EE 47010 / EE 67034 - Alternative Energy Devices & Materials

Course Syllabus version 0.8 (subject to change)

This course is for upper level undergraduates and early graduate students interested in the scientific challenges of alternative energy generation, storage, and efficient use. The course will cover photovoltaic and solar power in depth, with additional coverage of fuel cells, hydrogen, energy storage, wind power, modern nuclear power, thermoelectrics, geothermal, and more. Upon completion of this course, students should be able to analyze important devices and predict the power output under various conditions, compare their strengths and weaknesses, plan a sustainable power grid, and describe the technical, economic, and political challenges to making each of these alternative energies successful.

Time: Monday-Wednesday-Friday, 8:30-9:20 AM
Location: to be determined (see course web site below)
Instructor: Prof. Mark Wistey (mwistey@nd.edu)
Office hours: tentatively Wed/Fri, 9:30-11 AM or by appointment
Grading: Homework 25%, Midterms 20%, In-class presentation with partner 15%, Paper 15%, Final Exam 25%.
Late policy: Homework is due at 5pm sharp on due date. Late work is penalized 15% per day thereafter, waived only in exceptional circumstances or if arranged in advance.

Required Text (Available at Notre Dame Bookstore):
Aldo V. da Rosa, *Fundamentals of Renewable Energy Processes, 2nd Edition* (Elsevier Academic Press, 2009). **PLEASE NOTE 2nd Edition**. We will skip around quite a bit.

Suggested Reading Material (not required):
Martin A. Green, *Solar Cells: Operating Principles, Technology, and System Approaches* (Prentice-Hall, 1998)
Jenny Nelson, *The Physics of Solar Cells* (Imperial College Press, 2003)
Ryan P. O'Hayre, *Fuel Cell Fundamentals* (Wiley, 2005)

Quick notes...
•Honor Code. Cheating isn't just dangerous as engineers, it's personally offensive. Cheating fails this course; egregious cheating may lead to suspension. It is your responsibility to avoid the appearance of cheating and it is my duty to enforce the University rules on academic honesty. By taking this course, you hereby agree to the Academic Honor Code (http://www.nd.edu/~hnrcode/docs/handbook.htm).
•Grades are earned, not given. Everyone gets the same assignments: no favors.
•Opportunities for you to change the course curriculum: Feedback and Presentation.
•Disability: Please have Disabilty Services provide a Course Accommodation Letter.
•Students are responsible for reading emails sent to the mailing list.
•Interruptions due to tardiness, personal electronics, or loud talking will lead to escalating embarrassment and you may be required to leave. Please be on time and courteous to your fellow students.

Course Schedule (particularly subject to change)

Date	Reading	Topics
8/26 Wed	--	Lecture 1 – Introduction, Background, Overview. Course structure & syllabus. Intro to global warming, evidence for anthropogenic causes, & the energy status quo. Outline of alternative energy schemes – solar, wind, biomass, hydro, nuclear, etc.
		PART 1 - Solar Energy and Photovoltaics
8/28 Fri	AvdR	Fundamentals of Photovoltaic Energy Conversion. Electric field to separate charges. Current implementation (crystalline single gap semiconductors).
8/31 Mon		Solid State Physics of Photovoltaics. P-N junctions. Fermi level, flat bands. Charge, field, potential. Depletion width. I-V characteristics. Photo current.
9/2 Wed		Solar spectrum, atmospheric attenuation, geometric effects. Survey of types of cells and installations.
9/4 Fri		PV Efficiency, Types of Cells, & Manufacturing. Measures of efficiency. Detailed balance efficiency limit (Shockley-Queisser). P-N semiconductor & Schottky cells.
9/7 Mon		How to manufacture a crystalline Si cell. Other types of P-N junction cells & their manufacturing.
9/9 Wed		Improving Efficiency & 3rd Generation Cells I. Real efficiency, sources of losses. Contacts. Light management (AR coatings, texturing). Plasmonics. Maximizing module performance.
9/11 Fri		Solar concentration. Multijunction solar cells. Tunnel junctions. Solar tracking. Materials for multi-junction cells.
9/14 Mon		"3rd Generation" (high efficiency) Cells II (High Performance, High Cost). Multiple excitons. Hot carrier cells. Multiband solar cell proposals.
9/16 Wed		"2nd Generation" (inexpensive) PV. Organic and thin film PV. Supplies limits. Also PV loose ends.
9/18 Fri		Power matching. Challenges for efficient inverter circuits. High voltage DC transmission. How solar fits into the energy supply.
9/21 Mon		Engineering Economics, Policy. Non-technical complications of solar. Economics of installations. Materials scarcity & environ. impacts. Policy issues (tax incentives).
9/23 Wed		**Midterm 1.**
		PART 2 - Portable Power for Transportation
9/25 Fri		Additional background. Geopolitics & global energy supplies and limits. Carbon stabilization wedges. Requirements for transportation. Carnot cycle.

Date	Reading	Topics
9/28 Mon		Fuel Cells 1: When you don't have an outlet nearby. Basic theory. Proton exchange membranes. Materials and operational issues. Compare heat engines, Membrane lifetime and degradation.
9/30 Wed		Fuel cells 2: Advanced fuel cell designs. Recent developments and implementation. Large scale vs small scale applications.
10/2 Fri		Where will we get the hydrogen? Hydrogen generation. Electrolysis. Intro to biomass, ethanol.
10/5 Mon		Solar cracking: photoelectrochemical.
10/7 Wed		Portable energy storage: batteries and hydrogen. What's in a battery? Supercapacitors.
10/9 Fri		Hybrid cars. System requirements. Energy storage needs. Electric car: car of the future but never of the present?
10/12 Mon		Intro to electric propulsion and generation. Motors and generators. Motor types, wiring, torque, efficiency. **Final Paper Abstract Due.**
10/14 Wed		Alternative chemical generation of liquid fuels. Biomass, ethanol. Feed cars or feed people? Farm subsidies, fossil fertilizer. Switchgrass, corn, sugar cane, bacteria. Ethanol in conventional engines.
10/16 Fri		**Midterm 2.**
10/17-10/25		Fall Break
		PART 3 - New approaches to old problems
10/26 Mon		Wind power. Energy density. Ideal extraction laws. Environmental impact.
10/28 Wed		Ocean floor methates. Clean coal conversion. Oil shale and tar sands. Chlorophyll and genetically designed materials/organisms.
10/30 Fri		Nuclear 1: Basic principles and Old Technology. Physics; engineering; politics. Environmental effects: heat, waste. Ratcheting regulations. Proliferation concerns. Old reactor designs and operating philosophy. Major accidents, causes, prevention.
11/2 Mon		Nuclear 2: Modern nuclear power. New reactor designs and philosophy. “Meltdown resistant.” Materials. Ceramics. Metal fatigue, radiation damage, extended lifetime.
11/4 Wed		Nuclear 3: Other nuclear power. Hydrogen generation. Micropower, satellites, submarines & portable. Prospects for fusion. Long term disposal packaging.
11/6 Fri		Geothermal. Energy density, location, environmental impact. Uses. Tradeoffs. Carnot cycle. Recent developments.
11/9 Mon		Other localized sources and micropower. Wave/tidal. Energy density, locations.

Date	Reading	Topics
11/11 Wed		Thermoelectrics
11/13 Fri		TBA
11/16 Mon		Intro to conservation devices and solid state lighting. **4-6 page paper due.**
11/18 Wed		Solid State Lighting. Efficiency and conservation. Compact fluorescents and mercury. LED lighting.
11/20 Fri		LED physics. Color rendering. Total brightness and total output efficiency. LED applications.
11/23 Mon		Alternative energy and grid instability. Feedback. Sensing grid instability. Automated recovery from outages. Lessons from California, NY. Smart grids.
11/25-11/29		Thanksgiving Break
11/30 Mon		Other devices for innovative conservation.
12/2 Wed		student talks
12/4 Fri		student talks
12/7 Mon		student talks
12/9 Wed		Wrap-up and future directions.
12/18 Fri		**Final Exam, 8-10 AM**