SUSTAINABLE ENERGY SYSTEMS
(NRE 574, PUBPOL 519, ESENG 599)
Fall Term 2016

SYLLABUS

Time  Tuesday and Thursday, 2:30 – 4:00 pm
Location  1040 Dana Bldg.

Instructor  Gregory A. Keoleian
Peter M. Wege Endowed Professor of Sustainable Systems
Professor, Sustainable Systems, School of Natural Resources and Environment
Professor, Civil and Environmental Engineering
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Office Hrs  On-Campus students: Tuesday and Thursday, 4:00 – 5:00 pm
Off-Campus students: Thursday, 7:00 – 8:00 pm or by appointment

Graduate  Kevin (Zicheng) Bi bizc@umich.edu
Student Instructors  Option Recitation: Wednesday 6:00 pm - 7:00 pm in 3038 Dana Bldg.
Office Hours (some exceptions will be announced): On-Campus students:
Wednesday 4:30 pm - 6:00 pm in 2560 Dana and Thursday 1:00 pm - 2:30 pm in
4325 Dana; Off-Campus students: Wednesday 7:00 pm - 9:00 pm in 3038
Dana/via Internet
Daniel Ryan danpryan@umich.edu
Optional Recitation: Tuesday 6:00 – 7:00 pm in 3038 Dana Bldg.
Office Hours: Monday 2:30-4:00 pm 3552 Dana and Wednesday 2:30 – 4:00 pm
3038 Dana.

DESCRIPTION

This course examines the production and consumption of energy from a systems perspective.
Sustainability is examined by studying global and regional environmental impacts, economics, energy
efficiency, consumption patterns and energy policy. First, the physics of energy and energy accounting
methods are introduced. Next, the current energy system that encompasses resource extraction,
conversion processes and end-uses are covered. Responses to current challenges such as declining fossil
fuels and climate change are explored with an emphasis on emerging renewable energy technologies
(e.g., biomass, wind, and photovoltaics), building technologies, alternative vehicle technologies, and
end-use efficiency and conservation.

This is an interdisciplinary course that integrates the following analytical tools for advancing energy
sustainability: Technology Assessment
Economic and Policy Analysis
Energy Analysis and Environmental Sustainability Assessment
Students from SNRE, Engineering, Public Policy, Business, and other fields provide important perspectives useful for transforming energy systems to enhance sustainability.

FORMAT

Learning in this course is facilitated through lecture, readings, discussion, in class exercises, assignments, and term projects. Analytical skills are developed and demonstrated through problem sets, a term project and the mid-term and final exams. Required readings on canvas reinforce topics and concepts covered in lecture; reference materials on Canvas (optional reading) include supplemental articles, reports, data and web sites. For On-Campus students, class participation is a key element of the course and critical analysis and discussion of course topics is expected in class and through the blog. Off-Campus students are expected to participate by contributing to the blog.

COURSE RESOURCES

1. Course readings and other reference are available on Canvas: https://umich.instructure.com/
2. Reference textbooks available through UM library
3. Key energy websites:
   e. OpenEnergyInfo Gateway to world energy information/ data http://en.openei.org/wiki/Main_Page
COURSE OUTLINE

Part A. Introduction and Energy Fundamentals
   1. Sustainability challenges and opportunities (Sept 6)
   2. Physics of energy (Sept 8)

Part B. Energy and Carbon Accounting
   3. Energy accounting I: EIA convention (Sept 13)
   4. Energy accounting II. LCA convention (Sept 15)
   5. Energy growth analysis and carbon accounting (Sept 20)

Part C. Energy Supply
   6. Fossil energy resources (Sept 22)
   7. Electricity from fossil resources (Sept 27)
   8. Electricity from nuclear fuels and other generating systems (Sept 29)

Part D. Energy Demand
   10. Industrial and Commercial Sectors (Oct 6)
   11. Residential Sector (Oct 11)
   12. Transportation Sector (Oct 13)

MIDTERM (Oct 20)

Part E. Renewable Energy Technologies and Policy
   13. Introduction renewable energy technologies and policy (Oct 25)
   14. Wind energy (Oct 27)
   15. Hydropower, Marine and Geothermal (Nov 1)
   16. Solar energy (Nov 3)
   17. Biomass: electricity (Nov 8)
   18. Biomass: transport fuels (Nov 10)

Part F. Other Emerging Sustainable Energy Technologies and Policy
   19. Which option? Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Plug in Hybrid Electric Vehicles (PHEV) or Fuel Cell Vehicles (FCV) (Nov 15)
   20. Building technologies and policy (Nov 17)
   21. Storage technologies: electricity storage and carbon storage (sequestration) (Nov 22)

PART G. Course Synthesis
   22. Climate science: global energy balance (Nov 29)
   23. Climate mitigation and policy (Dec 1)
   24. Term project posters (Dec 6 and 8)
   25. Course review (Dec 13)
   26. Optional review session: Q/A format (Dec 14; first study day)

FINAL EXAM (Dec 21 and Dec 15 optional date)
PART A. INTRODUCTION AND ENERGY FUNDAMENTALS
Sept. 6

   What are the critical challenges for a sustainable energy future?
   Sustainable energy systems: definitions, indicators.
   Key energy stakeholders
   Levers: investments, divestments, conservation, efficiency
   Course objectives

Reading
UN Sustainable Development Goals (SDG 7 – Energy) 2015
Global Energy Assessment Toward a Sustainable Future Key Findings Summary for Policymakers Cambridge University Press xii – xviii (browse the rest).

Reference
Building a Sustainable Energy Future National Science Foundation (2009)
Energy for the Poor: Underpinning the Millennium Development Goals Department for International Development, United Kingdom, August 2002.
Sustainable Energy for All
Overview
http://www.se4all.org/sites/default/files/l/2014/12/fp_se4all_overview.pdf
Progress Toward Sustainable Energy 2015

Sept. 8

2. Physics of Energy: Laws of Thermodynamics
   Energy Forms and Conversion
   First and Second Laws and Efficiencies
   Devices: Heat Engines, Refrigerators and Heat Pumps
   Instantaneous and Average Power

Reading
Chapter 2: The Physics of Energy, Ross, M.

References
Thermodynamics resource (some useful material but much is more advanced than this course): http://hyperphysics.phy-astr.gsu.edu/hbase/heacon.html#heacon

PART B. ENERGY ANALYSIS AND CARBON ACCOUNTING
Sept. 13

3. Energy Accounting I: EIA Conventions
   Energy Carriers: Liquid, Gaseous and Solid Fuels, Electricity
   Primary Energy
   Heat Rates and Power Plant Efficiency
   Site Energy
   Measurement issues
Reading
Chapter 4: Energy Carriers and Energy Accounting, Ross, M.

References

Sept. 15
4. Energy Accounting II: LCA Conventions
- Resource Energy (Total Fuel Cycle Accounting)
- Total Fuel Cycle (Upstream and Combustion) Energy
- Feedstock (Embodied in Materials) and Process Energy
- Life Cycle Energy Analysis

Reading
Chapter 4: Energy Carriers and Energy Accounting, Ross, M.

References
GREET (Argonne National Lab): http://greet.es.anl.gov/

Sept. 20
5. Energy Growth Analysis and Carbon Accounting
- International and US Statistics
- Energy and Carbon Intensity
  - Carbon Emission Factor
  - Role for Conservation and Energy Efficiency
- Growth Rates
  - Growth Rate Formalism
  - Forecasts and Future Scenarios

Readings
Chapter 5: The US Energy Use & Related Greenhouse Gas Emissions, Ross, M.
Excel growth chart tutorial
Annual Energy Outlook With Projections to 2035 - Executive Summary
International Energy Outlook - Highlights

References
EIA Annual Energy Review (superseded -- see MER for key annual tables), http://www.eia.doe.gov/emeu/aer/contents.html
EIA Monthly Energy Review (MER) http://www.eia.gov/totalenergy/data/monthly/
Key World Energy Statistics - International Energy Agency
U.S. Energy System Center for Sustainable Systems Factsheet
The Outlook for Energy A View to 2040 – Exxon Mobil

PART C. ENERGY SUPPLY
Sept. 22
6. Fossil Energy Resources
- Distribution and Classification of Fossil Resources: Oil, Natural Gas, Coal
- Unconventional: Oil Sands/Oil Shale/Shale Gas/Coal Bed Methane
- Oil Sands and GHG emissions
- Shale Gas and Hydraulic Fracturing (fracking)
- Projections of Future Supply, What is Peak Oil
- Drilling Offshore in the US?
Readings

Oil sands basics  http://ostseis.anl.gov/guide/tarsands/index.cfm (browse)  
Oil shale basics -- http://ostseis.anl.gov/guide/oilshale/ (browse)  
USGS World Petroleum Assessment 2000 Executive Summary  
Two perspectives on Fracking:  
http://www2.epa.gov/hydraulicfracturing (browse)  
http://www.marcellusprotest.org/ (browse)  

References

BP Statistical Review of World Energy  
http://www.bp.com/statisticalreview  
EIA Projection of Long Term Supply  
http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2000/long_term_supply/  
Shale in the US:  
http://www.eia.gov/energy_in_brief/article/shale_in_the_united_states.cfm  

Chapter 5: Fossil Fuel Resources in Energy Systems Engineering Vanek and Albright (mirlyn on-line)  
Chapter 3: Fossil Energy Resources, Ross, M.  
NETL Oil and Gas Supply: http://www.netl.doe.gov/technologies/oil-gas/index.html  
Peaking of World Oil Production: Impacts, Mitigation, & Risk Management, Hirsch Report, February 2005  
Potential Impacts of Proposed Oil and Gas Development on the Arctic Refuge's Coastal Plain: Historical Overview and Issues of Concern  
http://training.fws.gov/Pubs7/arctic_oilandgas_impact.pdf  
Offshore Oil  

Sept. 27

7. Electricity from Fossil Sources

U.S. and World Fuel Mix  
Power Generation Technologies  
Transmission and Distribution  
Can Supply Meet Demand? Capacity Factor, Load Curves, Peak Demand  
Plant Efficiency and Life Cycle Efficiency  
Your electricity bill  

Readings

Top 9 Things You Didn’t Know About Americas Power Grid DOE  
http://energy.gov/articles/top-9-things-you-didnt-know-about-americas-power-grid  


References
“Electricity” in EIA Monthly Energy Review:
http://www.eia.gov/totalenergy/data/monthly/#electricity


Life Cycle Assessment of Coal-fired Power Production June 1999 • NREL/TP-570-25119

The Future of the Electric Grid MIT 2011
AC vs DC http://energy.gov/articles/war-currents-ac-vs-dc-power

Sept. 29

8. Electricity from Nuclear Fuels and Other Generating Systems
What about Nuclear Power?
Nuclear Fuel Cycle
Nuclear Waste Storage in the US: Yucca Mountain
Japan Nuclear Disaster and Impact on the Nuclear Industry
Cogeneration/Combined Heat and Power
Distributed Power, Microgrids; the "Smart Grid"

Readings

Nuclear Fuel Cycle – World Nuclear Association
http://www.world-nuclear.org/education/nfc.htm
Discussion questions - https://www.theguardian.com/environment/damian-carrington-blog/2011/apr/21/chernobyl-nuclear-power-fukushima
International Atomic Energy Agency: http://iaea.org/ (browse)
US Nuclear Industry: http://www.eia.gov/nuclear/ (browse)
Combined Heat and Power DOE Infographic
http://energy.gov/articles/top-10-things-you-didn-t-know-about-combined-heat-and-power
What is the Smart Grid?
http://www.smartgrid.gov/the_smart_grid#smart_grid

References
Fukushima Daiichi Accident:

What is Distributed Power?
http://www.dg.history.vt.edu/ch1/introduction.html

Oct. 4

9. Electricity: Power Plant Economics and Regulation
Fixed and Variable Costs (Capital, Fuel, O&M)
Wholesale and Retail Prices; Energy Markets
Tradeable SO2 Permits with Caps
Demand Side Management and Conservation

Readings
Chapter 19: Simple Economic Analysis of a New Power Plant, Ross, M.
References

NREL Energy Technology Cost and Performance Data for Distributed Generation:
http://www.nrel.gov/analysis/tech_cost_data.html

Levelized Cost of Electricity Calculator: http://www.nrel.gov/analysis/tech_lcoe.html


Regional Greenhouse Gas Initiative (RGGI) – cap and trade http://rggi.org/

PART D. ENERGY DEMAND

Oct. 6 10. Industrial Sector

Energy Consumption by Manufacturers: Fuel and Non-fuel
Energy and Carbon Intensity
Efficiency Gains, Theoretical Limits
Cost of Conserved Energy

Readings

Manufacturing Energy and Carbon Footprints DOE (browse)
http://energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2010-mecs (browse)

References

Chapter B4: Industrial Energy Consumption & Efficiency, Ross, M.
Advanced Manufacturing Office (DOE)
http://energy.gov/eere/amo/advanced-manufacturing-office
Consumption of Energy for All Purposes (First Use) by Value of Shipments and Employment Size Category and Region - Manufacturing Energy Consumption Survey (MECS)
http://www.eia.doe.gov/emeu/mecs/contents.html

Oct. 11 10. Commercial Sector

Commercial Buildings Energy Consumption
Heat and Cooling Loads
LEDs
E-Commerce and the Internet: Saving Energy?
LEED

Reading

Commercial Buildings Center for Sustainable Systems Factsheet
http://www.css.snre.umich.edu/css_doc/CSS05-05.pdf

Reference

Commercial Buildings Energy Consumption Survey
http://www.eia.doe.gov/emeu/cbecs/
LEDs: http://www1.eere.energy.gov/buildings/ssl/
Oct. 11

**11. Residential Sector**

- Residential Buildings Energy Consumption
- Heating and Cooling Loads and Degree Days
- Building Envelope (e.g., walls, windows)
  - Modeling heat loss through windows
- Building Codes and Appliance Standards

**Readings**

- US DOE Building Codes Program
- US DOE Appliance Standards

**References**

- Chapter 8 Residential Energy, Ross, M.
- Residential Buildings Center for Sustainable Systems Factsheet
  - [http://www.css.snre.umich.edu/css_doc/CSS01-08.pdf](http://www.css.snre.umich.edu/css_doc/CSS01-08.pdf)
- Real Goods Catalog (energy efficient products) [http://realgoods.com/](http://realgoods.com/)

Oct. 13

**12. Transportation Sector**

- Freight vs Personal
- Historical Statistics
  - VMT Growth
  - Fuel Economy Trends
- Other Key Drivers Impacting Sustainability: Criteria emissions, Price, Safety, Sprawl
- Technology Options
- Policy Options

**Readings**

- Chapter 22: Transportation: Activity & Energy Use, Ross, M.
- “Conclusions: Key Findings and Paths Forward” Chapter in Sustainable Transportation Energy Pathways Edited by Joan Ogden and Lorraine Anderson, Institute for Transportation Studies, UC Davis, 2011. (browse)

**References**

- Annual Urban Mobility Study, Texas Transportation Institute

Personal Transportation Center for Sustainable Systems Factsheet
http://www.css.snre.umich.edu/css_doc/CSS01-07.pdf

Smog Formation - Ground Level Ozone US EPA Site
https://www.epa.gov/ozone-pollution

Oct. 17-18 Fall Study Break

Oct. 20 Midterm Exam (in class) Parts A, B, C, D.

PART E. RENEWABLE ENERGY TECHNOLOGIES AND POLICY

Overview of technologies
Economics
Learning Curves for Renewables
Land Use and Siting
Key policy mechanisms
Renewable Portfolio Standards (RPS)
Production Tax Credits (RTC)
Renewable Energy Certificates (REC)

Reading
US Renewable Energy Center for Sustainable Systems Factsheet
http://www.css.snre.umich.edu/css_doc/CSS03-12.pdf
NREL Renewable Electricity Futures Study website (browse)
http://www.nrel.gov/analysis/re_futures/
National Renewable Energy Laboratory website (browse)
http://www.nrel.gov/
“Riding on the Experience Curve” Chapter 1 in *Experience Curves for Energy Technology Policy* OECD/IEA, 2000

Production Tax Credit and Extension
http://energy.gov/savings/renewable-electricity-production-tax-credit-ptc

Renewable Energy Certificates (RECs):
https://www.epa.gov/greenpower/renewable-energy-certificates-recs

References
Interactive mapping tools from NREL: http://maps.nrel.gov/
Green Power 101: http://www.epa.gov/grnpower/
RE 100 Annual Report: Growing Market Demand for Renewable Power
World Renewable Energy Network (WREN) website (browse)
http://www.wrenuk.co.uk/
Levelized Costs of Renewable Electricity
http://www.nrel.gov/analysis/tech_lcoe.html
Emerging Markets for Renewable Energy Certificates NREL 2005
Renewable Portfolio Standards map (See dsireusa.org site)
http://www.dsireusa.org/resources/detailed-summary-maps/


Optimization Model for Distributed Power: HOMER
http://homerenergy.com/

Meta analyses of renewable energy technologies: NREL LCA harmonization project
http://www.nrel.gov/analysis/sustain_lcah.html

Deploying Renewables: Best and Future Policy Practice IEA 2011

A Framework for Project Development in the Renewable Energy Sector NREL 2013 (NREL/TP -7A40-57963)
http://www.nrel.gov/docs/fy13osti/57963.pdf


Oct. 27

14. Wind Energy

Wind Turbine Technologies
Wind Resources and Modeling
Energy Performance and Environmental Impacts
Economics and Economic Development Impacts

Readings

Chapter 21: Renewables: Electricity from the Wind, Ross, M.


References

Chapter 12 Wind Energy Systems, in Energy Systems Engineering Vanek and Albright (mirlyn online)


NREL Wind maps
http://www.nrel.gov/gis/wind.html

Wind Powering America (EERE)
http://www.windpoweringamerica.gov/

American Wind Energy Association: http://www.awea.org/

Nov. 1

15. Hydropower and Other Renewable Electricity Sources

Hydropower Potential and Impacts
Geothermal Potential and Technology
Other: Tidal and Wave Energy

Readings

Hydroelectric Power USBR 2005
Hydropower Overview, USBR and IEA
DOE Geothermal Technologies Program (including technology overview)
http://www.eere.energy.gov/geothermal/

EERE Marine and Hydrokinetic Technology:
http://energy.gov/eere/water/marine-and-hydrokinetic-energy-research-development

References

World Commission on Dams http://www.internationalrivers.org/node/348
DOE Hydropower Technologies Program (including technology overview)
  http://www1.eere.energy.gov/water/index.html
Marine and Hydrokinetic Resource Assessment

Nov. 3 16. Photovoltaics
  PV and BIPV Technologies
  Solar Resources and Modeling
  Energy Performance and Environmental Impacts
  Economics and Net Metering

Readings


PV technology web site (EERE): browse
http://energy.gov/eere/energybasics/articles/solar-energy-technology-basics
Chapter 20 Renewables: Photovoltaic Electricity, Ross, M.

References

NREL PVWatts Calculator http://pvwatts.nrel.gov/
Chapter 10 Solar Photovoltaic Technologies, in Energy Systems Engineering Vanek and Albright (mirlyn online)
Solar Radiation Resource Maps of US
  http://www.nrel.gov/gis/solar.html
Solar Radiation Resource Data of US
  http://rredc.nrel.gov/solar/old_data/nsrdb/
  https://maps.nrel.gov/nsrdb-viewer/

Nov. 8 17. Biomass: Electricity
  Biomass Technologies Introduction
  Biomass Productivity and Modeling
  Biopower: MSW, willows/switch grass/ poplar, wood waste

Readings

U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry US DOE, August 2011 Summary
  http://www1.eere.energy.gov/bioenergy/pdfs/btu_summary_findings.pdf

Wood-biomass-for-energy Forest Products Lab USFS 2004

References

Nov. 10

18. Biomass: Transport Fuels

Biofuels: Bioethanol, Biodiesel, Algal, Jatropha
Biofuels and Water
Land Use Impacts
Food vs Fuel
Renewable Fuels Standards

Readings

Biofuels Center for Sustainable Systems Factsheet
http://css.snre.umich.edu/css_doc/CSS08-09.pdf

Alternative Fuels Data Center (EERE): http://www.afdc.energy.gov/ (browse)


Renewable Fuel Standards (RFS):
http://www.epa.gov/otaq/fuels/renewablefuels/index.htm (browse)

References


Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus USDA/DOE May 1998 (browse)

US DOE Biomass Program: http://www1.eere.energy.gov/bioenergy/


UK Renewable Fuels Agency Review of the Indirect Effects of Biofuels
http://webarchive.nationalarchives.gov.uk/20110407094507/renewablefuelsagency.gov.uk/reportsandpublications/reviewoftheindirecteffectsofbiofuels
19. Which Option? Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Plug in Hybrid Electric Vehicles (PHEV) or Fuel Cell Vehicles (FCV)
   - EV, Regenerative Braking
   - HEV, Matching Load with Efficient Powerplants
   - PHEV, Extend Range of Electric Drive
   - FCV, The Fuel Cell Powered Hybrid Vehicle
   - Incentives and Tax Credits (Feebates, Gas Guzzler Tax, Rebates)

Reading

(browse)

(browse)


References


20. Building Energy Technologies and Policy

   - Smart buildings
   - Lighting and LEDs
   - Heating/cooling technologies
   - Energy Star Program
   - Effective Policies

Readings


EERE Building Energy Technologies Program http://www1.eere.energy.gov/buildings/index.html (browse site)

US DOE Appliance Standards (browse site)
http://energy.gov/eere/buildings/appliance-and-equipment-standards-program

US DOE Building Codes Program (browse site)
http://www.energycodes.gov/

References

Consumer Energy Tax Credits
http://www.energy.gov/taxbreaks.htm
LEDs: http://www1.eere.energy.gov/buildings/ssl/

Nov. 22

21. Electricity Storage Technologies
Batteries, Capacitors, Flywheels, Pumped Hydro

Readings

Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide,

References

Electricity Storage: Technologies and Regulation, National Regulatory Research Institute,
June 11, 2011.


Nov. 22

21. Carbon Sequestration
Five Sequestration Strategies: Biological (Terrestrial) Sequestration, Carbon
Capture, Geologic Sequestration, Ocean Sequestration, Advanced Concepts
Clean Coal?

Readings

DOE Sequestration Site
295(3): 68- 75.

References

National Carbon Sequestration Database & Geographic Information
Chapter 7 Carbon Sequestration, Vanek and Albright
“Carbon Dioxide Capture and Storage“ IPCC Special Report (Summary for Policymakers
and Technical Summary)
K.S. Lackner “Capture of carbon dioxide from ambient air” Eur. Phys. J. Special Topics

PART G. COURSE SYNTHESIS

Nov 29

22. Climate Change I: Climate Change Science
Earth’s Energy Balance
Greenhouse Effect
Greenhouse Gases
Feedback Mechanisms
Reading


References

Fourth and Fifth Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC)
http://www.ipcc.ch/

Emissions of Greenhouse Gases in the United States (EIA)
http://www.eia.gov/energy_in_brief/greenhouse_gas.cfm


Nov. 24

Happy Thanksgiving! (no class)

Dec. 1

23. Climate Change II: Climate Change Mitigation and Policy
Carbon Stabilization Targets
Stabilization Wedges
Climate Policy and Carbon Markets
  Policies of Developed (EU Climate Policy) and Developing Countries
  (Clean Development Mechanisms)
  Regional, State, City
Business and Industry: stockholders and the insurance sector

Readings

Climate Change 2007 - Contribution of Working Group III Report to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)
"Mitigation of Climate Change" Summary for Policymakers.

References

Stern Review on the Economics of Climate Change Executive Summary
Center for Climate and Energy Solutions
http://www.c2es.org/
The American Clean Energy and Security Act (Waxman-Markey Bill)
http://www.c2es.org/federal/congress/111/acesa
EIA Country Analysis Briefs
http://www.eia.gov/beta/international/analysis.cfm
United Nations Framework Convention and Kyoto Protocol
http:// unfccc.int/resource/convkp.html
http:// unfccc.int/kyoto_protocol/items/2830.php/
State and Local Climate Energy Program (US EPA):
https://www.epa.gov/statelocalclimate
ORNL Review, "Both Directions at Once: Can America simultaneously achieve energy independence and address global warming?" Oak Ridge National Laboratory Review 42(2), 2009.
Dec. 6  24. Term Project Presentations: Group I Posters
Dec. 8  24. Term Project Presentations: Group II Posters
Dec. 8  Individual Term Project Papers Due (Group I and II)
Dec. 13  25. Course Review
Dec 14  Optional Review: Q/A format (Dec 14 is the first study day)

Final Exam:

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>Wednesday, December 21</td>
<td>4:00 pm - 6:00 pm</td>
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<tr>
<td>Thursday, December 15</td>
<td>10:30 am - 12:30 pm (optional date)</td>
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COURSE REQUIREMENTS AND EVALUATION

- Class participation*: 10%
- Assignments: 20%
- Term Project: 20%
- Mid-Term Exam: 25%
- Final Exam: 25%

* Class participation: Attendance in class is required. For off campus students this means viewing lecture videos. Participation includes leading class discussion and contributing to the class blog; posing questions and answering questions; sharing articles and news; providing feedback on lectures and course materials; and active participation in the poster session.