AC 2012-4453: ONLINE RENEWABLE ENERGY FACILITY FOR SUP-PORTING A NEWLY DEVELOPED ENERGY AND ENVIRONMENTAL SYSTEMS TECHNOLOGY PROGRAM

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Internet Accessible Renewable Energy Facility for Supporting a Newly Developed Energy and Environmental Systems Technology Program

1. Introduction

This paper is reporting a case of work-in-progress. The Technology Department of Northern Illinois University (NIU) has developed a new program in Energy and Environmental Systems Technology (EEST). The program has started to offer from fall 2011. The program is an outcome of collaboration between NIU and a number of 2-year colleges around the region. The major focus is in two areas- a) Courses from 2-year colleges are articulated within the EEST program and b) Via NIU, 2-year colleges will have an online access to a large set of renewable energy data for their course offerings.

The web portal is a software environment that has been designed and developed to provide data transfer from Freedom Field (FdF) to NIU; as well as a provision for data visualization and download. The data transfer process involves converting the General Electric (GE) data format to MS SQL format, check for data integrity and outliers, developing SQL server database, interactive data visualization provision, data download option, password security for user and administrative access, user management along with the environment user statistics. The interactive data visualization part is implemented using Fusion Charts API that can take either XML or JSON data as input.

This software environment provides access to historical data that are collected by the FdF system. Data are primarily collected in a server within the FdF using the hardware and software developed by GE. An arrangement has been made to upload the collected data to a NIU server (located within the Department of Technology). The data are then converted to an appropriate file format and saved to a secured server. The whole transfer and conversion process are implemented using an automated system without any human intervention. A number of web applications are then developed to visualize the data in graphical form. A user can choose the duration of displayed data. In addition to the graphical visualization a user can download the data to his/her local drive and analyze whenever necessary.

The paper is divided into four parts. The first part of the paper will discuss about the EEST program as well as extent of collaboration with 2-year colleges. The second part will describe the FdF and its available facilities and systems. The third part will illustrate the data transfer mechanism, details of data transformation, its visualization and download, and user management. The fourth and final part of the paper will describe the potential of web-accessible control of the FdF facility and its use for live laboratory experiments to support the EEST program.

2. Energy and Environment Programs at NIU

In 2008, an interdisciplinary group of faculty members suggested that NIU needs to strengthen its course offerings and degree structure in the areas of energy and the environment. In these areas, the university had some course coverage; however, no real structure for a major was in place. From the university standpoint, it was widely agreed that environmental issues, from climate change to land and water usage, to alternative energy, represent critical challenges for society [1]. Thus, NIU Institute for the Study of the Environment, Sustainability, and Energy – the ESE Institute – was developed. In addition, the University administration made funding available for development, hiring faculty members and supporting students. The academic programs developed through the ESE Institute are cross-disciplinary, with the overall goal to address societal and scientific needs for a greater understanding of environmental issues [2]. Recognizing the complexity of environmental issues, a holistic approach was taken which connects energy (particularly alternative energy for Illinois), foundational and applied environmental science, with societal and policy issues. The strategies are twofold:

- 1. To train people in a broad-based environmental studies curriculum that complements our existing focused programs
- 2. To strengthen our research in environmental and alternative energy issues

The programs will produce graduates prepared to meet these challenges via careers in industry, small business, federal, state and local governments, non-governmental organizations (NGO), and academic research. The Initial work of the ESE Institute was the development of world-class comprehensive and competitive undergraduate programs in Interdisciplinary Environmental Studies and Energy and Environmental Technology. In addition to these the group also developed two undergraduate minors; additional minors are planned or in current process. The goals of the minors are introduce students from various unrelated majors to the area of energy and the environment.

2.1 Interdisciplinary Environmental Based programs

These degrees consist of both BA and BS tracks. Both tracks include core courses that cover topics from the environmental sciences, environmental law and policy, green technologies, and the human experience. The majors are- Environmental Studies (B.S. degree) and Environmental Studies (B.A. degree). This foundation will allow students to learn about the breadth of knowledge in Environmental Studies [3]. Students then will pick from one of six emphases: Biodiversity and Environmental Restoration, Energy Studies, Environment and the Human Experience, Environmental Policy, Non-Governmental Organizations, and Water. The overall goal of the undergraduate programs are to train students in the causes, scales, and remediation and mitigation approaches to major local, regional and global environmental problems. In either Environmental Studies majors, students are required to take one emphasis group, which includes approximately eleven courses from areas, which are germane to the given emphasis. In most cases, the course work covers study areas from five or six different departments within the university. More information can be found at <u>http://www.niu.edu/ese/major/index.shtml</u>.

2.2 The Energy and Environmental Systems Technology Program

In addition to interdisciplinary environmentally based programs, several technology based programs and minors have also been developed. The technical programs were developed out of the College of Engineering and Engineering Technology and provide the students a more technical program using applications in an energy and environmental curriculum. In this program, the students are instructed in applications used in industry, various forms of energy savings approaches, new materials and processes, or new sources and needs in the production of

energy. The EEST will provide undergraduate students with an understanding of the application and needs in areas as well as new advances, which better the environment and new technologies that utilize green principles, and green transportation topics. The program includes new areas of green manufacturing and materials used today and in the future, including the operation and manufacture of solar cells, the production of wind, thermal, and hydro-electric power. In addition, the curriculum will introduce students to basic and advanced topics in HVAC, biobased fuels and alternative energy, as well as the ability of our graduates to examine the carbon footprint and develop solutions in the reduction of energy consumption. The course listing of Energy and Environmental Systems Technology (B.S. degree) program is as below:

Foundations courses

- CHEM 110 Chemistry and CHEM 111 Chemistry Laboratory
- ENGL 308 Technical Writing
- MATH 155 Trigonometry and Elementary Functions
- MATH 229 Calculus I
- PHYS 210 General Physics I
- STAT 208 Basic Statistics or STAT 301 Elementary Statistics
- CSCI 215 or TECH 295 Visual Basic Programming
- Geog 256 Maps and Mapping
- Geog 359 Introduction to GIS
- ENVS 304 Environmental Law, Policy, and Economics

Required Technology core courses

- TECH 175 Electricity and Electronics Fundamentals
- TECH 211 Computer-Aided-Modeling
- TECH 245 Pollution, Prevention, Pestilence, & Cost of Doing Business
- TECH 262 Machine Production Processes
- TECH 265 Basic Manufacturing
- TECH 305 Green Technologies
- TECH 391 Industrial Quality Control
- TECH 406 Facilities Management Technology
- TECH 415 Heating, Ventilating and Air Conditioning
- TECH 416 Design for energy efficiency and Green Materials
- TECH 417 Bio-Based Fuels and Alternative Energy Applications
- TECH 418 Energy auditing
- TECH 432 Disaster Preparedness
- TECH 443 Engineering Economy
- TECH 484 Energy Management
- TECH 496 Industrial Project Management (Capstone experience)
- Three Technical Electives related to energy and the environment

2.3 Student Recruitment

Due to the State of Illinois rules, all new programs must receive Board of Education approval, and as such, the two new Liberal Arts programs that were created have just received approval to

be offered. The new Technology program received approval last year, and is in its first year of being offered. Recruiting for these programs is relatively simple; they are selling themselves! The Institute leadership and staff routinely attends new student fairs and new majors presentations on campus, as well as some events off campus. In addition, due to the crossdisciplinary nature of the programs and the instructors, there is a constant promotion of the new programs in the courses, which the Institute faculty teaches. Since it is known that the majors will officially start in the fall of 2012, many students have already indicated that they will be transferring into these majors, and they have started to take the foundations courses. At this point, over 40 students have indicated that they would like one of the Liberal Arts majors and there are currently about 20 students in the Technology major. It is anticipated that this number will grow in the very near future. The Community College system within the State of Illinois is very aggressive in the mode in which they adapt to the changing education landscape and offer new programs and courses. Within the Institute programs, we are working on a concerted effort with the regional Community Colleges to find modes in which their 2-year programs can merge with the NIU programs. In the NIU region, there are approximately 11 Community Colleges, almost half of which offer energy and environmental technology programs.

3. Freedom Field

The FdF is a non-profit organization and is formed as a center to facilitate the development and operation of renewable energy solutions. The concept of FdF is based on integration of various renewable energy sources while providing a platform to study the effectiveness of these sources and foster renewable energy education in the region [4]. The mission of FdF is to increase regional awareness of renewable energy opportunities and to facilitate development and commercialization of renewable energy solutions. The facility is located in Rockford (Illinois) within the Rock River Water Reclamation District and is partnered with Winnebago County (Illinois), City of Rockford (Illinois), Department and Commerce and Economic opportunity, Northwest Chicagoland Regional Airport, Rock River Water and Reclamation District, Ballard Engineering, Williams Charles, Northwestern Building Construction Trades Council, Growth Dimensions Economic Development, Hamilton Sundstrand, Bergquam Energy Systems, Eiger Lab, Rockford Illinois area Economic Development Council, Rock Valley College, Illinois Regional Energy Association, and NIU. The FdF is designed to:

- Install and characterize renewable energy technologies
- Integrate and test complementary technologies as viable systems
- Produce operational data for analysis
- Optimize new technologies for production, installation, and service
- Develop regional projects that use these technologies and systems
- Create education and outreach programs
- Foster and develop collaborations, innovative ideas, and applications



Figure 1: Diagram showing all the energy sources within the Freedom Field facility.

Figure 1 shows a diagram with all the renewable energy sources that are integrated within the FdF. As a part of their mission, FdF is collaborating with the authors and made their facilities available so that they can use their systems and collected data for course development. The sources are: 35kW solar thermal unit, 12kW solar photovoltaic unit, 1.2kW vertical wind turbine, Bergey 10kW wind turbine, bio-fuel facility, and weather station. Part of the generated electricity (30,000kWh/per year) is used for maintaining air-conditioning (heating and cooling) of FdF facility and at the same time pass the surplus to the local electricity company (ComEd Distribution). As an additional project, FdF is working on large scale Geo-Thermal Lake Loop HVAC study, Algae to bio-diesel study, and Waste Glycerin to Energy Collaboration. Images are provided to show the overall activities of FdF (Figure 2).



(a) Demonstration to a group of visitors.

(b) Reception area.

Figure 2: Shows the open space with the Freedom Field that is used as a reception area.

4. Energy Management

The heat energy generated by the solar thermal array and bio-fuel energy are managed by two different systems. Part of the heat energy is used for space heating, while discharges the surplus energy through sewerage system. When all the electric energy sources (photovoltaic and wind turbines) are integrated together and collected energy are used for operating the electric load of the FdF. The FdF is connected with the electricity utility company (ComEd) grid and can supply surplus energy to the grid. The energy collection and utilization process (within the FdF) is managed and controlled by a GE hardware and software system [5, 6]. The system also collects data that includes energy collection rate, energy flow at various points, energy consumption, and environmental conditions and stores these on a local server. Figure 3 shows a graphical user interface that illustrates the energy flow throughout the system and Figure 4 shows the control panel hardware.



Figure 3: Showing energy flow throughout the system.



Figure 4: Control panel hardware.

4.1 Solar Thermal Energy Generation

Figure 5 shows an image of the solar thermal heat collection panel. Heat energy collected from the 35kW solar thermal (heat) unit is passed through two independent heat exchangers. One is to pass the heat to a hot water tank and other is to release the excessive heat. Fluid from the hot water tank used for space heating and is done by passing hot water (from hot water tank) through floor heating tubes. An absorption chiller and cooling tower are used to supply with cold water and are used for space cooling.



Figure 5: Solar thermal heat collection panel.

4.2 Bio Gas Thermal Energy Generation

The bio-gas system uses wood chip or processed algae as a fuel. Figure 6 shows and bio fuel as well as a bio-gas unit that converts bio-fuel to heat energy. The system is connected with the thermal energy handling system that is used for the solar thermal system.



(a) Bio fuel.



(b) Bio-gas unit.

Figure 6: Bio-Gas there energy generation.

4.3 Electrical Energy Generation

There are three systems that generate electrical energy. These are 12kW solar photovoltaic, 1.2KW vertical wind turbine, and 10KW horizontal wind turbine. A picture of the solar PV panels are shown in Figure 7 and pictures of horizontal and vertical wind turbines are shown in Figures 8 and 9, respective. All these energy sources are integrated within a single dedicated

system. Part of the generated electricity (30,000KWh/per year) is used for supplying the electrical energy demand of the FdF facility and at the same time pass the surplus to the local electricity company (ComEd).



Figure 7: Solar PV panels.



Figure 8: Horiz. wind turbine.



Figure 9: Vert. wind turbine.

4.4 Data Collection and Storage

The system (hardware and software) used for energy management and data collection provided by the GE. It has a custom-built hardware when GE Experian software keeps a log of collected energy data as well as energy flow data all around the system. The data are then stored into a server. The data format is unique to the GE system and can only be accessed by using the Experian software. The collected data are grouped into 14 tables. A list of tables along with a brief description of collected data types are listed below:

- *Flow rate for Solar Collectors* Flow details for roof-top solar collectors.
- *Fluid temperatures for Solar Collectors* Temperature details for roof-top solar collectors.
- *Heat Exchanger-2 dealing with Solar Collector output-* Heat exchanger energy transfer details. This heat exchanger manages the collected heat energy from the roof-top solar collectors. Part of the heat energy is passing forward for the hot water tank when the remaining energy is dump to the drain.
- *Fluid temperatures to and from the Hot Water Storage Tank-* Provides temperature details of fluids around the Hot Water Storage Tank.
- *Heat Exchanger-1 with Hot Water Storage Tank-* Provides temperature details of the heat exchanger and hot water storage tank.
- *Indoor and Outdoor conditions* Provides details of indoor and outdoor environment like temperature and humidity.
- *Air Handling Unit and under floor tubes* Provides details of Air Handling Unit as well as flow details through the under floor piping.
- *Absorption chiller for cooling facility-* Provides temperature data of chilled water for the cooling facility.
- *Hot Water Storage Tank and Absorption Chiller* Provides details of fluid flow (and their temperature) between the hot water storage tank and absorption chiller.
- *Absorption Chiller and Cooling Tower* Provides details of fluid flow (and their temperature) between the absorption chiller and cooling tower.
- *Total energy generation and consumption* Provides details of the total energy generation using various sources as well as energy consumption of the FdF.

- *Electrical Energy Generation summary* Provides generation details for electrical energy generation systems. This includes PV solar and wind turbines (horizontal and vertical), as well as the total energy consumption from the commercial grid.
- *Bio Energy Generation summary* Provides bio-energy generation details. This includes temperature data at various points of the system.
- *Data collected via Weather Station* Provides details of weather station state data. This includes temperature, humidity, wind speed and direction, and radiance.

5. Web-based Control and Data Portal

The GE system that is used for FdF can be accessed and controlled over the web. This provides a potential to control the facility as a living experimental system and can be accessed by both the NIU and 2-year colleges. As an initial step towards a full web-based control, a provision has been made to transfer daily collected data to a NIU server. The data are processed and available via a web portal for visual display as well as download to a local PC for user analysis (www.niu.edu/ffrenergy). Students and faculty has access to the web portal and with the guidance of a faculty, students are able to use the data for their courses. Figure 10 shows an image of the home page for the portal.



Figure 10: An image of the web portal home page.

5.1 Data Transfer and Pre-Processing

The whole data transfer and visualization system can be divided into three steps. The Step-1 includes the data manipulation as a pre-processing for transfer process as well as the data transfer itself; Step-2 describes the data format conversion and pre-processing; and Step-3 illustrates the web application development for data visualization and downloading.

Step-1: At the FdF, GE Experian software keeps a log of all the collected data and is stored into a secure server. The data format is unique to the GE system and can only be accessed by using the Experian software. In order to export it to the NIU server, FdF server transforms the data into a Comma Separated Value (CSV) format. A batch script is developed to automate this process and is being executed on daily basis. These transformed CSV files are copied to a NIU server via ftp. The NIU web server has a password protected shared folder to which data can be remotely uploaded.

Step-2: Once the CSV files received at NIU, the server stores the data to a secure location. Within the NIU server a script is executed on a daily basis (at a fixed time) to import the CSV files to Microsoft SQL Server database. Through this process all the CSV files are imported into their concerned database tables. The received data are collected at every 5-minute interval and there is a problem in visualizing the data over the web, when a user needs to display a longer duration of data. To handle this problem a re-sampling scheme is implemented through averaging process. This calculates the mean values of the data and results are stored into a separate database. The re-sampled data are then used for data visualization over the web. This averaging process provides a much smooth graph as well as ensure a faster display of graph.

Step-3: Provides data visualization as well as data downloading. Both these features utilize data from the SQL Server database. For both data visualization and downloading user can select a time range, such as 1 day, 7 days, 15 days, 30 days, and 90 days.



Figure 11: Data visualization downloading page.

5.2 Web Applications

A number of web applications are developed for user interaction with the facility. The home page of the developed facility is shown in Figure 10. The home page provides a five menu buttons describing the objective of this facility, information about the FdF, Facilities available within the FdF. Link for access to Energy Data, and contact information. Energy Data menu button will provide access to the data visualization and download options. An image of the data visualization and download page is shown in Figure 11.



Figure 12: Image of a web page with data visualization and download option.

Once clicked on the 'Data Visualization" button within the page (Figure 11) it opens another window with data selection options. An image of a part of this page is shown in Figure 12. Within the page, there are two options. With the option 1, one can click on a part of the GUI to access a desired data for visualization or download, while option 2 provides a list of data tables that can be accessed.

Figure 12 shows an image of the page with two options. In option 1, user can choose an area on the GUI to select a group of data. When option 2, allows one to choose a group of data by clicking on a table name. Once a table has been selected, it will open a new window with an a diagram showing the placement all the sensing point within the part of the system as well as real-time data as available from the FdF web site. This page has two parts. The upper part shows the real-time data of that part of the system (automatically collected from the FdF) as well as a static diagram of the data collection area around the heat exchanger 2. When the lower part of the window shows a list of available data within the table along with visualization and downloading options. The Figure 13 shows an image of the upper part of the page with the data options associated with Heat Exchanger-2 (dealing with solar collector output) and Figure 14 shows an

image of the lower part of the page. Within the lower part, the user needs to select whether to visualize the data for a desired duration or download them on a local PC. One can choose a desired length of data and this can be: 1 day, 7 days, 15 days, 30 days, and 90 days. Once selected a desired length, one can choose either for Show Graphs option or Download CSV option.



Figure 13: Real time sensor data as well as placement of the sensors (upper part).





6. Access Control

The data visualization and download area of the facility is password controlled. There are two levels of access to the facility, one is for user level and other is admin level. Figure 15 shows a software flowchart for user and admin level of access.



Figure 15: Flowchart for admin and user levels of activities.

With the user level one can update their account information, change password, and get access to energy data, and view the site map. Figure 16 shows an image of the home page with user level of access.

NORTHERN ILLINOIS UNIVERSITY	Green Energy Data- Freedom Field College of Engineering and Engineering Technology
User Panel	
Home Logout	This page provides two activities. One of this allows a user to update their account information as well as change the password. Other activity is to access to the data either in graphical form or to download on your system. Update Information Change Password Energy Data Site Map

Figure 16: An image of the web portal for user access home page.

With the admin level of access, one can do all these as well as create new user accounts, edit user information and perform user information analysis and system usage analysis. The Energy Data option will allow them to get access to the data, while other options are for account management. Figure 17 shows an image of the web page with admin level of access.

Admin Home						
Create New Account						
Edit User Information						
Energy Data						
User Analysis						
Usage Analysis						
Site Map						

Figure 17: Image of page for admin level access

Account management activity with admin level of access involves the creation of new accounts, update an existing account, user data analysis, and usage data analysis. User data analysis involves the visualization of user contact and other details. An image of the application page with user data analysis is shown in Figure 18. The usage analysis tracks information involving the usage of the facility. An image of the application page with facility usage analysis is shown in Figure 19. This two application pages allows an admin to gather the information regarding the facility utilization and the user profiles.

	Back User Analysis										
	Choose Criteria										
Username Country Organization Profession User Type All All All Personal Select											
	User Name	First Name	Last Name	Email	Phone	Address	City	State	Country		
	avi	Avinash Varma	Gadiraju	agadiraju@niu.edu	6302549939	945 Regent Dr	Dekalb	IL	USA		
	amar	Amar	Makana	amakana@niu.edu			New York	NY	India		
	uday	Uday	Reddy	udayreddy1989@gmail.com	8155080543		Dekalb	IL	USA		
	uday4	uday4	reddy4	udayreddy1989@gmail.com	8155080543	945 regant dr apt 310	dekalb	IL	usa		
	uday2	Uday2	Reddy2	xyz@gmail.com	123456789	945 West Ridge	Deklab	IL	USA		
	uday3	uday3	abas	adad@yahoo.com	2158497895	335,Palm drive	hyderabad	AP	India		

Figure 18: Image of User Data Analysis page.

Usage Analysis										
Choose Criteria										
Account	Browser	IP	Star	t Time End	End Time					
uday 👻	All 🗸	All	All	✓ All	•					
Select										
User Name	Intime	IP	Browser	OS	Outtime					
uday	10/28/2011 9:31:00 AM	131.156.24.62	Firefox	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	10/28/2011 9:32:56 AM					
uday	10/28/2011 10:38:21 AM	131.156.24.62	Firefox	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	10/28/2011 10:38:48 AM					
uday	10/28/2011 11:12:00 AM	131.156.24.130	Firefox	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	10/28/2011 11:12:21 AM					
uday	10/28/2011 11:16:03 AM	131.156.24.130	Firefox	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	10/28/2011 11:16:15 AM					
uday	10/28/2011 12:48:48 PM	131.156.24.62	Firefox	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	10/28/2011 12:50:42 PM					
uday	11/2/2011 5:44:51 PM	131.156.83.229	Firefox	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	11/2/2011 5:44:54 PM					
uday	11/9/2011 11:15:22 AM	166.137.140.89	AppleMAC- Safari	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	11/9/2011 11:16:07 AM					
uday	11/9/2011 11:40:50 AM	131.156.24.130	IE	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	11/9/2011 11:41:05 AM					
uday	12/8/2011 2:41:13 PM	131.156.24.130	Firefox	Microsoft Windows NT 5.2.3790 Service Pack 2, v.4789	12/8/2011 2:49:45 PM					

Figure 19: An image of the User Analysis page.

7. Conclusions

The paper describes the development process of an Internet accessible facility where data can be accessed and visualized for a renewable energy facility. The renewable energy facility has its own data collection system and collects data related to a number of renewable energy sources as well as the collected energy flow within the facility. The developed facility gathers the data periodically and provides a portal for direct data visualization as well as download to clients' systems. The portal is to support a newly developed energy and environmental technology systems program and will be shared by 4-year and 2-year institutions. In addition to this, the

Internet accessible facility has a client management system and provides a provision for various statistical parameters in terms of the facility use and user data. The facility has now been developed and is in the process of integrating with the program.

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