An Engineering Elective on Energy Resources

Shih-Liang (Sid) Wang [1]

Abstract – The energy sector in the past several years has gone through transformative changes and the implications are huge. According to a recent IEA (International Energy Agency) report, America could become the world's largest oil producer by 2020, outstripping Saudi Arabia and Russia. It could also be more or less self-sufficient in energy by 2035. To prepare our students for jobs in the energy sector during these transformative changes and equip them with energy literacy and numeracy, the author is offering an engineering elective covering renewable energy, nuclear power, and fossil fuels.

The objective of this course is to introduce fundamental principles of various energy options as we face climate change and other environmental impact, and to develop an appreciation of the energy challenges that confront our present and future generations. Although several textbooks are useful as references to this course, additional resources are needed to make the course contents contemporary and relevant. This paper reports the author's effort in preparing course materials for this course. The course was offered in Spring 2012 as a special topics course with an enrollment of 17 students. Student surveys are very positive and the course will be offered in the future.

Keywords: Energy, Nuclear, Renewable Energy,

INTRODUCTION

While the production of natural gas and oil in the United States has significantly increased in the past few years, concerns about environmental impact of burning fossil fuels and climate change (especially after super storm Sandy) has prompted a critical review of all energy options. Green energy (especially wind and solar) has made significant progress in recent years but cannot replace fossil fuel or nuclear for base-load power generation. After the Fukushima nuclear disaster, many countries abandoned nuclear energy. However, nuclear is still an option for large-scale base-load electricity generation without greenhouse gas emission.

At this disorderly time, the author is preparing an engineering elective on energy options to provide students with a technological foundation and economic fundamentals of different options. The course will review the history of energy resources and usage, and will outline the science, technology and economics of each option. A premise of the course is that a sustainable energy technology must be technically feasible, economically viable, and environmentally responsible. The course will examine various energy options, including solar, wind, biomass, oceanic, geothermal, hydropower, fuel cell, nuclear, oil, gas, and coal. Technological progress of each option will be reviewed, along with economic opportunities and challenges.

The objective of this course is to introduce fundamental principles of the various energy options as we face climate change and other environmental impact, and to develop an appreciation of the energy challenges that confront our present and future generations. Although several textbooks are useful as references to this course, additional resources are needed to make the course contents contemporary and relevant. This paper is to report the author's effort in preparing course materials for this course.

[1] Department of Mechanical Engineering, North Carolina A&T State University, Greensboro, North Carolina 27411, wang@ncat.edu

OVERVIEW

Energy and environmental issues are constantly grabbing headlines: climate change and extreme weather, fossil fuel burning and greenhouse gas emissions, water pollution of hydraulic fracturing of shale gas, BP oil leak, Fukushima nuclear accident, Keystone pipeline for Canadian tar sand oil, and recent bankruptcy filings of two American solar companies: Silicon Valley's Solyndra and Evergreen Solar of Massachusetts. While these headlines are getting our attentions on safety, environmental impact, and commercial viability of renewable energy, the energy sector (oil and gas companies, utilities, and equipment manufactures) is actively recruiting our students. This course is intended to prepare our students with energy literacy and numeracy, and prepare those who want to seek jobs in the energy sector.

This course intends to provide scientific and engineering backgrounds of these energy systems. The course will address the present status of conventional fossil fuels and nuclear power. These systems, along with hydropower and traditional biofuels, currently supply the majority of the world's commercial energy.

Concerns over non-renewable energy resources have spurred research and development in renewable energy. With tax credits and subsidies, wind and solar energy are being rapidly deployed. However, the intermittent nature of renewable energy prevents its large-scale adoption, as the storage and transmission issues are not resolved yet. This course will provide our students with a background necessary for the transition to the future.

In the aftermath of Fukushima accident, nuclear safety becomes a big concern. Japan is reconsidering its nuclear policy, while Germany and Switzerland are phasing out nuclear energy. However, nuclear energy accounts for about 20 percent of electricity generation in the United States and 14 percent of the world’s electricity, and nuclear will be in the energy mix for the foreseeable future. In this course, different types of light water reactors will be addressed and safety of nuclear power will be discussed through major accidents – Three Mile Island, Chernobyl, and Fukushima.

COURSE OBJECTIVES

The subject of energy and sustainability is multifaceted and interdisciplinary, involving engineering, applied sciences (physics, chemistry, biology, and geology), economics, and public policy. This course intends to give an introductory account of the present world energy situation with basic energy concepts and human energy needs. Energy supply from various resources is studied and analyzed as we face climate change and other environmental issues. It is intended that students will develop a better understanding of the energy challenges that confront our present and future generations.

COURSE DESCRIPTION

The course introduces the basic concepts, principles, potentials and limitations of various energy sources, including fossil fuels, nuclear power, and renewable energy. The course will cover how that energy is supplied, the anticipated global growth in energy demand, the resource availability, and meeting that demand in a sustainable way. Basic characteristics energy storage systems and smart grids will also be addressed.

COURSE OUTLINE

I. Overview

- Energy and Environment
  - Energy demand and population growth
  - Greenhouse gases and climate change
  - Renewable and non-renewable energy
- Energy Conversion
  - Thermodynamics: first and second laws, Rankine cycle and steam turbine
  - Brayton cycle and gas turbine
- Electricity
  - Generation, transmission, distribution, and smart grid

  - Base-load and peaking power plants

II. Fossil fuels

- Coal
  - Types, sources, mining, and reserves
  - Coal-fired power plants and environmental impacts
- Oil
  - Geology, history, exploration and production
  - Oil refineries
  - Oil sand and shale oil
  - Deep sea exploration and oil spills
- Natural Gas
  - Geology, history, exploration and production
  - Shale gas
  - Gas turbines and combined cycle

III. Nuclear

- Nuclear Energy
  - Fission and light water reactors
  - Nuclear safety and major accidents
  - Nuclear fuel and waste

IV. Renewable

- Solar Energy
  - Sun path and insolation
  - Photovoltaic systems
  - Concentrated solar power systems
- Wind Energy
  - Wind resources, turbines, and electricity generation
  - Offshore wind farms
- Hydroelectricity
  - History, resources, and hydroturbines
  - Dams, reservoirs, and pumped storage
- Geothermal:
  - Resources
  - Types of power plants
- Biomass
  - Ethanol
  - Waste to energy
  - Biodiesel
- Tidal and Wave Power:
  - Physics and resources
  - Energy conversion devices
- Energy Storage and Transmission
  - Batteries, super-capacitors, and flywheels
  - Compressed Air Energy Storage (CAES)

TEXTBOOKS AND REFERENCES

As the author intends to cover the comprehensive subjects with enough technical depths and up-to-date information like shale gas, oil sand, nuclear disaster, wind and solar energy, it becomes obvious that an ideal textbook is not there. Therefore the author decides to use several books [1, 2, 3, 4, 5, and 6] as references, and supplement these books with additional resources.

Supplementary resources are mostly on-line documentations. Energy Explained, by U.S. Energy Information Administration [7] has good explanation on energy fundamentals with important statistics. Energy Topic Guides from New York Times and its Green blog [8] contain the following tabs: Biofuels, Tidal & Wave, Natural Gas, Geothermal, Hydro, Nuclear, Coal, Oil, Solar, and Wind. Likewise, the Guarding has an Energy page [9] containing the following tabs: biofuels, energy efficiency, fossil fuels, green technology, nuclear power, renewable energy, solar power, wind power. These two newspaper sites, along with other news media, provide up-to-date and good photos, graphs, and videos on energy and environment issues. In addition, NRC Information Digest [10] contains useful information on nuclear energy. Tennessee Valley Authority on its web site [11] has good graphics and videos on fossil-fuel generation, hydroelectric power, nuclear energy, and renewable energy. Many universities offer courses in energy, and several professors put a lot of valuable course materials on the web [12, 13, and 14].

The course was offered in Spring 2012 as a special topics course with an enrollment of 17 students. Student surveys are very positive and the course will be offered in the future.

REFERENCES

[1] Godfrey Boyle, Bob Everett and Janet Ramage, Energy Systems and Sustainability: Power for a Sustainable Future, Oxford University Press, 2004.
[2] John Randolph and Gilbert Masters, Energy for Sustainability: Technology, Planning, Policy, Island Press, Washington, DC, 2008
[3] Jefferson Tester, Elisabeth M. Drake, Michael, Driscoll, and Michael Golay, Sustainable Energy: Choosing Among Options, MIT Press, 2005
[4] Boyle and Godfrey, Renewable Energy (2nd edition), Oxford University Press, 2004.
[5] Grossman Cassedy, Introduction to Energy, Cambridge University Press1998
[6] Francis Vanek and Louis Albright, Energy Systems Engineering: Evaluation and Implementation, McGraw-Hill Professional, 2008.
[7] Energy Explained, U.S. Energy Information Administration (EIA), http://www.eia.gov/energyexplained/
[8] Green blog of New York Times, http://green.blogs.nytimes.com/
[9] Energy of The Guarding, http://www.guardian.co.uk/environment/energy
[10] NRC Information Digest, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/
[11] Tennessee Valley Authority, http://www.tva.com/power/index.htm
[12] ChE 359-384 Energy Technology and Policy - UT Austin, http://www.che.utexas.edu/course/che359&384/lecture_notes.html
[13] Physics 207 Energy and the Environment, Illinois State University, http://www.phy.ilstu.edu/~marx/phy207/
[14] ENS 4300 Renewable Energy and the Environment, Florida Institute of Technology, http://my.fit.edu/~fleslie/