An Engineering Elective on Energy Sustainability: Renewable, Nuclear, and Fossil Fuels

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Abstract

As the Fukushima nuclear disaster discredits nuclear energy and the price of oil continues to soar, renewable energy (wind and solar, especially) seems promising but can yet replace coal for base-load power. At this disorderly time, the author is preparing an elective on energy for next semester to provide students with a technological foundation and economic fundamentals of energy 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 upcoming course.

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 a thorough introduction to the economic, social, environmental, and policy issues related to current systems of energy use. In addition, key physical and engineering features of these systems will be studied. 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.

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 the 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
    - The Kyoto Protocol – the United Nations Framework Convention on Climate Change
- Energy Conversion
    - Thermodynamics: first and second laws, Rankine cycle and steam turbine, Brayton cycle and gas turbine
- Electricity
    - Generation, transmission, distribution, smart grid
    - Base-load, intermediate and peaking power plants

II. Fossil fuels

- Coal
    - Types, sources, mining, and reserves
    - Coal-fired power plants, flue-gas, and other environmental impacts
- Oil
    - Geology, history, exploration and production
    - Oil transportation and refineries
    - Deep sea exploration and oil spill

    - Tar sand and oil shale
- Natural Gas
    - Geology, history, exploration and production
    - Shale gas
    - Gas turbines and combined cycle

III. Nuclear

- Nuclear Energy
    - Fission, light water reactors, and safety
    - Nuclear fuel and waste

IV. Renewable

- Solar Energy
    - Sun path, insolation, radiation, and tracking
    - Photovoltaic systems
    - Solar thermal systems
- Wind Energy
    - Wind resources, turbines, aerodynamics, and electricity generation
    - Offshore wind farms
    - Efficiencies, economics
- Hydroelectricity
    - History, resources, and hydroturbines
    - Dams, reservoirs, and pumped storage
- Geothermal:
    - Physics and resources
    - Electricity generation
- Tidal and Wave Power:
    - Physics and resources
    - Energy conversion devices
- Energy Storage and Transmission
    - Batteries, super-capacitors, 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, tar 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.

For example, 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. Professor T.F. Edgar of the University of Texas at Austin has a course website on ChE 359-384 Energy Technology and Policy [12]. Dr. David T. Marx of Illinois State University has a course website on Physics 207 Energy and Society [13]. Professor Frank Leslie of Florida Institute of Technology has a course website on ENS 4300 Renewable Energy and the Environment [14].

References

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