

A Review of the Commercial Trainers and Experiment Kits for Teaching Renewable Energy Manufacturing

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Abstract

This paper summarizes the product information from the major suppliers of the commercial trainers and experiment kits that are used to teach renewable energy manufacturing. It serves as an informational resource for the universities, colleges and schools that are interested in finding their lab equipment from these suppliers.

Introduction

Both the U.S. and the world economies have long depended on nonrenewable fossil energy sources (coal, oil, and natural gas). Supplies of fossil energy are expected to decline in the future and become more expensive. Meanwhile, their use contributes to the accumulation of greenhouse gases in the atmosphere. Therefore, there is an urgent need for renewable energy sources [1].

Renewable energy manufacturing is considered a new worldwide industry. Renewable energy manufacturing is referred to as the process of converting one form of energy from a renewable source, such as sunlight, wind, or biomass, into another form of energy that consumers can use directly (for example, electricity or transportation fuel). Countries that make and sell more renewable energy will have a competitive advantage. Many countries are competing for leadership in renewable energy manufacturing. To enhance the global competitiveness of the U.S. in renewable energy manufacturing, there is a dramatic need for a skilled workforce that has been trained in the field [1].

To meet the workforce needs, more and more academic programs to study renewable energy are being formed [2]. In these programs, renewable energy lab exercises have become an essential part. Several educators have highlighted the importance of lab activities in teaching

renewable energy manufacturing. According to their observations, the students can better comprehend complex concepts and theories through a series of lab experiments and projects [3-8].

The authors of this paper did the research to find out what trainers and experiment kits are used by different universities to teach renewable energy manufacturing. It is found that the majority of the schools built their own equipment for labs and projects [4, 7-13]. Only a few schools used commercial lab equipment and experiment kits for their teaching [6, 14, 15].

The authors posted a question in March 2013 on the Engineering Technology Listserv (etd-1@listproc.tamu.edu) to seek more information on the trainers and experiment kits:

“We are looking for experimental kits that introduce renewable energy (such as wave, tide, geothermal, biomass energy) to the students. Could anyone share information with us on where we can find these kits? So far, we have found some experiment kits for wind and solar energy.”

The authors received dozens of responses from 18 higher education institutions, 4 equipment suppliers and 5 related individuals. A lot of repliers expressed the same interest as the authors did. These communications clearly indicated that the public domain needs a comprehensive informational reference to the commercial educational trainers and experiment kits in the renewable energy manufacturing areas.

To satisfy the needs of the public domain, this paper collects the product information from all the major suppliers of the commercial trainers and experiment kits that are used to teach renewable energy manufacturing. The authors hope that these trainers and experiment kits can be used by the universities and colleges to help their students more effectively obtain the professional skills in problem identification, engineering design, hands-on experience, team management, communication and documentation, and social and environmental impact assessment.

Solar Energy Trainers

The major providers of the solar energy experiment equipment are

- EDIBON (<http://www.edibon.com>)
- Lab-Volt (<http://www.labvolt.com/>)
- De Lorenzo (http://www.delorenzoenergy.com/products_energia.html)
- Hampden (<http://www.hampden.com>)

EDIBON Equipment

- Computer-controlled photovoltaic solar energy unit: It is a computer-controlled unit to study the transformation of solar energy into electric energy. This unit uses the photo conversion solar system for the direct conversion of solar radiation into electricity. (<http://www.edibon.com/products/?area=energy&subarea=alternativeenergies/>)

- Photovoltaic solar energy modular trainers: It is designed for the theoretical and practical study of the electrical installations with photovoltaic solar energy.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/MINI-EESF.pdf>)
- Computer-controlled thermal solar energy unit: This unit transforms solar energy into calorific energy.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EESTC.pdf>)

Lab-Volt Trainers

- Solar thermal energy training system: It is a solar hot water heating system.
(<http://www.labvolt.com/products/alternative-and-renewable-energy/solar-energy/solar-thermal-energy-training-system>)
- Solar power technology training system: It is designed to study the production of electrical energy from solar power. (<http://www.labvolt.com/products/alternative-and-renewable-energy/solar-energy/solar-power-technology-training-system-8805>)

De Lorenzo Trainers

- Photovoltaic solar energy trainer: The equipment is for the theoretical and practical study of photovoltaic solar energy facilities.
(http://www.delorenzoenergy.com/sheets_en/DL%20SOLAR-A%20ENG.pdf)
- Solar energy modular trainer: This modular trainer is for the theoretical and practical study of the electrical installations with photovoltaic solar energy.
(http://www.delorenzoenergy.com/sheets_en/DL%20SOLAR-B%20ENG.pdf)
- Photovoltaic solar energy trainer: This trainer is for the theoretical and practical study of the applications of the photovoltaic solar energy in a house.
(http://www.delorenzoenergy.com/sheets_en/DL%20SOLAR-C%20ENG.pdf)
- Photovoltaic solar energy trainer for connection to mains: It studies the generation of electrical energy and its connection to the mains network.
(http://www.delorenzoenergy.com/products_solare_en.html)
- Photovoltaic and thermal panel simulator: It performs the experiments and troubleshooting on photovoltaic cells in series and in parallel and thermal panels with liquid circulation.
(http://www.delorenzoenergy.com/sheets_en/DL%20TM11%20ENG.pdf)

- System for the study of photovoltaic solar energy: The system is composed of a set of electronic sub-boards for basic experiences on solar photovoltaic cells.
(http://www.delorenzoenergy.com/sheets_en/DL%203155BRS%20ENG%20photovoltaic.pdf)
- Solar thermal energy trainer: This trainer is for the study of thermal solar energy with heat exchanger and water storage tank. The solar energy is simulated by means of a panel provided with electric resistance.
(http://www.delorenzoenergy.com/sheets_en/DL%20THERMO-A1%20ENG.pdf)

Hampden Trainers

- Solar photovoltaic trainer: The trainer demonstrates the electrical characteristics of the solar array, storage battery, AC/DC distribution, and AC/DC loading.
(<http://www.hampden.com/tortoisecms/uploads/files/Alternative%20Energy.pdf>)
- Solar system trainer: The trainer is a solar hot water heating system.
(<http://www.hampden.com/tortoisecms/uploads/files/Alternative%20Energy.pdf>)

Wind Energy Trainers

The suppliers include

- Quanser (<http://www.quanser.com>)
- EDIBON (<http://www.edibon.com>)
- Lab-Volt (<http://www.labvolt.com>)
- De Lorenzo (http://www.delorenzoenergy.com/products_energia.html)
- Hampden (<http://www.hampden.com/>)

Quanser Wind Turbine

This wind turbine consists of a wind blower inside a wind tunnel.

EDIBON Wind Energy Trainers

- Computer-controlled wind energy unit: This is a laboratory-scale unit designed to study the wind energy and the influence of some factors on this generation.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EEEC.pdf>)
- Computer-controlled wind energy basic unit: This unit is a small-scale unit and is designed to study the wind energy and the influence of some factors on this generation.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/MINI-EEEC.pdf>)

Lab-Volt Trainers

- Wind farm simulation software: It simulates the behavior of every aspect of the wind turbines in a wind farm. (<http://www.labvolt.com/products/alternative-and-renewable-energy/wind/wind-farm-simulation-software-46128>)
- Wind power systems: It is an interactive program for technicians in the systems of wind power generation. (<http://www.labvolt.com/products/alternative-and-renewable-energy/wind/wind-power-systems-46127#>)
- Wind power training system: This unit studies the complete process of wind power generation right in the classroom. (<http://www.labvolt.com/products/alternative-and-renewable-energy/alternative-and-renewable-energy/wind-power-training-system-8010-3>)
- Wind power technology equipment: It is designed to introduce students to the small-scale production of electrical energy from wind power. (<http://www.labvolt.com/products/alternative-and-renewable-energy/wind/wind-power-technology-8216-86618-86630>)
- Nacelle training system: This system offers hands-on training for real-world operation and maintenance situations. (<http://www.labvolt.com/products/alternative-and-renewable-energy/wind/wind-turbine-nacelle-training-system-46122>)

De Lorenzo Trainers

- Wind tunnel: This trainer is for the theoretical and practical study of the generation of electricity by means of wind power. (http://www.delorenzoenergy.com/sheets_en/DL%20WIND-B%20ENG.pdf)
- Wind energy modular trainer for indoor use: This trainer includes a set of control and application modules, such as inverter, battery, loads, etc., and a DC motor to use the system without wind (http://www.delorenzoenergy.com/sheets_en/DL%20WIND-A1%20ENG.pdf)

Hampden Trainers

- Wind power generator: This trainer has been designed to provide the student with the basic understanding of how wind generator function as an alternate source of energy. (<http://www.hampden.com/tortoisecms/uploads/files/Alternative%20Energy.pdf>)
- Wind turbine (<http://www.hampden.com/tortoisecms/uploads/files/Alternative%20Energy.pdf>)

Fuel Cell Trainers

The suppliers include

- Lab-Volt (<http://www.labvolt.com>)
- Heliocentris (<http://www.heliocentris.com/>)
- EDIBON (<http://www.edibon.com>)
- Shatz Energy Research Center (<http://www.schatzlab.org/>)
- De Lorenzo (http://www.delorenzoenergy.com/products_energia_en.html)
- Hampden (<http://www.hampden.com/>)

Lab-Volt Trainers

- Hydrogen fuel cell training system: This trainer is designed in a modular format to integrate with the existing systems. (<http://www.labvolt.com/products/alternative-and-renewable-energy/energy-efficiency/hydrogen-fuel-cell-training-system-8010-80>)

Heliocentris Trainers

- 50-W fuel cell training system: This trainer introduces the operating principle of a fuel cell system, thermodynamics, characteristic curves and efficiency ratings, system and power electronics. (<http://www.heliocentris.com/en/academia-offering/products/training-systems/fuel-cell-trainer/overview.html>)
- 1.2-kW fuel cell training system for system dimensioning and hybridization: Students can design and simulate fuel cell energy systems towards specific load profiles on the basis of the system's industrial components. (<http://www.heliocentris.com/academia-angebot/produkte/trainingssysteme/nexa-training-system/uebersicht.html>)

EDIBON Trainers

- Computer-controlled PEM fuel cell advanced unit: This unit has been designed to allow the students to understand the fuel cells technology especially that of a proton exchange membrane fuel cell (PEM). (<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EC6C.pdf>)

Shatz Energy Research Center Trainer

- Fuel cell test station: The test station allows the students to gain hands-on experience in testing proton exchange membrane (PEM) fuel cell stacks. (<http://www.schatzlab.org/projects/hydrogen/masdar.html>)

De Lorenzo Trainers

- Trainer for experiences on hydrogen fuel cells: The trainer includes: PEM fuel cell stack, electrolyser, monitoring software, hydrogen storage tank, lamp, fan and solar module. (http://www.delorenzoenergy.com/sheets_en/DL%20HYDROGEN-A%20english.pdf)

- Fuel cells systems trainer: This system is designed for the study of fuel cell systems. It teaches engineering principles and it allows performing a set of experiments. (http://www.delorenzoenergy.com/sheets_en/DL%20HYDROGEN-B%20ENG.pdf)

Hampden Trainers

- Fuel cell technology trainer: This trainer allows the student to create a grid independent power supply that uses only hydrogen as the fuel. (<http://www.hampden.com/tortoisecms/uploads/files/Alternative%20Energy.pdf>)

Solar/Wind/Fuel Cell Hybrid Trainers

Some companies provide hybrid trainers in which solar, wind and fuel cell energies are incorporated together. These companies include

- Heliocentris (<http://www.heliocentris.com/>)
- Lab-Volt (<http://www.labvolt.com>)
- De Lorenzo (http://www.delorenzoenergy.com/products_energia_en.html)
- Horizon (http://www.horizonfuelcell.com/contact_us.htm)
- Hampden (<http://www.hampden.com/>)

Heliocentris Trainers

- Training system for solar hydrogen production: The system enables complete balancing of the solar/hydrogen generation. (<http://www.heliocentris.com/academia-angebot/produkte/trainingssysteme/solar-hydrogen-extension/uebersicht.html>)
- Hybrid energy training lab for experiments related to energy management: The off-grid hybrid system allows studying each technology individually or in combined set-ups. (<http://www.heliocentris.com/academia-angebot/produkte/labore-fuer-erneuerbare-energien/new-energy-lab.html>)
- Training and demonstration unit for solar and hydrogen technology: It resembles a complete solar/hydrogen cycle. (<http://www.heliocentris.com/academia-angebot/produkte/schulprodukte/professional/uebersicht.html>)

Lab-Volt Hybrid Trainers

- Solar/wind energy training system: It consists of a wind turbine generator powered by DC motor drive without turbine blades, for classroom safety. (<http://www.labvolt.com/products/alternative-and-renewable-energy/solarwind-energy/solarwind-energy-training-system>)

De Lorenzo Hybrid Trainers

- Solar-wind-fuel cells energy trainer: It is for the study of renewable energy, solar energy, wind energy and hydrogen fuel cells.
(http://www.delorenzoenergy.com/sheets_en/DL%20GREENKIT%20ENG.pdf)
- Solar/wind energy modular trainer: It includes a set of modules for practical exercises for the theoretical and practical study of a hybrid system with solar energy and wind energy.
(http://www.delorenzoenergy.com/sheets_en/DL%20SUN-WIND%20ENG.pdf)
- System with master-slave inverters: This trainer is for the study of a solar-wind energy system where one of the two inverters, operating as master, synchronizes the frequency of the second inverter. (http://www.delorenzoenergy.com/sheets_en/DL%20SUN-WIND2%20ENG.pdf)

Horizon Hybrid Trainers

- Zero carbon panel: This H₂/air and H₂/O₂ fuel cell system includes modular panels.
(<http://www.horizonfuelcell.com/educationcatalog2013/educationcatalog2013.html>)

Low Enthalpy Geothermal Energy Trainers

The major suppliers for low enthalpy (low temperature and low pressure) energy trainers include

- Lab-Volt (<http://www.labvolt.com>)
- EDIBON (<http://www.edibon.com>)

Lab-Volt Trainers

- Geothermal training system: This system is designed to teach the fundamentals of heat transfer, refrigeration, and air conditioning applied to geothermal energy HVAC projects.
(<http://www.labvolt.com/products/alternative-and-renewable-energy>)

EDIBON Trainers

- Computer-controlled geothermal (low enthalpy) energy unit: This unit introduces how to use the geothermal energy control to the climate of the buildings.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/SCE.pdf>)

Bio-Fuel Trainers

The major suppliers of the bio-fuel trainers include

- EDIBON (<http://www.edibon.com>)
- De Lorenzo (http://www.delorenzoenergy.com/products_energia_en.html)

EDIBON Bio-Fuel Trainers

- Computer-controlled biogas process unit: This unit is designed to study the different processes given during the biogas generation through anaerobic breakdown, as well as to study the different parameters that affect the anaerobic digestion and the value of the obtained biogas.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EBGC.pdf>)
- Computer-controlled biodiesel process unit: It is a unit which allows the study of the biodiesel production cycle different stages.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EBDC.pdf>)
- Computer-controlled bioethanol process unit: This unit is designed to study and control the process of bioethanol.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EBEC.pdf>)
- Computer-controlled biomass process unit: The main objective of this unit is to study the biomass process for heating applications, using different types of biomass fuels such as pellets and wood chips.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EBMC.pdf>)

De Lorenzo Bio-Fuel Trainers

- Biodiesel plant: This unit undertakes a chemical process of transesterification with methanol. It produces biodiesel which is a vegetable oil or animal fat based diesel fuel.
(http://www.delorenzoenergy.com/sheets_en/delord_biodiesel_low.pdf)
- Bio-ethanol plant: This trainer is for the production of bio-ethanol from sugar cane or, optionally, from tubers (sweet sorghum, manioc, potatoes, rice or corn).
(http://www.delorenzoenergy.com/sheets_en/DL%20ETAL-15%20Bio-Ethanol%20Pilot%20Plant%20-ENG.pdf)

Wave, Tide And Hydro Trainers

The major suppliers include

- EDIBON (<http://www.edibon.com>)

EDIBON Trainers

- Computer-controlled waves energy unit: The unit is mainly formed by rectangular transparent tank, to be filled with water, where the different energy generation modules will be placed.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EOMC.pdf>)
- Generating stations control and regulation simulator: This unit is designed to simulate the regulation behavior of a hydroelectric generating station, as a didactic application with different aspects of regulation, control and simulation.
(<http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/SCE.pdf>)

Smart Grid Training Systems

The major suppliers include

- Lab-Volt (<http://www.labvolt.com>)

Lab-Volt Training Systems

- Smart grid technologies training system: It combines Lab-Volt's modular design approach with computer-based data acquisition and control to provide unrivaled training in smart grid technologies. (http://www.labvolt.com/downloads/datasheet/dsa8010_C.pdf)
- Grid-Tied training system: It provides hands-on training in developing the skills required for installing a grid-tied system. (<http://www.labvolt.com/products/alternative-and-renewable-energy/solarwind-energy/grid-tie-training-system-46125>)

Experiment Kits

There are quite a few suppliers for the experiment kits. These companies provide inexpensive kits that use solar, wind, hydro, bio-fuel and fuel cell energies. The companies listed below are the ones appeared in the literature the authors have reviewed or in the feedback from the ETD list-serv. The products provided by these suppliers are very diverse.

- Heliocentris (<http://www.heliocentris.com/>)
 - Students science kit for solar hydrogen technology
(<http://www.heliocentris.com/academia-angebot/produkte/schulprodukte/science-kit/uebersicht.html>)
 - Model car with reversible fuel cell (<http://www.heliocentris.com/academia-angebot/produkte/schulprodukte/model-car/uebersicht.html>)
 - Experiment set for energy generation, storage and supply
(<http://www.heliocentris.com/academia-angebot/produkte/trainingssysteme/clean-energy-trainer/uebersicht.html>)
- Lab-Volt (www.labvolt.com)

- GREENtech Energy Efficiency & Renewable Energy Training Lab (<http://www.labvolt.com/products/alternative-and-renewable-energy/solar-energy/graymark-greentech>)
- Kid Wind (<http://learn.kidwind.org/>)
 - Wind kits (<http://store.kidwind.org/solar-kits/solar-electric-kits/solar-car>)
 - Solar Boat Science Kit (<http://store.kidwind.org/solar-kits>)
 - Advanced wind experiment kit (<http://store.kidwind.org/wind-energy-kits/complete-kits/advanced-wind-experiment-kit>)
 - Kid Wind Science fair wind project (<http://store.kidwind.org/wind-energy-kits/complete-kits/science-fair-wind-project>)
 - MudWatt microbial fuel cell kit (<http://store.kidwind.org/more-kits/miscellaneous/mudwatt-microbial-fuel-cell-kit>)
 - Hydro power wheel
- PITSCO Education (www.pitsco.com)
 - Solar car, wind turbine, solar panel/hydrogen fuel cell
- PASCO (<http://www.pasco.com/home.cfm>)
 - Hydro accessory (http://www.pasco.com/prodCatalog/ET/ET-8772_energy-transfer-hydro-accessory/)
- Horizon (<http://www.horizonfuelcell.com/#>)
 - Ethanol fuel cell (<http://www.horizonfuelcell.com/educationcatalog2013/educationcatalog2013.html>)
 - Fuel cell storage, super capacitor (<http://www.horizonfuelcell.com/educationcatalog2013/educationcatalog2013.html>)
- Fuel cell store (<http://www.fuelcellstore.com/en/pc/home.asp>)
 - Tutorial HyRunner (<http://www.fuelcellstore.com/en/pc/viewPrd.asp?idproduct=1253>)
- Shop4ScienceKits.com (<http://www.shop4sciencekits.com/>)
 - Wind, solar, hydro, fuel cell energies (<http://www.shop4sciencekits.com/alternative-energy-and-environmental-science.htm#TK623913>)
- Eastern Kentucky University, Center for Renewable and Alternative Fuel Technologies (<http://www.craft.eku.edu/BEAM>)
 - Bio-Energy Activity Module
- Kelvin Educational (<http://www.kelvin.com/>)
 - Wind tunnel, solar, fuel cell (<http://www.kelvin.com/catpdfs.html>)

Conclusions and Future Research

This paper identifies the major suppliers of the commercially available trainers and experiment kits for teaching renewable energy manufacturing. The major product lines of these suppliers are presented. It can be seen that most of the trainers and experiment kits focus on the study of solar, wind, low enthalpy geothermal, bio-fuel, hydrogen fuel cell energies, and smart grid technologies. The option for wave and tide energy trainers is quite limited. The trainers for high enthalpy geothermal energy have not been found (even though EDIBON claimed that they had the design available). Among these commercial trainers and experiment kits, many products have the following distinct features:

- They have more sophisticated control systems for better reading and analysis.
- They have pre-designed lab assignments, thus saving the instructors a lot of time in lab preparation.
- They are made according to the industrial standards, thus they are safer and more reliable to use.

In the future research, the authors will focus on the comparison of the equipment they have included in this paper. Analysis will be made on the costs, technical specifications, operation performances, product warranty, advantages, disadvantages, and training options.

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