be used by students for a number of studies including plant biology, energy conservation, and automation.

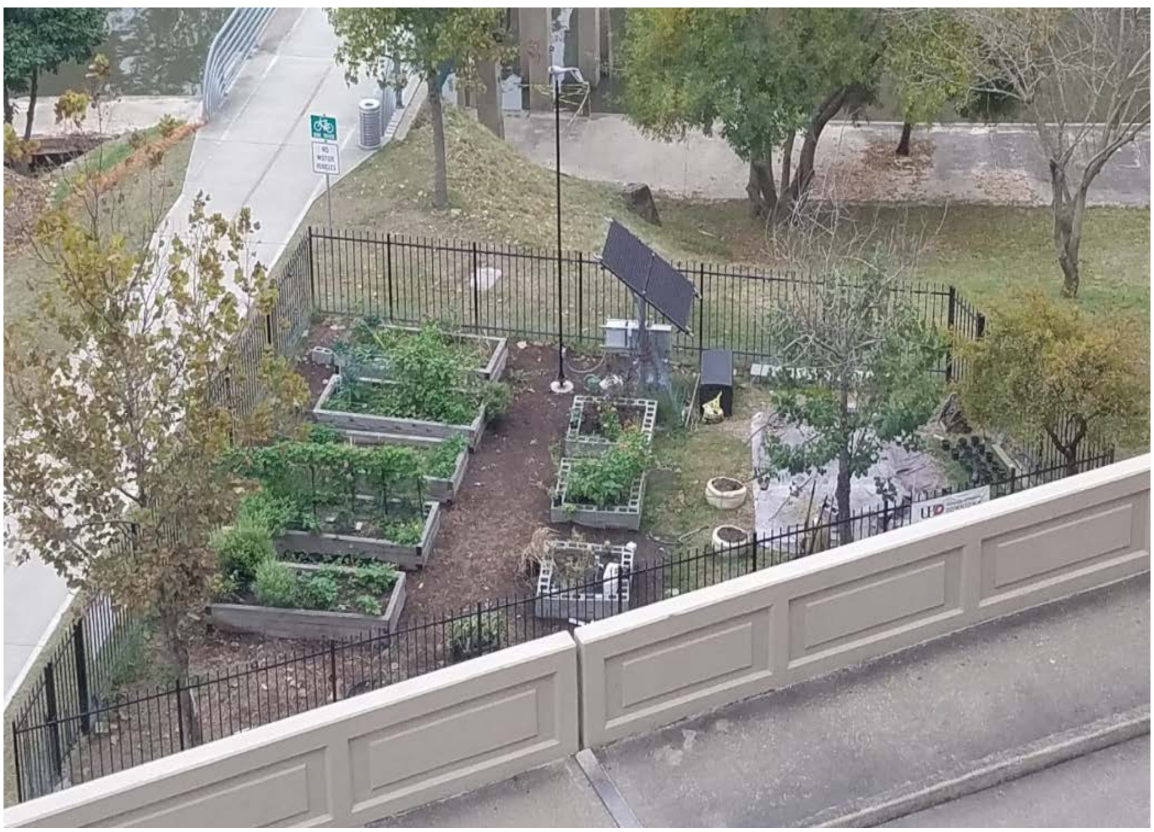

Figure 1: The as built UHD Sustainability Garden System

In the following section, the design of the sustainable, automated irrigation system is described in detail.

III. Methods and Materials

Renewable Energy System

The energy required to make the garden self-sustained is generated using a combination of solar and wind energy. The energy harnessed is stored in two batteries which eventually supply the energy required to run the system (computer, sprinkler valves and garden lights). A block diagram with the main components of the system is shown in Figure 2.

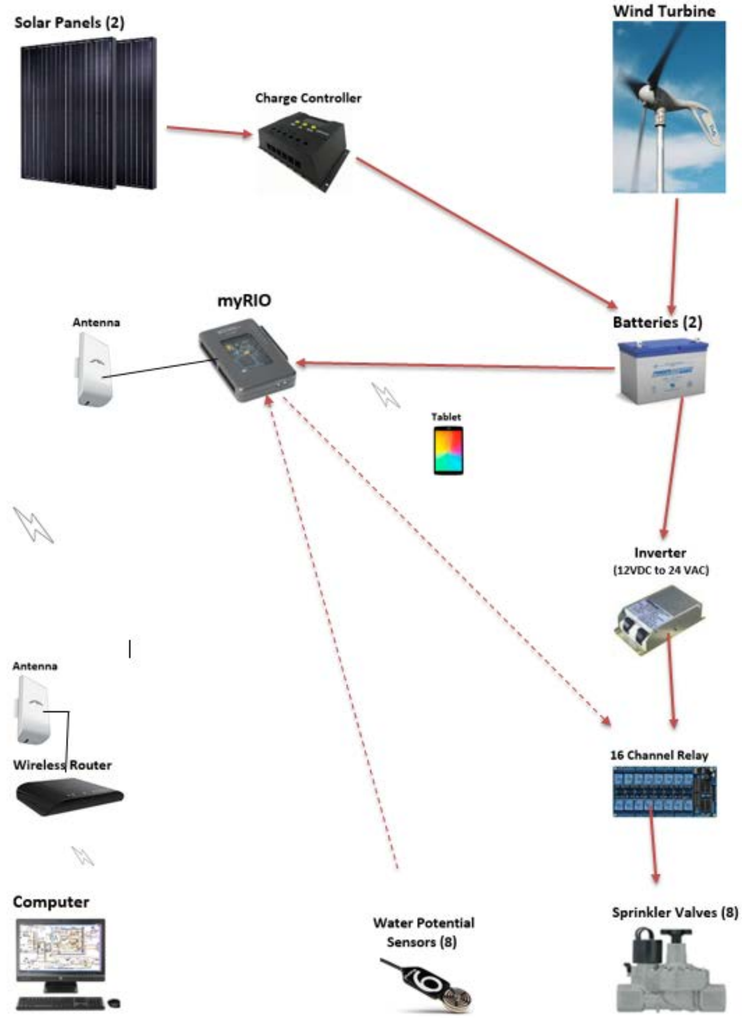

Fig. 2: Block Diagram of UHD Sustainability Garden Automated Irrigation System

To collect solar energy, two RENOGY® 250W mono-crystalline black photovoltaic panels are used[6] (Figure 3). An Air Primus Air40 wind turbine[7] (Figure 4) is used to provide a secondary source of energy in addition to the solar panels. The wind turbine is mounted to a steel pole at a height of 23' and contains an integrated charge controller that allows the wiring to be directly connected to the battery bank. It requires a 7 mph wind to begin spinning the turbine blades. The rated output is 160 watts given a 12 mph wind speed.

Other major components of the renewable system include the batteries for energy storage (two 100 Ah are used), charge controller for proper charging of the batteries, and the inverter to invert the 12 VDC to 24 VAC for the proper powering of the sprinkler valves. Sizing of the batteries is in Appendix A.

Fig. 3: Solar Panels

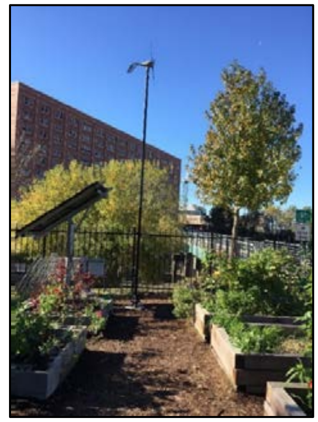

Fig. 4: Wind Turbine

Components of the Irrigation System

The major components of the irrigation system are the soil water potential sensors and the sprinkler valves. Using water potential sensors leads to optimal watering of plants and water conservation. The particular sensor used is the MPS-6 water potential sensor by Decagon[8]. It is shown in Figure 5. The MPS-6, like many environmental sensors, utilizes a protocol called Serial Digital Interface at 1200 baud rate (SDI-12). However, SDI-12 communication is not supported by the myRIO[5] requiring the conversion into a separate communications protocol. LabVIEW recognizes a commonly used communications protocol known as RS232 which can be converted from SDI-12 using a translator board. While a PC running, LabVIEW can use RS232 communication, the myRIO cannot. The myRIO has a serial data interface called Universal Asynchronous Receiver/Transmitter (UART), this interface is analogous with the RS232 protocol. However, it only has connections for grounding, transmitting, and receiving. To convert to the UART connections, dubbed Transistor-Transistor Logic (TTL) on the myRIO, the implementation of another communications translator was required. This RS232 to TTL translator limits voltage swings from -13V to + 13V to what the UART uses which is 0 – 5V. The TTL also closes off signaling on all RS232 pins with the exception of the ground, receiver, and transmitter. Once the end to end translation is in place, the myRIO is able to read the serial data sent from the MPS-6 sensor. The sprinkler valves are typical for home irrigation systems (see Figure 6). The only notable fact is that they require 24VAC which necessitated the use of a 12VDC to 24VAC inverter as shown in Figure 2.

Fig. 5: MPS-6 Water Potential Sensor[8]

Fig. 6: Sprinkler Valve

Computer Platform

To design a robust control system for automated water irrigation many factors were considered to reach an ideal solution. Prior work included a micro control system utilizing an Arduino board with humidity sensors. However, this system was not optimal for this application which led to the retrofit project. Initial considerations for the retrofit included the use of a smart relay or a programmable logic controller (PLC) coupled with water potential sensors. While the water potential sensors were deemed to be the best choice, the PLC would have limited programmability ultimately limiting wireless data transfer. After careful consideration, it was decided that a control system with National Instruments' myRIO in conjunction with the MPS-6 water potential sensors would be used.

Process Control Block Diagram

The following block diagram (Figure 7) outlines the feedback control loop that is used within the irrigation system for each individual plant bed. There are 8 such control loops, one for each bed. A user is able to enter a set point (SP) for a desired soil water content within a plant bed. The soil moisture content is measured by the MPS-6 water potential sensor which sends the measurement (PV) to the controller and the difference in the set point and the process variable is determined. Based on this difference, the controller (programmed in LabVIEW) opens or closes the sprinkler valves.

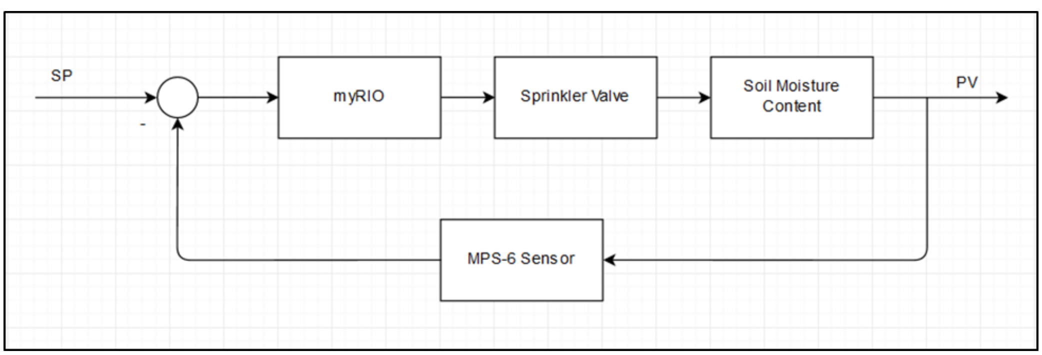

Fig.7: Individual Bed Control Loop

Networking

To enhance connectivity for multiple users and to actively manipulate controlled variables (i.e. soil water content), a network was established with a modem, two smart antennas, and the myRIO wireless hotspot capabilities (Figure 8). A host computer running the LabVIEW control program is wirelessly connected to a modem with a smart antenna attachment. The second antenna is placed in the garden and is hardwired to the myRIO via Ethernet to USB 2.0 converter. Both antennas are configured in bridge mode which allows for a robust mode of data transmission. However, it limits data transfer to the two points. The myRIO that is connected to the outdoor antenna receives the network signal from the host computer and can run the LabVIEW program that is simultaneously operating on the host computer. For added usability, the myRIO is set up as a hotspot where a programmed tablet can control the garden as well as monitor values of interest. To account for an unplanned power cycle that results in a loss of connection to the host computer, the myRIO has the capability of rebooting with a real-time application that is configured to run at start-up.

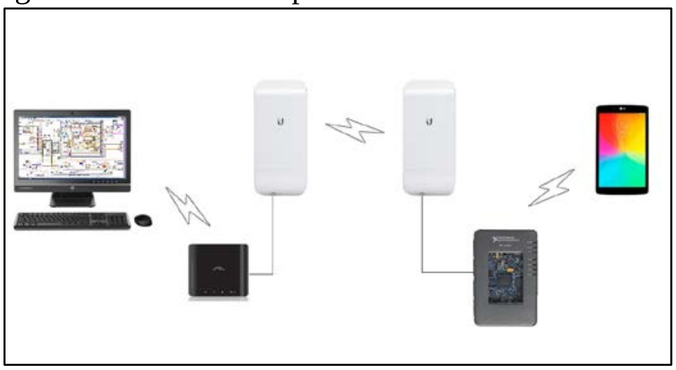

Fig. 8: Networking Scheme

Control Program

LabVIEW is being used to control irrigation to the garden by utilizing the data sent from the MPS-6 sensors in each bed to turn on/off the sprinkler valves. The sensor transmits the water potential reading for each bed in kilopascals (kPa) to the myRIO. In order for the control program to receive data using the RS232 protocol from the MPS-6 sensor, a Virtual Instrument (VI) was created using LabVIEW. The VISA serial communication block within LabVIEW was utilized to configure the correct settings required for communication with the MPS-6 sensor. A Front Panel was created so that data from the sensors could be viewed and the settings could be easily changed if needed. This is shown in Figure 9 below.

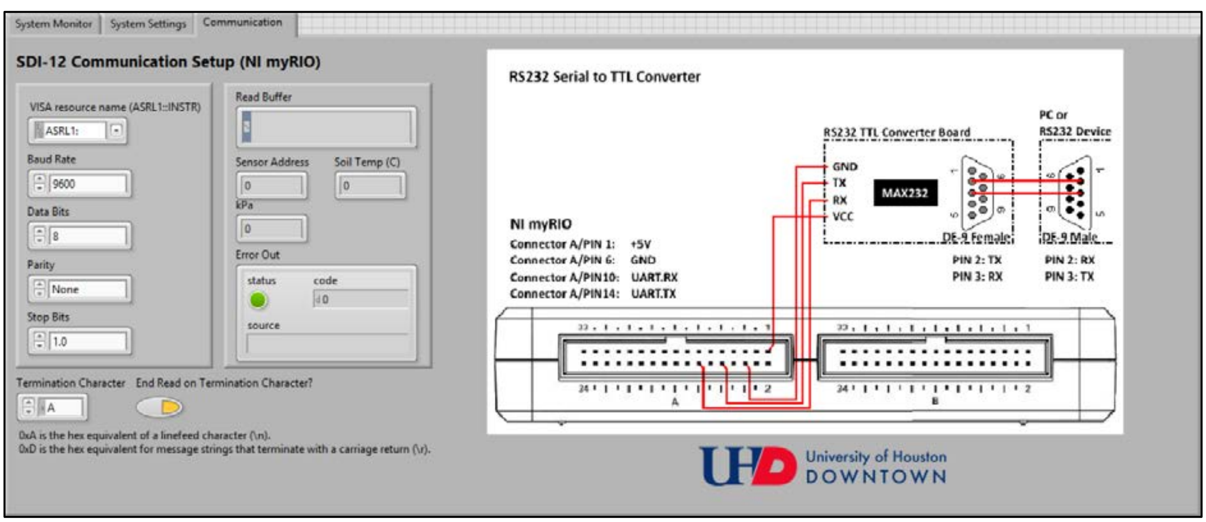

Fig. 9: Visa Serial Communication

Soil water potential readings are compared to user defined set points to determine if the sprinkler valves being used to irrigate each garden bed should be opened or closed. The setpoint for each garden bed can be adjusted using the Front Panel shown in Figure 10. Each garden bed can be configured independently of one another to allow for the different needs of each garden bed's specific crop requirements. Also, each garden bed has an LED indicator that displays when the sprinkler valve is opened or closed and each sprinkler valve can be forced open using the toggle switch labeled "Manual Open".

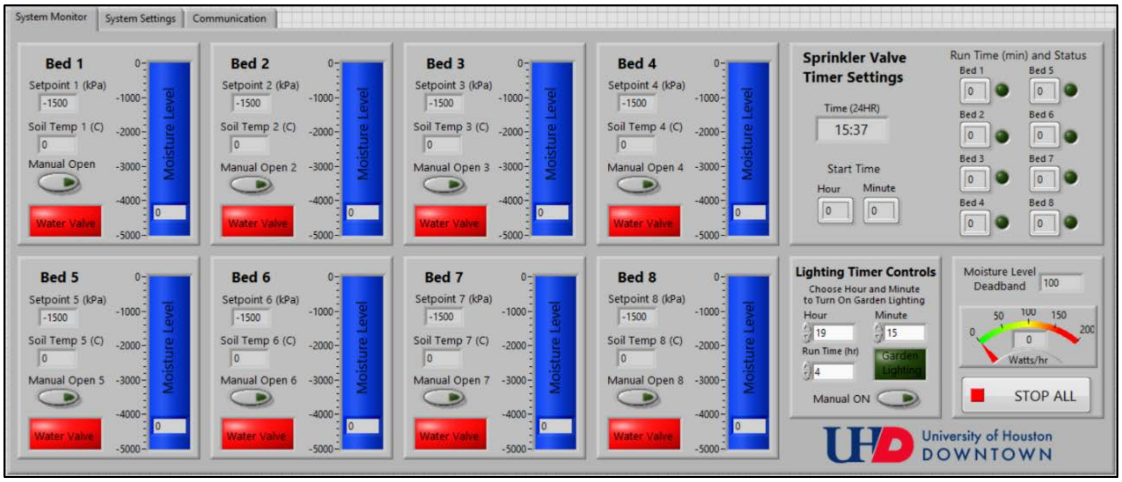

Fig. 10: Control System Front Panel

The programming used to control when the sprinkler valves are opened or closed is shown in Figure 11 below. In addition to the automatic mode, the user can also use the "Manual Open" toggle switch to manually override the program and open the sprinkler valve. There is also a "Timer" mode that allows the user to irrigate the beds based on a set amount of time rather than having the irrigation controlled by the MPS-6 sensor data. This feature is important in the event of a sensor failure to ensure that the bed still receives proper irrigation.

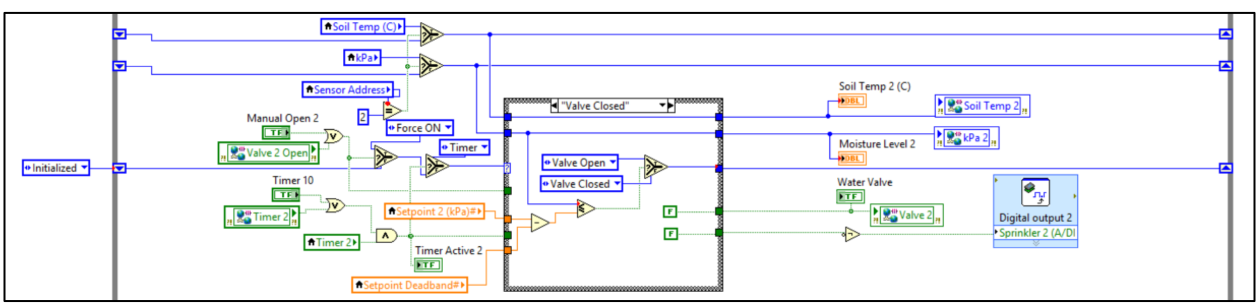

Fig. 11: Control System Programming

The garden lighting installed for this project is also controlled by the myRIO. The lights can be turned on manually using a toggle switch located on the front panel of the main control system program shown in Figure 8 above. The lights can also be configured to automatically turn on at a specific time of day and remain on for a specified amount of time.

Remote HMI

For increased usability, a smartphone application was created to allow remote control of the garden system. As Figure 12 shows, control of the system can be assigned to a user working the host computer or to a user using a tablet. On a tablet, the user is able to manipulate lighting control, water control valves, individual plant bed water potential set points, and a watering timer. To avoid numerical conflicts between the remote HMI and the host computer running the program, the host computer has the ability to turn on and off some tablet capabilities. This toggling of capabilities eliminates the sporadic cycling between the host computer input and the tablet input that would ultimately put stress on the sprinkler valves causing premature failure.

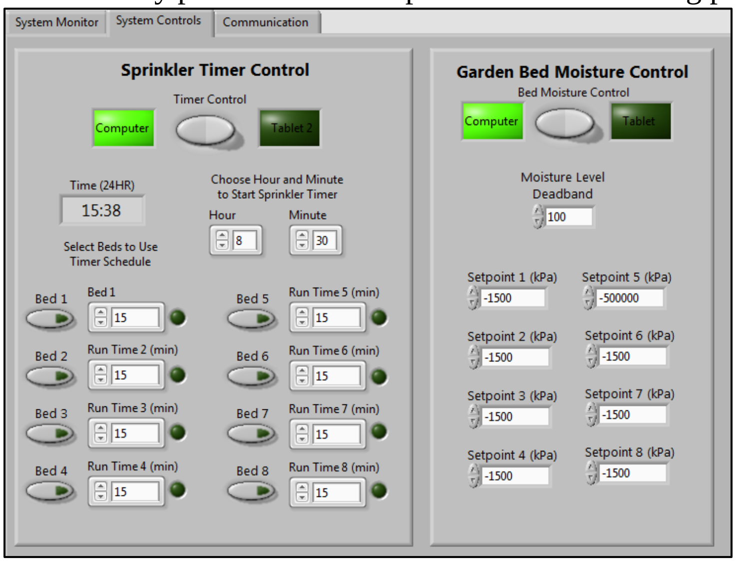

Fig. 12: Host Computer "System Controls" Control Panel

Figures 13 and 14 show the front panel with the access indicators as well as other various controls when a tablet is used to either automatically/manually control the garden (Figure 13) or use the "timer" mode (Figure 14).

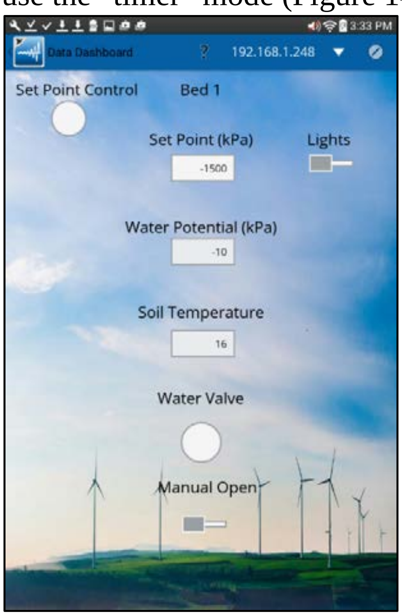

Fig. 13: Individual Bed HMI

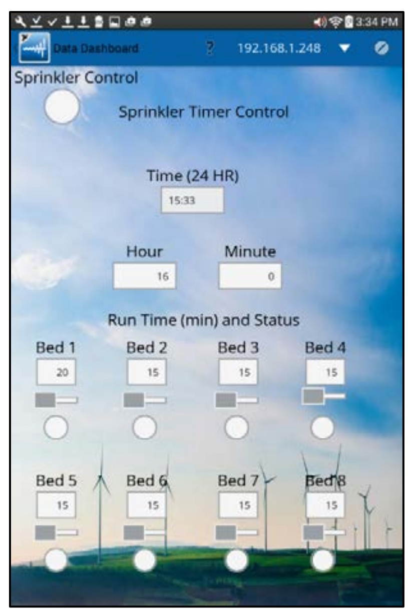

Fig.14: Timer Control HMI

IV. Results

This section summarizes results which demonstrate the functionality of the system and discuss project execution from a cost and schedule viewpoint.

System Performance

Initially, to test the integrity of the sensor, an RS232 terminal named Termite was utilized. This terminal allows the user to send and receive data from a sensor based upon written commands. When commands were sent to the sensor through the terminal, desired responses and measurements were received assuring that the sensor was in good working order and ready to be employed. Further experimentation included the testing of the sensor in dry soil and wet soil to confirm that the sensor's measurement numbers are consistent and reflect nominal values. Figure 15 demonstrates such results.

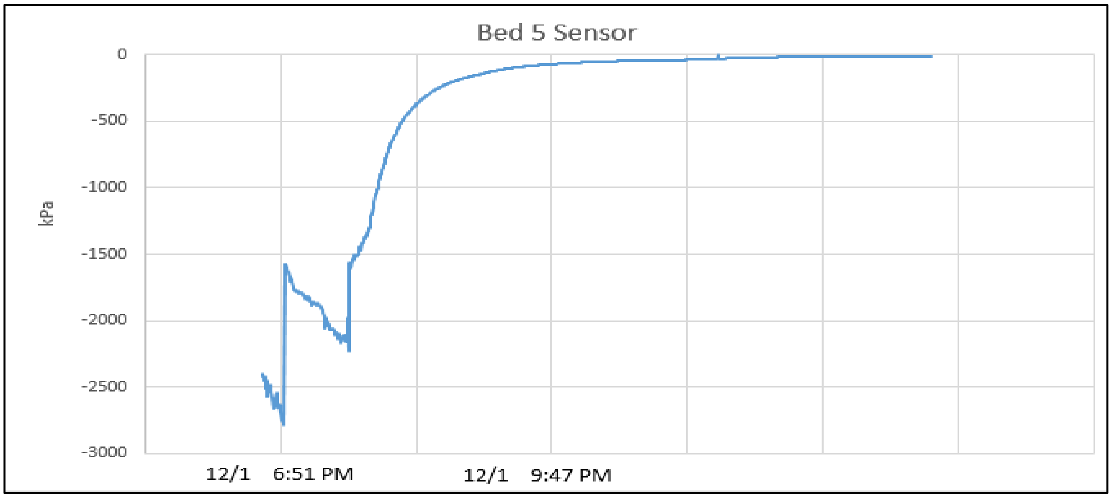

Fig. 15: Bed 5 Entering Wet Region

Figure 15 shows data captured in bed 5 where initially the soil was dry with water potential reading in the -2500 to -3000 kPa range. As rain started on that day, the reading started moving into the wet region as indicated by the readings close to 0 kPa.

Figure 16 shows how the water usage for each bed is logged in Excel. The flow rates for each bed are calculated based on the length of drip tubing and the amount of time the valves are open. By manually opening the valves using the control system, data on water consumption was gathered and is shown in Figure 16.

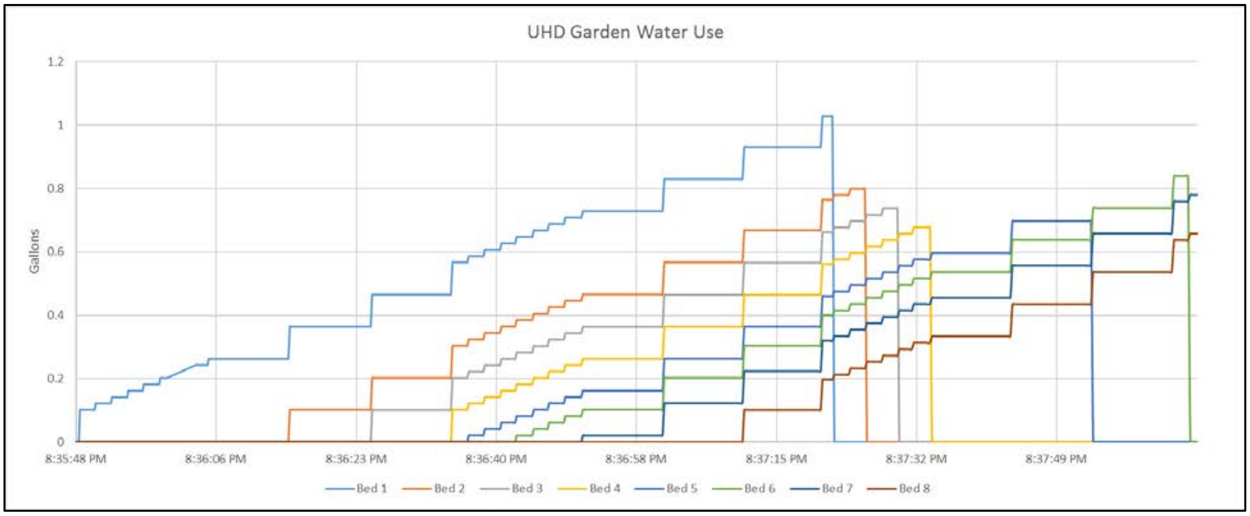

Fig. 16: Garden Water Use Graph

The slopes for each line are all the same because the garden beds are all configured for the same length of drip tubing. This graph is not intended to be a precise measurement of water use but instead provide a close estimate of water use without having to add costly flow sensors to monitor water use.

Figure 17 shows the energy use of the control system, sprinkler valves and garden lighting.

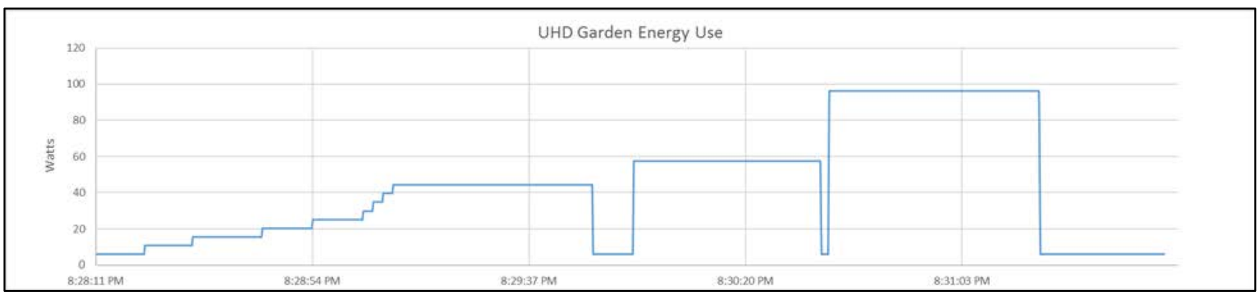

Fig. 17: UHD Garden Energy Use Graph

Figure 17 shows data collected by manually energizing each sprinkler valve and the garden lighting. The start of the graph shows each sprinkler valve being energized in succession. Next the garden lighting is energized and finally all sprinkler valves and lighting are energized to show the total system energy use.

The garden is located in an urban environment which places several tall buildings directly adjacent to the wind turbine which causes both inconsistent and turbulent wind patterns. Consequently, the possible energy production of the wind turbine is severely hampered. The solar panels on the other hand are positioned so that direct sunlight is received throughout most of the day making this form of energy production far more efficient. However, the advantage of having both forms of energy production can be seen during days of inclement weather when the solar panels are receiving no sun while the wind turbine is producing energy.

Project Cost and Schedule

The irrigation system with renewable power in the UHD Sustainability Garden was completed as part of a team-based, senior capstone project. As such, the students had to follow a detailed project execution methodology similar to what is being followed in an industrial environment. Key deliverables included: project proposal with budget, time schedule, roles & responsibilities; mid-term project status update with a written report and presentation; final project report, presentation and demonstration. Weekly status meetings and written reports helped manage project execution and address any deviations from schedule. Student performance was assessed not only by the quality of work delivered but also by the timeliness and cost of such work.

This project was benefitted by a previous team which had developed the garden beds, installed the photovoltaic panels and installed an initial version of the irrigation system. A budget and schedule was proposed to further enhance the capabilities of the garden through the implementation of wind energy, new water potential sensors and wireless control of the garden using the LabVIEW platform. The proposed project cost was $4888.27 while the actual was $4958.68. This corresponds to an overrun of +1.48% of the proposed budget. Such a performance is excellent from a project cost management viewpoint.

From a schedule viewpoint, the team overran the initial completion date of November 30, 2016 by one week. Final project report, presentation and demonstration took place on December 7, 2016. Several reasons contributed to this delay including unforeseen difficulties with water potential sensor data communication and the installation of the wind turbine support pole. Figure 18 shows the team project schedule.

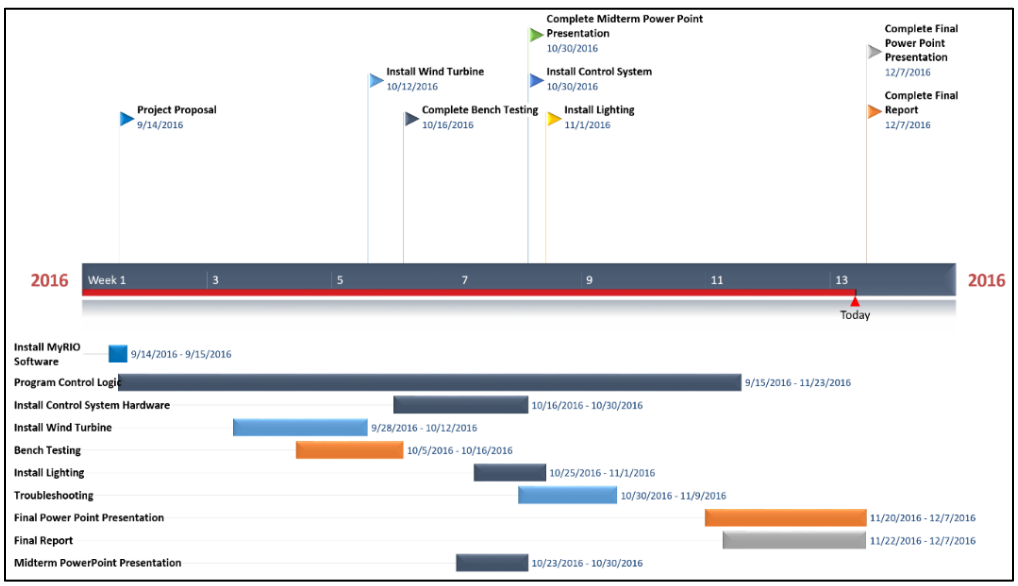

Fig.18: Project Timeline

Even though the project was delayed by one week, it should be noted that this is one week ahead of the scheduled completion date as defined by the university academic calendar. In conclusion, the team developed a well-planned project proposal and delivered the project within budget and schedule allowances.

V. Community Outreach: A Second System in a Community Garden

The hands-on irrigation project at UHD inspired us to introduce students to renewable energy technologies and a local community garden as part of the USDA funded summer program associated with the CUAS. This summer program supports students of multiple disciplines and allows them to gain experience and develop expertise in designing and implementing projects in a team and collaborative environment where students from different disciplines can interact for research purposes but also to help address other important societal problems.

The particular problem we attempted to alleviate was how to grow food more sustainably in our neighboring communities. This larger effort was undertaken under the auspices of the university's new CUAS. Specifically, we worked with a community garden in one of the most impoverished neighborhoods of our city with the following objectives: bring energy to the garden using renewable energy sources and technologies; install an irrigation system; choose and grow plants/vegetables in need; engage the community in this effort. Projects like this not only serve as a model for how community gardens can be made more sustainable but they also educate groups of multidisciplinary students so they may go on to solve future food availability challenges in our cities.

To accomplish these goals a diverse team of biology, social sciences and engineering technology students was formed and worked together over five weeks in summer of 2016. Although there was collaboration in all activities, biology students led the development of the garden beds, planting and growing the plants; a social sciences student led the efforts to document the impact of the garden on the local community; and engineering technology led the design and implementation of the renewable technologies and irrigation system. Due to budget, time, and reliability constrains, the installed system is based on one photovoltaic panel which stores harvested energy in a deep cycle battery to power a timer which turns on/off sprinkler valves at fixed times and for a specified duration. Figures 19 and 20 show the irrigation system and the photovoltaic system with the plants, respectively.

This CUAS summer program was designed with cross-disciplinary interactions as a goal. Future sustainable solutions will require that teams of people with different areas of expertise (social science, environmental science and engineering technology) work together to solve the complex issues of our future. Students in the program had different areas that they were the lead on, but students met as a group every morning to discuss the challenges and accomplishments of the previous day. Many days began with a collaborative goal such as removing the weeds from an overgrown garden bed so that the work on multiple fronts could begin. If students from different disciplines had an interest in any of the projects of the day (DNA extraction from plants, hooking up irrigation system) they were encouraged to work in an area outside their comfort zone. On Fridays we had a pot-luck lunch together where all 11 students and 2 faculty ate lunch together. We also had several professional development activities during Friday meetings including: building a CV/resume, oral communication practice, written communication practice and successful interviewing. We also took a field trip one Friday to the Children's Nutrition System of the Children's Nutrition Center which runs complex research projects on plant nutrition and has extensive hydroponic systems.

Fig. 19: Installation of Irrigation System

Fig. 20: Solar Panel and Beds of Plants

VI. Lessons Learned

Collaborative Multi-disciplinary Summer Program

This subsection summarizes experiences and advice gained after running the UHD Sustainability Garden and the CUAS summer program community garden projects.

- This project provided the opportunity to gain valuable experience related to project management. Before beginning any work, a project proposal was presented to the class instructor for approval and after beginning the project, weekly status reports were completed and discussed. The weekly deliverables required by the instructor provided a real world experience. Midterm and final presentations were completed which also provided the opportunity to improve public speaking and presentation skills.
- Teamwork was an important aspect of the successful completion of this project. The amount of time and effort required to complete this project in such a relatively short amount of time meant that the individual skills and abilities of each team member had to be successfully utilized. Assigning roles and responsibilities to each member was paramount, along with holding everyone accountable. Weekly team meetings were conducted to keep everyone on the most critical task and keep the project on schedule.
- Having multiple status updates and intermittent report deadlines forced an organizational element into the project. These deadlines assured successful completion of the project in a timely manner because it gave the students an overall observation of the project where students can easily succumb to tunnel vision.
- Be conservative when placing deadlines on yourself, difficulties in achieving deadline goals will undoubtedly arise.
- Having to work on a demanding project over an extended period of time forced the group to develop key communication and time management skills to maximize productivity.
- Knowing that the project was designed to be an interdisciplinary and community engagement venture gave that much more incentive to put forth maximal effort to assure that the final outcome was of optimal design.

Students gained a great deal from the cross-disciplinary, hands-on summer program. Below are two quotes from students involved in the summer collaboration that are representative of what the students got out of the program.

- There are many things [I learned] however one will be the collaboration between biology and engineering technology. It was interesting how we worked together to accomplish our goal without each group knowing much about the subject of the other group simply because of the different majors, it was so interesting seeing how all our minds worked together to accomplish.
- This program was awesome. I was able to truly see the real problems the world as a whole is facing now. I also understand now that there must be so much more involvement in the sustainable background to get things moving the way they are supposed to in order to have a safe and healthy environment for the future.

Capstone Project for Engineering Technology Students

The work described in this paper was meant to be the capstone project for Engineering Technology students. Currently, the capstone course is being offered as a three credit hour course and thus the project must be completed in a full semester's timeframe. During this timeframe, students must come up with a project idea, develop a detailed project design proposal, obtain approval for project execution, order parts required for the construction of the project, implement the proposed design, demonstrate its functionally relative to proposed success criteria (part of the design proposal), document the work and present it to the department. Depending on the scope and complexity of the project, it may not be feasible to complete a meaningful project in a semester's timeframe. So, the work reported here on the UHD Sustainability Garden has been completed by two different teams over two semesters. If it were to repeat the work, some changes could be made (and are currently in the works) in the way the capstone course is being offered. The semester prior to taking the three credit hour capstone project course, students could develop the project design proposal and seek project approval by registering in a one credit hour course. This will allow enough time to order various parts required by the project to arrive in time so that students will hit the ground running at the semester when they are to execute the project.

If it were to replicate this work on a larger scale, for example to automate the irrigation system and conserve water for a large farm by using renewable energy sources, a number of factors should be taken into consideration:

a. What are the energy needs for the project?
b. What is the most appropriate renewable energy source: solar, wind or a combination of the two?
c. What are the most appropriate technologies to measure soil water needs? Are such technologies wireless?
d. How will system operation will be monitored? Locally or over the web?

Once the scope of the project is defined, then an economic analysis must be performed to calculate the rate of return and payout time relative to using traditional energy sources. If the project is economically viable, then the project management methodology followed in the present work should be sufficient for the successful execution of the project.

VII. Conclusions

This paper focused on sustainable development and engineering technology. There is a need for responsible use of natural resources to minimize the impact on the environment. Renewable energy technologies can help minimize carbon footprint. Engineering technology students used such technologies in conjunction with computer control methods to contribute towards sustainable development. Interdisciplinary projects and community outreach efforts can serve as a valuable model of not only what future jobs will require of our students but what will be required to solve our current sustainability challenges.

References:

1. http://documents.worldbank.org/curated/en/605011468739497097/pdf/multi0page.pdf
2. https://sustainabledevelopment.un.org/?menu=1300
3. Perlman, U. H., "How much water is there on, in, and above the Earth?", http://water.usgs.gov/edu/earthhowmuch.html
4. Aravind, A., Aravind, T., Prathap, J. and Shanthi, K. J., "Project HARITHA - an automated irrigation system for home gardens", Annual IEEE India Conference, 635-639, 2012.
5. LabVIEW and myRIO, National Instruments, www.ni.com
6. RENOGY® 250W mono-crystalline black photovoltaic panels, www.renogy.com
7. Air Primus Air40 wind turbine, www.primuswindpower.com
8. MPS-6 Dielectric Water Potential Sensor, www.decagon.com

Acknowledgements:

1. Financial support from the following sources is gratefully acknowledged:
   a. USDA-NIFA Grant 2015-38422-24081
   b. University of Houston- Downtown 2016 CTLE Grant
2. The following students have contributed in various phases of the project and the Summer EL CUAS program: Freddy Lara, Steven Bennett, Brian Ly, Jose Vega, Anthony Alizadeh, Allan Soto, Ashley Barlow, Donald Williams, Ivan Gomez, Leticia Villalobos, Rajani Dhadral, Valdez, Reyna, Tony Garza, Vicente Rodriguez, Yarmilla Reyes, Zakariya Mahmod, and Amanda Howard.

APPENDIX A - Sizing of Batteries

Table A.1 shows the Excel spreadsheet used to determine the required size of the battery bank. This method of calculating the battery bank size was provided in the Air40 owner's manual[7]. Excel was used so that different parameters could be changed and the results would be instantly calculated.

To size the battery bank, the first calculation performed is the total amount of watts used per day. The power consumption of each component is given in their respective data sheet. This is then multiplied by the operating hours to determine the total watt-hours consumed each day.
The total watt-hours per day is multiplied by the number of desired days to be able to power the system without generating any additional power via the photovoltaic cells and wind turbine. In this case only a single day is needed.

Since the system is not connected to the grid, sealed lead acid batteries are used. These types of batteries cannot be fully discharged without causing serious damage to the battery. Next, the depth of discharge (DOD) must be considered. The DOD is the fraction of battery capacity that can be used from the battery and is specified by the manufacturer. For example, a 100 Ah battery with a DOD of 40% can only provide 100Ah x 0.4 = 40 Ah. In order to account for the DOD in the battery bank sizing calculations, the total watt hours are taken after the days of autonomy have been calculated and divided by the DOD percentage to obtain the equivalent watt-hours per day.

Colder temperatures have a negative effect on the capacity of the battery bank. To account for this, select a multiplier from Table 2, which is provided in the Air40 owner's manual[7], which corresponds to the coldest average temperature to be expected in the area where the batteries will be kept. Based on Table A.2 and our region, a multiplier of 1 was chosen for this application. Lastly, the total watt-hours rating per day is divided by the system voltage to obtain required Ah battery capacity.

As can be seen in Table A.1, an 188Ah battery capacity is needed. For this project, two 100 Ah batteries were chosen.

Table A.1: Battery Sizing Spreadsheet

Component	Watt Rating	Operating Time (hrs)	watt-hrs/day
MyRIO	8	24	192
Relay Board	3	24	72
Inverter	2.4	24	57.6
Moisture Sensor (x8)	0.96	24	23.04
Lights (x8)	80	6	480
Valves (x8)	38.4	2	76.8
Total watt-hrs/day			**901.44**
Days of Autonomy	1	901.44	W/hr
DOD	0.4	2253.6	W/hr
Avg. Working Temp (80+)	1	2253.6	W/hr
System Voltage	12	187.80	Ah
Required Battery Size		**188 Ah**	

Table A.2: Battery Bank Sizing Procedures[7]

STEPS:	EXAMPLE:
1.) Identify total daily use in Watt-hours (Wh)	***6,000** Wh/day*
2.) Identify Days of Autonomy (back-up days); multiply Wh/day by this factor.	***3 days of Autonomy:*** *6,000 x 3 = 18,000 Wh*
3.) Identify Depth of Discharge (DoD) and convert to a decimal value. Divide result of step 2 by this value.	***40% DoD:*** *18,000 / 0.4 = **45,000 Wh***
*4.) Select the multiplier corresponding to the lowest average temperature your batteries will be exposed to. Multiply result from Step 3 by this factor. *Result is minimum Wh capacity of battery bank:* *Temp in degrees* *°C / °F / Factor* *26.7 / 80 + / 1.00* *21.2 / 70 / 1.04* *15.6 / 60 / 1.11* *10 / 50 / 1.19* *4.4 / 40 / 1.30* *1.1 / 30 / 1.40* *-6.7 / 20 / 1.59*	*15.6 ° C (60 ° F) = 1.11* *45,000 x 1.11 = 49,950 Wh*
*5.) Divide result from Step 4 by system voltage. Result is the **minimum Amp-hour (Ah)** capacity of your battery bank.*	*49,950 / **48 = 1,040 Ah***