AC 2010-1232: DEVELOPMENT OF A RENEWABLE ENERGY COURSE FOR A TECHNOLOGY PROGRAM

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Abstract

Energy systems play a critical role in everyday life and are an important part of engineering. The academic, business, and industry fields have been seriously pursuing renewable energy systems advantageous to their needs. Students graduating from engineering and technology programs are involved in buying, managing, and trading alternative energies during their careers as part of their job requirements. It is essential for engineering and technology students, at a minimum, to be familiar with renewable energy technologies and their applications and implementations. This course serves as an introduction to renewable energy with an emphasis on energy harvesting, conversion, and storage systems. It is a combination of lecture, demonstrations, student inquiry, in-class problem solving, and hands-on projects. Students are required to complete a series of exercises/projects and/or tests that reflect their knowledge of the stated objectives. A short power electronics section covers the major electrical equipments required for power transmission and power conditioning. Topics include photovoltaic systems, solar thermal systems, green buildings, hydrogen fuel-cell systems, wind power (generator and gear train systems), waste heat, biomass fuels, wave power, tidal power, active/passive human power, nuclear and hydroelectric energy, storage technologies (battery, supercapacitors), and hands-on laboratory projects. This course acquaints students with existing and potential ambient alternative energy sources, production capacities and energy harvesting, conversion, and storage techniques. Key concepts, terminology, definitions, and nomenclature common to all energy systems are introduced by using historical traditional energy generation methods and by reviewing typical energy consumption patterns. The course concludes with a general review of how to integrate energy harvesting technologies into a system that provides a continuous and uninterrupted power stream.

1. Introduction

Renewable energy related courses are becoming an essential part of engineering and engineering/industrial technology curricula. Many schools are integrating renewable energy programs or courses to their core curriculum to support existing programs to expose students to energy systems [1-7]. The nature of renewable energy courses differs depending on the program of studies in various departments. For example, construction and civil engineering technology/science programs usually adopt green building and geothermal related classes and projects [8], engineering programs adopt thermal systems, solar, wind, human power, energy conversions systems, and biomass classes related to their curricula.

Usually, renewable energy courses provide an assessment of potential for various alternative and appropriate energy technologies to meet regional and global energy demand. They also explore conservation and end-use efficiency improvements that may allow civilization to exist in a more sustainable manner. Studies of modern energy resources, extraction techniques, conversion technologies, and end-use applications consistent with a conventional engineering and engineering/industrial technology curriculum are used as a baseline. Against this baseline, the courses introduce the physics, systems, and methods of energy harvesting from non-conventional energy sources such as solar, geothermal, ocean-thermal, biomass, tidal-lunar, hydroelectric, wind, thermoelectric, human power, biomass, and waves. Advantages and disadvantages of these

alternative energy sources and the engineering challenges inherent in harnessing such forms of energy are covered. Evaluation and analysis of energy technology systems are taught in the context of achieving civilization's future economic and environmental goals [9-16].

The Energy Harvesting, Conversion, and Storage Systems of Alternative Energy Sources course is a general renewable energy course designed to enhance students' knowledge of renewable as well as traditional energy sources and their impacts on the environment and society. There is no prerequisite for this class so that all students who have an interest in energy technologies on campus may be reached. The basic concepts of electricity and power generation are covered at the beginning of the course to help students who do not have a background in electrical systems. Traditional energy sources include coal, hydro, nuclear, oil, or natural gas; non-traditional sources include renewable energy such as wind, solar, geo-thermal, wave, hydrogen, and bio-energy. The course strives to help students develop an in-depth understanding of issues related to energy and renewable energy including bio-fuels and renewable products and associated markets. Another goal of the course is to increase the public awareness of renewable energy and renewable products through presentations, projects, and discussions in the class environment. The course is the first level in a series of renewable energy related classes which will lead to create an interdisciplinary minor in which students can apply their academic expertise to the area of energy and renewable energy. The course will lead to development of more renewable energy related courses and eventually will create a degree program in the department.

2. Course Goals

The main goal of the course is to help undergraduate students develop and apply an in-depth understanding of issues related to energy, renewable energy, and bio-renewable products and associated markets. The course is designed to be a hands-on interdisciplinary class with an emphasis on the study of the economic, social, and environmental aspects of various renewable energy sources including bio-fuels. Ultimately, the program strives to educate students to understand the technical, economic, social, political, and environmental aspects of various sources of energy and to become more knowledgeable citizens. A summary of program objectives are listed below:

- Learn and apply applications of
    - photovoltaic energy systems
    - wind energy system
    - passive solar air and water heating systems
    - active and passive human power
    - hydrogen fuel cell systems
- Learn the role of energy, energy sources, and energy usage patterns in society.
- Develop basic knowledge to understand social, economic, and environmental aspects of renewable energy.
- Develop a multidisciplinary background in renewable energy, energy conservation and efficiency, and self-sufficient products.
- Develop an appreciation of how renewable energy technology works and how it is currently being used in U.S. and around the world.
- Gain knowledge and hands-on experiences in renewable energy systems.

- Learn site surveying and load analysis for renewable energy customer needs.
- Develop skills to handle hybrid renewable energy technologies.

2.1. Course Description

This course is a comprehensive introduction to ambient energy sources and its applications. Topics include photovoltaic, solar thermal systems, green building, fuel-cells systems, hydrogen, wind power, waste heat, biomass, wave power, tidal power, nuclear energy and hydroelectric. This course will acquaint students with existing and potential ambient alternative energy sources, production capacities and energy harvesting, conversion, and storage techniques. By using traditional energy generation methods and by reviewing typical energy consumption patterns, key concepts, terminology, definitions, and nomenclature common to all energy systems are introduced. Design Development majors/ minors, Industrial Technology majors/ minors, Construction Management, Industrial Management, and Electronics majors/minors can take this course as an elective in the technology department. In addition, any majors and minors at the college should be eligible to take this class as an elective.

3. The Need and Capability

Not all engineering and engineering/industrial technology departments will be able to offer a variety of renewable energy courses due to faculty, budget, laboratory, and knowledge limitations. Unless a school decides to establish a renewable energy related program or degree, it becomes difficult for faculty to teach renewable energy related classes in addition to the classes in core curriculum. Since tenure-track and tenured faculty are usually allowed to teach three classes a semester, it may become an issue to offer more classes if there are not enough faculty available. If this is the case, it would be better to have at least one or two general renewable energy classes to respond to all the needs of the programs/degrees in the department. In this way, students can be exposed to general renewable energy systems and will be given the opportunity to learn further information by enrolling in general renewable energy courses in the department. Since the Spring'09 semester, students were involved in a renewable energy course and accomplished several projects under the supervision of a faculty who teach and research renewable energy systems. The class project titles are as follows:

- Building a small scale wind turbine
- Installation of a four wind turbine system
- Study of renewable energy systems and applications
- Integration of renewable energy components
- Data acquisition with green meter (data acquisition system)
- Building a renewable energy training unit
- Self-Powered Athletics Field Striping Machine
- Energy harvesting systems from renewable energy resources
- Design a green building (3D CAD modeling)
- Self-sufficient energy-efficient house design (3D CAD modeling)
- Installation of skylights
- Installation of passive solar air heater
- Installation of passive solar water heater

- LED lightening analysis
- Piezoelectric powered hand light

These projects were accomplished in the Spring, Summer, and Fall'09 semesters, and students requested access to a general renewable energy class before they graduate. There are several students registered in a renewable energy course to accomplish several projects during the Spring'10 semester. In addition to these projects, a comprehensive renewable energy course was developed by several faculty members to extend topics to all major/minor students. Faculty are currently teaching bio-fuel systems, construction technology, electronics, design and development, and industrial safety classes; they contributed to this curriculum by suggesting topics to be included. The course topics were identified after several meetings to respond to students' needs and to extend their knowledge for future projects. There were also several presentations and meetings with interested student club members to discuss and discover potential renewable energy resources for energy harvesting. The Delphi Method was used to determine researchable alternative energy topics [17]. It is an approach which consists of a survey conducted in two or more rounds; the participants in the second round were provided with the results of the first so that they could alter the original assessments. Students from different majors/minors shared their ideas in the meeting group and the ideas were discussed by the participants. If an idea was not accepted by participants, students came with supportive documents to the next meeting to explain their ideas in details. Students and faculty found this method quite enlightening to discover and learn different ambient energy resources. Table 1 summarizes the potential ambient energy source ideas discussed by students and faculty in the last meeting in Fall 2009 semester.

The meeting participants were divided into 5 groups of 6 students in each group. In Round 1, the students were instructed to come up with 3 innovative topics/ideas, which, to the best of their knowledge, have not been developed or researched before. The groups presented and described their concepts. Each topic/idea was voted on by all participants for most achievable by the IT program. Table 1 shows the list of ideas identified by meeting participants.

Table 1. Explore new research related to renewable energy systems

Group	Topics / Ideas	Vote Count
1	1. Amplification of electromagnetic fields	2
	2. Photosynthetic electricity source	19
	3. Different ethanol process and source	1
2	1. New battery materials	0
	2. Geothermal cooling method	5
3	1. Flooring that stores kinetic energy	10
	2. Thermoelectric generators in walls as energy source	5
	3. Magnetic engine	4
4	1. Capture ocean and water currents as energy source	13
5	1. Ocean buoys to harvest electricity	X*
	2. Hemp as alternative organic for fuel production (ethanol)	0
	3. Harvest wind from exhaust fans and A/C units for energy source	20

*Group 5, topic 1, was deemed to be the same as Group 4, topic 1 and rejected.

Based on the counts, the top 3 topics were selected. In Round 2, groups were reassembled to prioritize those 3 topics according to which topic the students were most likely to pursue. The group results and consensus ranking follows in Table 2:

Table 2: Top three energy sources for research ranked by meeting groups

Topic	Group					Rank
	1	2	3	4	5	
Photosynthetic electricity source	2	3	1	3	2	**3**
Capture ocean and water currents as energy source	1	2	2	2	3	**2**
Harvest wind from exhaust fans and A/C units for energy source	3	1	3	1	1	**1**

Based on the results of the meeting using the Delphi Method, three topics in Table 2 were considered and ranked for alternative energy research in the IT program at Sam Houston State University. In future planning, the number of these meetings will be increased based on the interest and availability of students.

4. Course Content

Upon completion of this course, the student will able to:

- Locate and identify potential ambient alternative energy sources
- Understand electric power generation, harvesting, conversion, and storage systems
- Identify appropriate storage (battery, supercapacitor) technologies
- Learn about solar energy systems using photovoltaic systems
- Learn to harvest energy from wind power
- Learn how to generate electrical power from biomass
- Understand hydroelectric power systems work
- Learn the applications of hydrogen fuel cells
- Explore active/passive human power sources
- Learn about geothermal energy and ground-source heat pumps
- Become knowledgeable about working principles of renewable energy transportation systems
- Understand energy systems management and auditing
- Learn about energy utilization in our homes, businesses, and schools
- Define relationships between renewable and non-renewable sources of energy
- Learn electric circuit design for energy harvesting system
- Learn process and materials safety for alternative energy technology

5. Class Projects

Students are required to complete a series of projects in the developed class (Energy Harvesting Systems from Alternative Energy Sources) as part of course requirements. Depending on the

class size, groups are established to complete assigned projects in rotation. The Instructor assigns a timeline for each group to finish their projects. If a group fails to finish the project according to the timeline, they receive partial credit for the incomplete project. Usually a projected timeline to complete the project is sufficient for a group, because each group consists of at least three students. Students are allowed to work during the weekends and during the week days under the supervision of an instructor or lab assistant. All of the information about the projects is provided to the group members. Group leaders are in charge of updating the instructor about their projects; they are cautioned to ask for help if any issue occurs. Groups are required to make a presentation for one of the projects they accomplish through the semester at the end of the semester to class. The groups should start their projects the third week of the classes and finish them before the finals week. A total of fourteen weeks are allowed to finish projects. Table 3 is a sample project assignment timeline with the list of projects.

Table 3. List of projects assigned to groups

Projects & Project Timeline (2 weeks)	**Weeks/Groups**													
	3. week	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Skylight Installation	Group 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7	
Passive Solar Air Heater Installation	Group 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1	
Passive Solar Water Heater Installation	Group 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2	
Wind Turbine System Installation	Group 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3	
Photovoltaic System Installation	Group 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4	
Hydrogen Fuel Cell System Installation	Group 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5	
Basic Geothermal System Installation	Group 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6	

6. Lab Environment and Equipment

Establishing a renewable energy teaching and research laboratory involves undergraduate and graduate students, faculty, and community in learning about alternative energy and its impacts in details. Hands-on renewable energy related classes, labs, and projects promote alternative energy education at university campuses. A fully functional laboratory delivers applied energy education workshops for local community colleges, secondary/high school science/technology teachers and students and the general population especially who are not exposed to state-of-the-art renewable energy information. Information concerning solar, wind, passive solar water and air heating, fuel cells, and human power can only be offered to small groups of students because of very limited laboratory space, current tools, and components which are available. Depending on tools and component availability, self-sufficient energy-efficient building design and construction, biomass, thermoelectric, and advance alternative energy systems may be offered at campuses. The current electronics, construction, and production laboratories are used for the projects and

equipment is housed at Sam Houston State University. In addition, construction major students built a small house (storage sheds) to be used for the projects part of their class projects. These small storage sheds are used as temporary laboratories, are placed next to the construction laboratory, and have a southern exposure for efficient sunlight. All the necessary parts for projects were purchased with internal and external grant supports and donations. No additional tools, equipment, or technological resources were necessary for students to finish the projects since the university laboratories are well equipped and already have these supplies stocked. The systems below are used for the laboratory sections and hands-on projects of the course.

Skylight Installation

Tubular Skylights are energy efficient high performance lighting systems that are cylindrical in shape and are designed to light rooms with natural sunlight. A small clear collector dome on the roof allows sunlight to enter into a highly reflective "light pipe" that extends from the roof level to the ceiling level. The light pipe is coated with a silver mirror quality finish that allows the full spectrum of sunlight to be channeled and dispersed evenly into a room through the means of a diffuser located in the ceiling. This project involved installation of four units, 13" tubular prismatic diffuser type skylights on the roof of storage shed. Students learned to identify a best location on the roof to install skylights for efficient use and increase illumination in the dark places in the house or building. They determined the length of light pipe for installation. The picture of an installed skylight is shown in Figure 1.

Figure 1. Skylight Installation.

Passive Solar Air Heater Installation

Solar air heating systems are a supplement to regular heating systems and can dramatically reduce heating costs. Air in the building is circulated through a collector on the exterior wall where it can gain up to 30 degrees before being vented back into the room. A 1500GS glazed secondary air heater (passive device resembling a large door) was mounted on a sunny south facing wall of storage shed built by students. A 270 CFM AC powered combi fan is used to circulate the air in the storage shed for test purposes. The air circulation and quality of warm air were tested different times in a day and different weather conditions. Some of the questions

below were assigned to students to learn air heating system in detail. The passive solar heating system is shown in Figure 2.

- Does a solar air heater work at night?
- Can I mount the air collector upside down?
- What happens during the summer?
- Can I mount it horizontally?
- How long does the installation usually take?
- Where are the units manufactured?
- Will it produce heat on cloudy days?
- Is it better to use a 2 pack (solarsheat 1500G and 1500GS) or two stand alone units (2-1500G units)?
- Do air heaters need to face true south and at a tilt angle 90 degrees to the sun?

Figure 2. Passive solar air heating system.

Passive Solar Water Heater and Basic Geothermal System Installation

Students involved in this project learn to distinguish solar electric and solar thermal and an understanding of the uses of both; have a good understanding of how to identify a proper site for a solar thermal system, and have resources to explore local installation options. Initially a wheeled cart was designed using a computer design and drafting software tool with all major components were shown in the design. After the design of a complete system (with real dimensions) a wheeled cart was built to test the passive solar heater system in different locations. The passive solar water heating system is shown in Figure 3.

Figure 3. Passive solar water heating system.

Wind and Photovoltaic Systems Installation

Five units of wind turbines (12V 200W) and fifteen units of solar modules (12V 65W) were purchased for student projects. All the related parts to build a complete wind and photovoltaic energy systems were also purchased to supplement student projects. Students built a wind/solar hybrid system to control and record data to investigate the reliability of both systems. A data acquisition system was implemented to record and analyze temperature changes, solar irradiation, wind speed, power generation and consumption with load changes. The hybrid alternative energy system (solar and wind) is shown in Figure 4.

Figure 4. Hybrid solar and wind energy system.

Hydrogen Fuel Cell System Installation

The solar module converts radiant energy into electrical energy to power the electrolyzer, which breaks water into its basic constituents of hydrogen and oxygen. These gases are stored in the graduated cylinders. When electrical power is required, the PEM fuel cell recombines the stored gases to form water and release heat and electricity. Students are familiarized with fundamental principles of fuel cells through solar-hydrogen fuel cell technology. The provided module is a

training unit and students are involved in a variety of laboratory experiments provided by manufacturer. In this project, students engage in twenty to twenty five hands-on experiments for introductory and advanced environmental science, as well as demonstrate the sustainable benefits of fuel cells and hydrogen technology. Figure 5 shows a hydrogen fuel cell training unit with a data acquisition system.

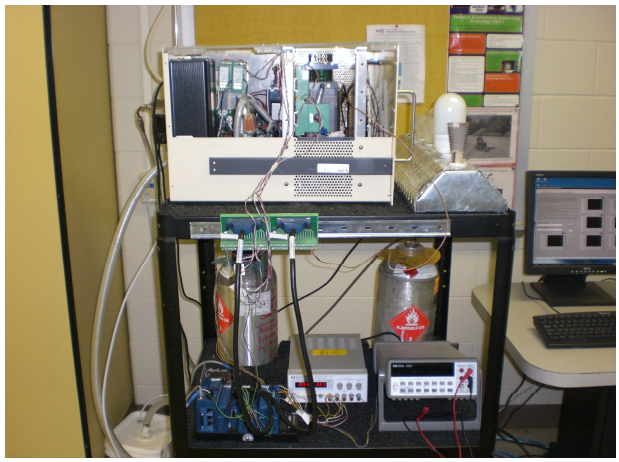

Figure 5. Hydrogen Fuel Cell system

Human Power Generator System

In this project students are familiarized with conversion of mechanical energy (through human kinetic energy) to electrical energy. A low Rpm permanent magnet DC generator, generator types, mechanical torque, human power applications, charge controller, battery types, measuring voltage and current, voltage rectification, power output changes with mechanical force were studied by students. The instructor provided exercises to be accomplished by students and submitted for their project grade. The Human power trainer is shown in Figure 6.

Figure 6. Human power trainer

Conclusion

An increasing quantity of alternative energy resources presents much promise for our society. Due to this fact, the next generation of students will need more curricular support in this area, especially for those students engaged in engineering and technology programs. This is especially true as the issues of depletion fossil fuel sources, climate change, global warming, increased electricity blackouts, and oil price variations continue to overwhelm the people through news media. So far, however, many schools including K-12 and community colleges do not have robust educational programs in these critical fields because of budget, laboratory, and knowledge limitations. Alternative energy systems and sources are frequently discussed in the media and are thus continually on the minds of students from daily life experiences and conversations. The public's general concern and interest concerning the environment has been increasing recently and many attempts are being made to incorporate green technologies in the school curriculum. The number of alternative energy related courses and programs are increasing due to the considerable demand for alternative energy sources. This demand will lead to greater competition between students in the future as they begin to seek career opportunities. Students getting engineering and technology degrees need a general knowledge of alternative energy systems, at least, to apply to their future fields.

In this paper, the Energy harvesting systems from renewable energy sources course that have been developed and offered at the Sam Houston State University are described; these courses continue to evolve and expand. The main themes covered in the course are the needs, concepts, operation principles, modeling issues, and simulations of solar, wind, passive solar air/water heating, human power, geothermal, hydrogen fuel cell systems and techniques. This course is aimed at providing the student with the concepts and theoretical background as well as the various applications of utilization and grid connection methodologies for energy harvesting. The class developed and detailed is a general hands-on alternative energy class to expand the knowledge of industrial technology students, in particular, for their future careers. This class does not cover all potential energy sources due to time and equipment limitations. Students showing an interest and who wished to accomplish energy projects enrolled in directed study courses. This class is offered as an elective course and is not in the current catalog, but was already a full class by the end of the first day of class registration. Several students attempted to register for this class but were not allowed because of equipment limitations in the laboratories. Several faculty members who are currently on the curriculum development committee hope to increase the number of energy related classes; under consideration is a change in the electronics degree program title to encompass alternative energy.

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Appendix: Major Parts & Equipment List for Each Student Project

- Skylight System
  - 13” Tubular Skylight (Prismatic Diffuser and Pitched)
  - Remote Controlled Dimmer, 13"
  - Light Pipe Elbow and Extension

- Photovoltaic System
  - KC65T 65W 12V Solar Panel with J-Box
  - Ground/Roof Fixed Tilt Legs

- 10-12 10A, 12V Light Controller
- BabyBox 4 Slot AC or DC Breaker Panel
- 6 Amp Din Rail Mount Breaker
- 20 Amp Din Rail Mount Breaker
- 8G24 12V, 73 AH (20HR) Sealed Gel Cell Battery
- 125W XP 125-12 12V Inverter
- 110A Fuse & Holder W/Set Screw Lug
- Vivid PAR 20 Floodlight (36 LEDs), AC & DC
- Solar Pathfinder with Case & Tripod
- Assistant Software (PV Only)
- LA302 DC Lightning Arrestor
- Voltage/Current DC Sensors Dual
- Irradiation Sensor
- Temperature Sensor

- Wind Power
  - Anemometer (Wind Meter)
  - Air Breeze Wind Turbine Land 200W 12V
  - 2-Position Stop Switch for Air Turbines
  - LA302 DC Lightning Arrestor
  - Analog Amp Meter Kit
  - BabyBox 4 Slot AC or DC Breaker Panel
  - 50 Amp Din Rail Mount Breaker
  - 63 Amp Din Rail Mount Breaker
  - 27FT Tilt-up Tower Kit for Air Turbines
  - Galvanized Augers for 27' Tower
  - 8A22NF 55 Ah (20 Hr) AGM Sealed Battery
  - Sdf CB50 50A Circuit Breaker
  - CBBOOT for 30A/50A Circuit Breaker
  - 12V 135AH (20HR) Sealed AGM Battery
  - SureSine Inverter SI-300-115
  - 110A Fuse & Holder W/Set Screw Lug

- Passive Solar Air Heating
  - 4", 5" 6" Combi Fan 270 CFM AC Powered
  - 1500GS Glazed Secondary Solar Air Heater (passive device)
  - Roof Flashing Alum. for Shingled Roofs
  - Collector Flush Mount -Tall Pads Style

- Passive Solar Water Heating
  - 2'X3' Sample Collector for Workshops
  - Standard Mount Kit for AE Series
  - D5/710B PV Circulating Pump- threaded
  - Kyocera KS10 10W 12V Solar Panel
  - 35-250F Thermometer
  - AET PV Mount

- 10 Gal. SS DB Tank w/ Heat Exchanger
- Whirlpool 15G Tank w/ Electric Element
- TACO 1/25 HP Cast Iron Pump, 0-14 GPM
- 3/4" Cast Iron Flanges
- Eagle II Data Port Adapter
- Eagle 2 Differential Temperature Control w/t Display
- 3/4" Boiler Drain
- Taco 1/40 HP Bronze Pump, 0-6 GPM
- GPM Flow Meter
- Air Vent, 150 PSI, 1/4" MPT
- 2.0 Gal Expansion Tank
- "MAXI-FLOW" Spring Check Valve, 3/4" SWT
- 150 PSI Pressure Relief Valve
- 3/4" 2-WAY Sweat Ball Valve
- 100 PSI Pressure Gauge 1/4" MPT

- Human Power Generator System
  - Bike Power Generator
  - Power Monitor
  - Electromate 400, 12V Power Pack
  - 10FT Connecting Cable – Diode Protected with Power Pack Connector
  - Low Rpm Permanent Magnet DC Generator
  - Power-Up Reverse Current Diode Assembly
  - 35A Power-Up Reverse Current Rectifier Bridge Assembly

- Hydrogen Fuel Cell System
  - Dr FuelCell™ Professional Complete
  - Solar Module
  - Electrolyzer
  - Fuel cells
  - Load Box
  - Display meters
  - Stopwatch, tubes and cables
  - 550 mm Panel Support Frame