Department of Chemical and Biochemical Engineering
Rutgers University, New Brunswick

16:155:571

Sustainable, Renewable, and Clean Energy Science and Engineering

Fall 2023

Meeting Day/Time: Wednesdays 5:40-8:40 pm

Class-Room: Room: BME-116 (in Biomedical Engineering Building) on Busch Campus, Rutgers University at New Brunswick

Instructor: Professor Teddy (Tewodros) Asefa

Office: Room CBE-138 (in Chemical Engineering Building or Engineering C-Wing)

Contact Info: E-mail: tasefa@chem.rutgers.edu (preferable to phone); Tel.: 848-445-2970

Office hours: Wednesdays 4:00 - 4:45 pm or by appointment

Course Lectures: Check at Canvas (see info below)

Course Content This course is intended to give mainly but not exclusively a chemical engineering and scientific perspective about conventional energy resources, energy challenges and our endeavors on the development of future, sustainable, clean, and renewable energy sources. This course will start by offering an introduction and fundamental knowledge and science about available energy resources and fossil fuels. It will follow with the challenges we face related to energy; the current state-of-the-art in energy production; various energy resources and how they work; sustainable methods being developed for generation of various clean and renewable energy sources; and the design and optimization of materials, biomass, chemical products, and processes that enable energy conservations. The course will also provide information on new materials/nanomaterials, engineering concepts, and thermochemical, photochemical, and electrochemical devices for energy applications. The course will examine the relationship between materials, material designs, energy systems and energy resources to address sustainability and clean energy challenges, by providing special emphasis on fundamental roles played by engineering and basic scientific principles.

Specific Learning Objectives:

- To understand topics related to energy resources, methods for conversions from one form of energy to another, and prospects on energy.

- To understand our energy challenges, traditional energy resources and the advantages and disadvantages of various energy resources, including renewable energy sources.
- To understand the principles of operation of various electric power plants, energy conversion systems, *e.g.*, fossil, biomass, nuclear powered plants, hydroelectric, etc.
- To cover basic science and engineering concepts and principles (*e.g.*, mass transport, thermodynamics, catalysis, bioengineering, modeling, etc.) pertinent to energy and renewable energy applications for sustainable future (*e.g.*, conversion of renewable resources to synthetic fuels; energy conversion techniques; solar, wind, biomass, geothermal, hydro-electric, wave and tidal energy technologies; bioenergy technologies for conversion of biomass into fuels; etc.).
- To highlight thermodynamics concepts and chemistries that can lead to improved power densities, efficiencies and emissions in power generating systems and green energy resources; chemical reactor designs that can lead to better energy resources; processes as related to combustion and combustion thermodynamics, reaction kinetics and combustion transport, chain reactions, ignition, quenching, etc.
- Topics related to energy supply options and/or that can affect decision making: solar, biomass, and geothermal resources, nonconventional fuels from heavy oils, tar sands, natural gas hydrates, and shale-oil, etc.
- Topics on catalysts and biocatalysts, catalyst improvement, and reactor engineering that can decrease energy consumptions or produce energy sources.
- Energy engineering topics related to chemical reaction networks, nonconventional fuel upgrading, carbon dioxide capture and conversion, design of novel energy conversion processes, energy supply chains, and combustion technologies (methane conversion, gasification, pyrolysis technology, etc.).
- Topics addressing chemical aspects of interfaces in materials for solar cells, efficient energy storage technologies, etc.
- Topics covering bio-derived energy and biochemical engineering of enzymes/microbes to produce fuels from biomass; biomass conversion technologies and bioenergy (collection, transport methods, preprocessing and treatment methods; hydrolysis and fermentation of biomass into ethanol, bioenergy technology, trans-esterification or bio-oil and biodiesel technology, etc.).
- Understanding scalable device structures for low-cost energy using chemical principles; process design, energy analysis, engineering economics and environmental assessment of renewable energy systems; and their advantages and disadvantages.
- Developing technologies for transporting and storing thermal and electrical energy and chemical synthesis and device fabrications involving some chemical concepts.

Lecture Notes: Although there is no single ideal textbook for the course, a few are recommended below and will also be used to cover many of the topics. Some of these books may be available in the Rutgers Book-Store. Lecture

materials and information from literature and other sources will also be used in many of the lectures. The lecture notes and other reference materials will be posted on Canvas or the class website. Access to these sites will be provided to all students enrolled in the course. The materials covered in lecture will be illustrative rather than exhaustive.

Suggested major (Textbooks)

Sustainable Energy, Second edition By Jefferson W. Tester, Elisabeth M. Drake, Michael J. Driscoll, Michael W. Golay and William A. Peters

Sustainable Energy, (SI) Edition, 2015, by Richard A. Dunlap, Cengage Learning.

Solar Engineering of Thermal Processes, 3rd Edition, by John A. Duffie, and William A. Beckman. 2006, John Wiley & Sons, Inc.

Sustainable Energy: Without the hot air, February 20, 2009 by David JC MacKay (http://www.withouthotair.com/Contents.html)

Renewable energy: Power for a Sustainable Future, by Godfrey Boyle, 2004, Oxford University press, Oxford, UK.

Other Possible Supplemental Books:

Biorefineries for Biomass Upgrading Facilities, by Ayhan Demibras, 2010, Springer publishers.

The Brilliance of Bioenergy, by Ralph Sims, 2002. James and James Publications, London, UK.

Exams: There will be two exams. Both exams will be given during the time of regular lecture hours (see below).

Grading and Grading Policy:

There will be no make-up exams.

The overall grade of the course depends on a combined score of the following:

Mid-term Exam	30%
Final Exam	30%
Written Report (one)	25%
Pop-Quizzes/Attendance/Class Discussion	15%

More About Exam **There is absolutely No make-up exam no matter the circumstances are**. If a student does not take any of the exams for a valid *documented in writing medical/emergency reason*, the remaining exam will be converted to make up for the missed one to calculate the final grade. Because an e-mail sent is not always an e-mail received, advance notice for absences cannot ever be accepted by e-mail and you will need to get a confirmation from Prof Asefa.

More About Report

The written report must be a critique paper on the area of renewable, clean, sustainable energy systems, processes, methods, techno-economics, fundamental science related to energy, etc. The report has to be on a recently published article (no news article, please!) on reputable international journals such as *Energy and Environmental Science, Biotechnology for Biofuels, International Journal of Hydrogen Energy, Progress in Energy and Combustion Science, Nano Energy, Applied Energy, Solar Energy Materials and Solar Cells, Journal of Power Sources, Energy Policy, Renewable Energy, Journal of Physical Chemistry C, Nano Energy, Advanced Energy Materials, Nature Catalysis, Biofuels, ChemSusChem, Bioproducts and Biorefining, Energy Economics, Renewable Energy, Journal of Power Sources, IEEE Transactions on Power Systems, Renewable and Sustainable Energy Reviews, Biomass and Bioenergy, International Journal of Renewable Energy Engineering, International Journal of Renewable Energy Technology, Bioresource Technology, Catalysis Science and Technology, Bioresources, Bioproducts, Biofuels, Bioproducts & Biorefining, Renewable and Sustainable Energy Reviews, Energy Conversion Management, Solar Energy, etc.*

Other requirements for the paper to be chosen:

- It must be on energy related or course related topics
- It must be a Research Article or Paper (**No <u>Review</u> Paper please**!)
- It must be a Full Paper (no short papers or short communications)
- It must be not older than 13 years (papers published after 2010)

Students need to choose the paper <u>as early as possible</u> and should send it to Dr. Asefa via e-mail for approval. Students that do not submit the report will get 0 for this part. No make-up writing assignments will be given to improve grades. The format of the report will be as follows:

The report should meet the following additional criteria:

- Page numbers: 7-15 pages without references
- Font: 12 Times New Roman or Arial
- Line Spacing: 1.5
- Paper Margins: No less than 1”
- **Due on November 8, 2023**

A hard copy (or printed copy) of the report must be submitted by its due date of November 8, 2023 in class. Any late submission will be accompanied by deduction of points (3% a day) from whatever the student receives for that part (20%).

Pop-Quizzes/Attendance Pop-quizzes that are unannounced may be given from time to time. These will make up 15% of the overall grade (see below). Attendance in classes is expected, and attendance may be taken during lectures and will be part of the 15% of overall grade. Students missing class for no reason and not taking the pop-quizzes or not participating in the discussions on that day gets 0 point for that day.

E-mail Professor Asefa may receive, read, and answer only e-mails that have a Rutgers e-mail address. E-mails from other e-mail accounts may get filtered out by the instructor's' e-mail server without the instructor's knowledge, for e-spam and computer virus reasons.

Cheating, plagiarism, and academic dishonesty:

Cheating will not be tolerated. You may have to show your Rutgers ID when you turn in your exam to compare your picture and signature. Students caught cheating will fail the assignment (gets 0 point on the specific assignment. University policy on academic dishonesty will be followed and the student(s) will be referred to the proper university office for disciplinary action. A letter will be sent explaining the punishment to the Associate Deans. If you have further complaints about the failed assignment or the letter, you must contact the Associate Deans directly.

Each student must turn in his or her own exams. Copying is considered cheating and will be treated as stated above, with 0 points given for the exam and a letter to the Dean's offices. If you let someone copy your quiz from you, you will have 50% deduction from your grade and a letter sent to the Associate Deans and persons in charge in your college describing these.

For more details on **Academic Integrity**, please also refer to:
http://ctaar.rutgers.edu/integrity/policy.html

Course Schedule/Calendar

(Subject to change depending on availability of guest lecturers or the pace of covering some lectures that may need more explanations in classes).

Lecture Schedule [a,b]

Date	Topics
Wed., Sept. 6	**Introduction** - Global Energy Reserves - World Energy Consumption and Demand and Challenges - Renewable versus Non-Renewable Energy Source - Clean and Sustainable Energy - Past, Present and Future Energy Use - Estimation and Evaluation of Energy Resources - Outlook
Sept. 13	**Energy Basics and Technical Performance** - Forms of Energy - Energy Efficiency, Production Rates, Estimation and Evaluation - Reviews of Engineering Concepts Pertinent to Energy - Some Basic Thermodynamics and Thermodynamic Analysis - Rate Processes in Energy Conversions - Sustainability Metrics and Measure of Sustainability - Systems Analysis Approaches
Sept. 20	**Fossil Fuels / Energy** - Introduction - Fossil Fuel Energy Base - Harvesting and Energy Products - Principles for Evaluating Fossil Energy Technology
Sept. 27	**Environmental, Geopolitical, Sociological and Economical Impacts of Fossil Fuel Use** - Thermal Pollution - Chemical Pollution - Particulate Pollution - Greenhouse Effect - Climate Change - Carbon Sequestration and Carbon Cycle - Geopolitical, Social and Economical Impacts
Oct. 4	**Bioenergy** - Biomass Sources

	- Advantages and Benefits - Available technologies and Challenges - Feedstock Collection and Transport Methods - Feedstock Pre-Processing and Treatment Methods - Biomass conversion technologies (Thermo-chemical, Combustion Gasification, Pyrolysis technology, Trans-Esterification, etc.) - Biochemical Conversion (Enzymatic Hydrolysis, Fermentation) - Recent Advances and Applications of Bioenergy technology
Oct. 11	**Geothermal Energy and Nuclear Energy** - Physics and Chemistry on Geothermal and Nuclear Energy Sources - Reactor Technology - Future prospects - Fuel Sources and Fuel Cycle
Oct. 18	***Exam 1***
Oct. 25	**Solar Energy and Solar Photovoltaics** - Solar-Thermal Energy - Materials for Solar Energy Conversions - Solar Photovoltaics or Solar Cells - PV Integration, Resources and Future Prospects - Grid-Connected PV systems - Environmental Impacts and Safety
Nov. 1	**Hydroelectric Energy** - Principles of Hydropower Technology - Turbine Design - Types of Plants - Utilization and Economics - Environmental Impacts and Other Challenges
Nov. 8	**Wind, Ocean Wave, Tide, Current, and Thermal Energy Conversion** - Wind Resources - Wind Turbines and Power Generating Systems - Energy from Tides and Waves and Economic Prospects - Current Status and Prospects
Nov. 15	**Energy Carriers and Fuel Cells** - Electric Power, Hydrogen Fuel, and Others - Fuel Cells - Hydrogen as Energy Carrier
Wed. ***Nov. 22[c]***	***No Class – Fridays Classes will be given on this day – as per Rutgers Course Planning Schedule / Policy***

Nov. 29	**Energy Management, Energy Storage and Energy Conservation** - Storage (Batteries, Capacitors and Supercapacitors, etc.) - Transportation - Energy Distribution
Dec. 6	**Energy Economics and Industrial and Commercial Energy Usage** - Technical and Economical Assessment of Renewable Energy Technology - Energy Associated with Reactors and Catalysis - Environmental Impact Assessments and Sustainability Issues - Energy Efficient Building systems - Prospects, Research and Design Projects
Dec. 13	***Exam 2***

[a] As mentioned above, students present a 12-15 min long presentation, followed by 2-4 min long questions and answer period, related to energy materials, energy policy, energy economics, etc. from the literature in the middle or at the end of the lecture (one or two students per class may be assigned).

[b] Subject to change depending on how long some lectures may take or how more discussions they may lead to.

[c] Please note that this class will be held on Tuesday, rather than Thursday that week, as per Rutgers University rule (please refer Rutgers Academic Calendar: See https://scheduling.rutgers.edu/scheduling/academic-calendar