Developing a New Graduate Program in Sustainable Energy Engineering

Linfeng Zhang, Xingguo Xiong, Junling Hu

Department of Electrical Engineering
Department of Mechanical Engineering
University of Bridgeport, Bridgeport, CT 06604

Abstract

The world energy demand keeps increasing in recent years due to the rapidly rising living standards and expanding populations. However, the non-renewable energy resource, fossil fuels, is running out and the crude oil supply from Middle East is unstable. To meet the energy demand and improve the energy security, developing sustainable energy, such as solar, wind, tide, geothermal, biomass energy, is a solution to this most urgent energy problems. Therefore, the rapidly increasing nationwide demand for well-qualified professionals in the sustainable energy can be predicted. In order to educate and prepare the technical and scientific workforce for the emerging sustainable energy technology, the School of Engineering at University of Bridgeport (UB) is preparing the M.S. Sustainable Energy Engineering program. In this paper, the structure of the curriculum and the course design in this program will be presented in more details.

1. Introduction

The crude oil price fluctuated dramatically in 2008 as shown in Figure 1 and all of us suffered from the high gas price. This crisis is hard to be explained with the demand and supply. Till to 2030, fossil fuels, including oil, coal, and natural gas, provide roughly 86 percent share of the total U.S. primary energy supply. However, the energy security is a big problem. Moreover, the using of fossil fuels causes air pollution and global warming with the accumulation of greenhouse gasses. To meet the energy demand, improve the energy security, and protect our environment, developing alternative or sustainable energy, such as solar, wind, tide, geothermal, biomass energy, is a promising solution.

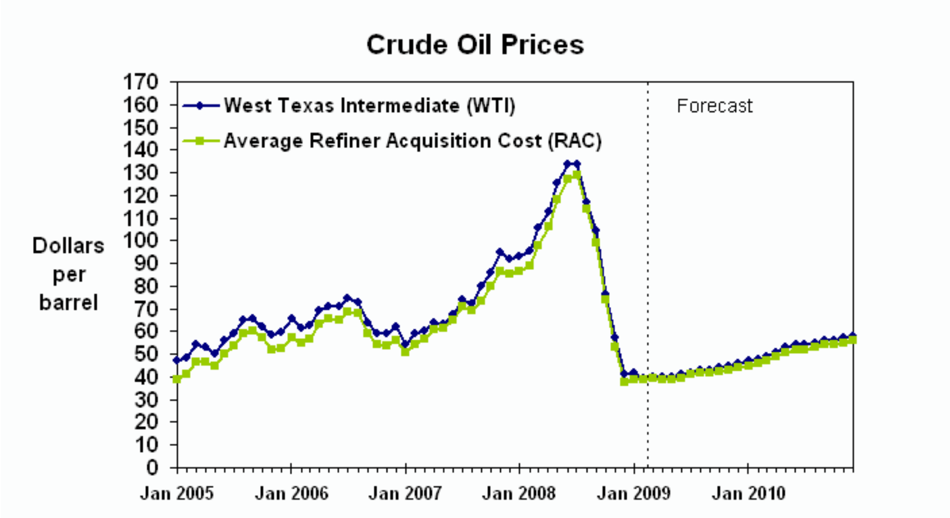


Figure 1 Crude oil price fluctuates from 2005 to 2010

In U.S., the energy consumption increases around 25% from 1970 to 2008 and the import energy resource increases proportionally due to the constant energy resource production as shown in Figure 2. Electricity from sustainable energy resources (excluding hydropower) have nearly doubled since 2000 as shown in Figure 3 (a). Wind grew 45% and solar (photovoltaic cells) PV grew 40% in 2007 from the previous year as shown in Figure 3 (b). Both of them are the fastest growing renewable energy sectors. However, electricity from sustainable energy resources (excluding hydropower) in 2007 still represents a small percentage of overall installed electricity capacity (3%) and generation (2.5%) in the U.S. as shown in Figure 2 (b).

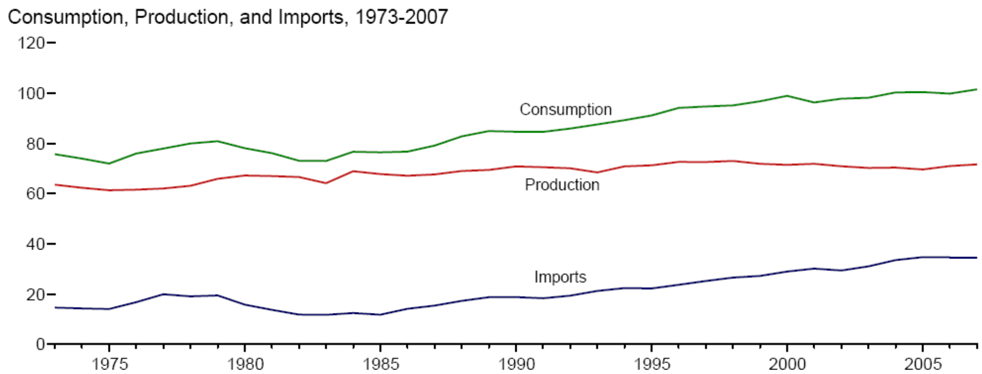
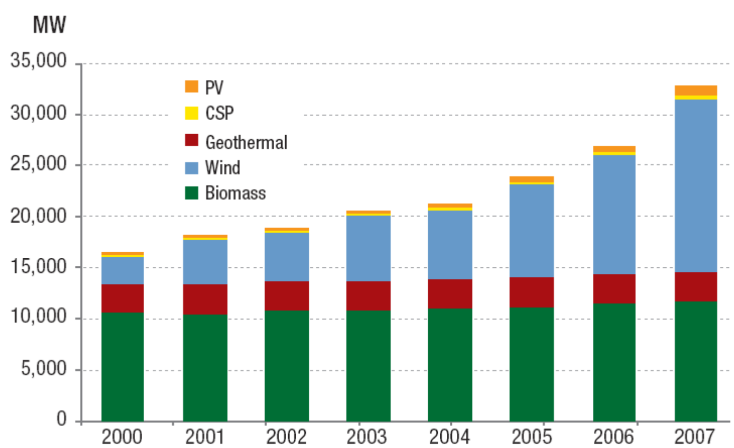
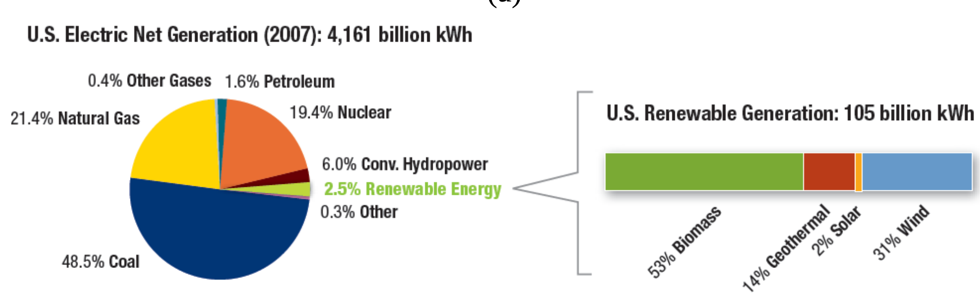


Figure 2 US Primary Energy Overview (Quadrillion Btu)[2]



(a)



(b)

Figure 3 sustainable energy overview (a) and the energy resources distribution in 2007 (b)[3]

To reduce national consumption of energy and to encourage a wide range of alternative energy sources, President Obama voted in favor of the Energy Policy Act of 2005, proposed a New Energy for America plan, and signed American Recovery and Reinvestment Act (ARRA). The key points in these policies are as following:

- Reduce the overall U.S. oil consumption by at least 35%, or 10 million barrels per day, by 2030 in order to offset imports from OPEC nations.
- Help create five million new jobs by strategically investing $150 billion over the next ten years to catalyze private efforts to build a clean energy future.
- Ensure 10 percent of our electricity comes from renewable sources by 2012, and 25 percent by 2025.
- Implement an economy-wide cap-and-trade program to reduce greenhouse gas emissions 80 percent by 2050[4].

Based on the above federal policies, U.S Renewable Energy (RE) and Energy Efficiency (EE) industries could generate over 37 million jobs per year by 2030 although RE&EE created only over 9 million jobs in 2007[5]. In order to educate and prepare enough technical and scientific workforce, education in alternative or sustainable energy is more and more important[6].

2. Education in alternative or sustainable energy

It is much more obvious that the knowledge in alternative or sustainable energy is essential to the engineering students and the nationwide demand for well-qualified professionals in the alternative energy rapidly increases. However, there are only two U.S. universities providing independent graduate programs in this area and neither of them is in Connecticut. In order to prepare the technical and scientific workforce in this field, the School of Engineering at UB is preparing the licensure application material for M.S. Sustainable Energy Engineering (SEE) program. The SEE degree certifies that knowledge has been gained in the Sustainable Energy Engineering discipline. Graduates will combine knowledge of energy with engineering principles to produce solutions and innovations in sustainable energy generation and utilization. In addition, program graduates will have critical thinking skills for producing scholarship in the SEE area, showing enterprise in engineering work, and communicating with proficiency about issues related to the SEE area.

Table 1 is the structure of the curriculum and this curriculum ensures that graduating students have breadth in SEE-related disciplines and depth in one of two tracks. Students take two required courses (Advanced Mathematics and Solid State Electronic Devices) to acquire knowledge of fundamental scientific and engineering principles. The program has two tracks as shown in Table 3: (1) Sustainable Energy Generation, (2) Sustainable Energy Utilization. Students take at least four courses in one of the tracks to acquire depth in that area. A plan of work from each student should be approved in the first semester.

In the M.S. program, a Master student must complete 30 credits hours of graduate level (500-level) course work, including a master project or a thesis. The structure of the curriculum is shown in Table 2 with the following requirements in the study:

- Successfully complete Advanced Mathematics and Solid State Electronic Devices;
- Successfully complete Thermodynamics, Applied Electrochemistry for the Sustainable Energy Generation track;
- Successfully complete four courses in one SEE track;
- Successfully complete at least one courses in another SEE track;
- Successfully complete a project (3 credit hours) or complete and successfully defend a thesis (6 credit hours).

Table 1 The structure of the curriculum

Basics	
Sustainable energy generation	Sustainable energy utilization
Project or Thesis	

Table 2 List of representative courses

Basics
Advanced Mathematics
Solid state electronic devices
Thermodynamics
Applied Electrochemistry

Sustainable energy generation track	**Sustainable energy utilization track**
Alternative (Sustainable) Energy Technology	Hybrid System Fundamentals
Fundamentals of Photovoltaic Cell	Electrical Power System
Sustainable Energy Lab	Power Electronics
Biofuel	Power Electronics Lab
Nuclear power	Mass and Heat Transfer
	System Integration and Optimization
	Advanced Controls
	Energy Storage

Besides the education, the SEE master's degree program will create opportunities for faculty-student research and grant-seeking. Recognizing the importance of sustainable energy, the NSF and DOE will be the most important funding sources. These efforts will be supported by additional faculty in SEE, expanded physical space, and student enrollment in the program. The licensure application for this program will take around one and half year and this program will start in Spring, 2010.

Sustainable Energy Lab

To obtain some hand-on experience, a sustainable energy lab is quite helpful. Currently, hydrogen fuel cells, potentiostat, impedance analyzer are available for the students to characterize the power devices and understand the effects of the operating conditions on the device performance. There are also some PCs with Labview/Matlab and data acquisition boards for the course project design.

Course project and student contest

There usually are two design projects and the students can integrate their knowledge in alternative energy and in engineering to solve a real problem. The projects are developed on our platform, a new greenhouse, implemented through Matlab Simulink. Here is a general description of this platform:

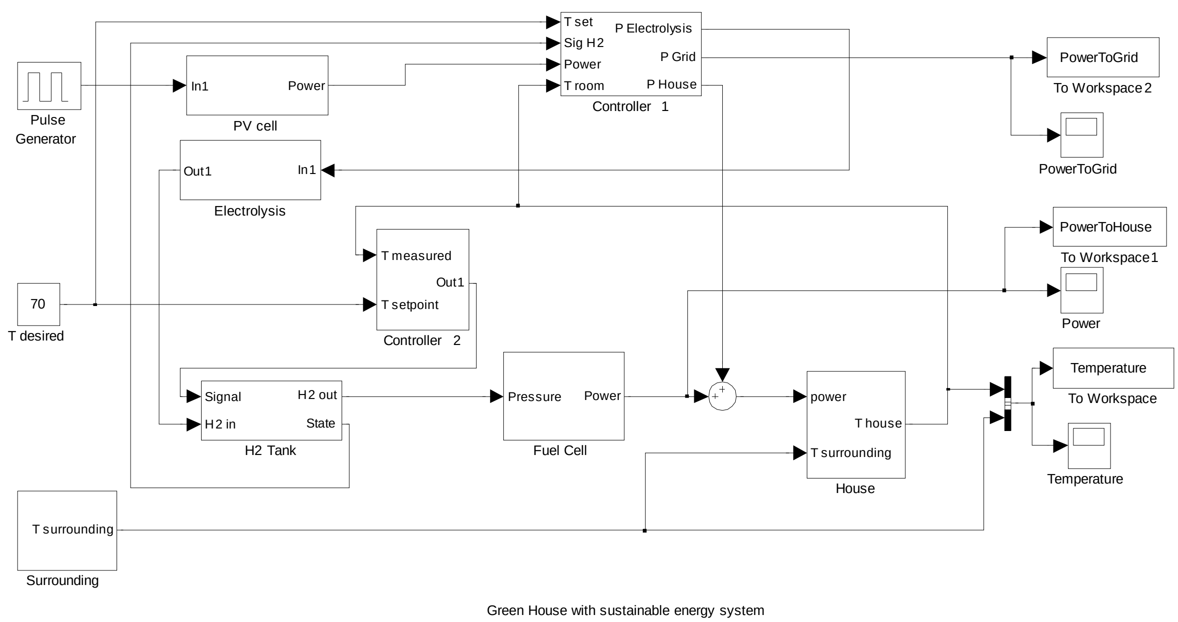


Figure 4 The block diagram of the power system for a green house

To maintain the greenhouse temperature, power is supplied from a hydrogen fuel cell (FC) system and a photovoltaic (PV) cell system. These two systems are inter-related: some power from the PV system is used to produce hydrogen for the fuel cell system through water electrolysis. Moreover, several nonlinear feedback controllers are used for the process control. The design includes four subsystems: house, fuel cell/PV cell, controllers, and surrounding temperature, as shown in Figure 3.

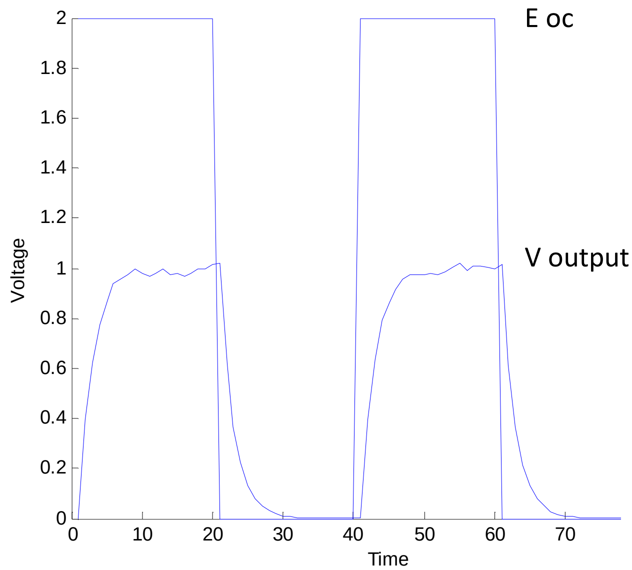
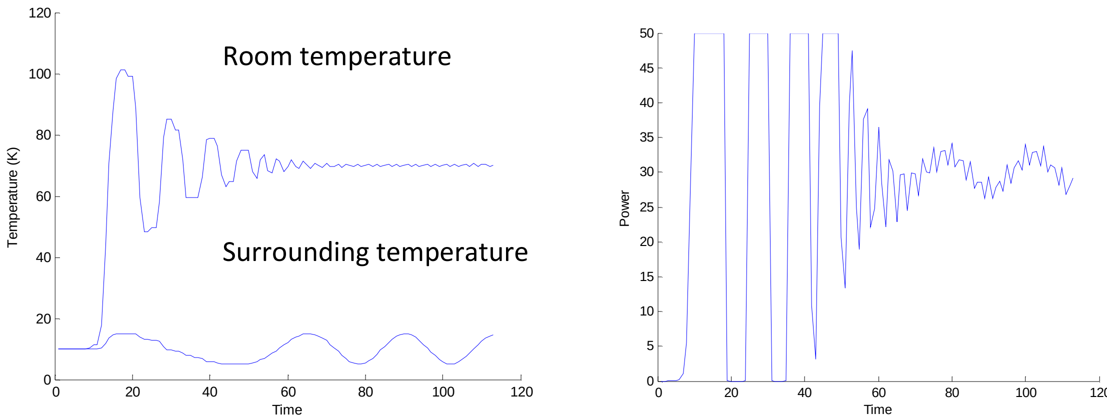


Figure 5 The output voltage from fuel cell system



(a) (b)

Figure 6 The room temperature and the surrounding temperature (a) vs. time.
The power supplied from fuel cell system (b) vs. time.

The course projects can be the implementation of one subsystem in the above greenhouse platform. For example, the output voltage of a fuel cell subsystem can be simulated with the consideration of different overvoltages and double charge layer on the surface of the electrodes as shown in Figure 4. Similarly, other energy sources, such as PV cell system, can be simulated as other subsystems. Finally, the whole power system of a green house can be simulated and the preliminary results are shown in Figure 5. In the future, a optimal design for the best performance/cost ratio will be investigated with the commercial FC and PV cell systems.

Besides the above course projects, students are encouraged to participate the annual hydrogen student design contest sponsored by National Hydrogen Association

3. Conclusions

This paper discussed the design and implementation of the graduate course, Alternative Energy Technology, in the Department of Electrical Engineering at University of Bridgeport. The paper provides the contents of the course in details: topics, references, and projects. The experience presented is quite helpful for the licensure application for M.S. SEE program. The results of the course are encouraging and the feedback from the students is analyzed to improve the teaching.