SUSTAINABLE ENERGY SYSTEMS

(EAS 574/PUBPOL 519/ESENG 599/RCNSCI 419)
Fall Term 2019
SYLLABUS

Time
Tuesday and Thursday, 2:30 – 4:00 pm

Location
1040 Dana Bldg.

Instructor
Greg Keoleian
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Office Hrs
Tuesday and Thursday, 4:00 – 5:00 pm or by appointment

Graduate Student Instructors
Ellen Abrams, egabrams@umich.edu

Optional Recitation: Wednesday 6:00 – 7:00 pm in 3552 Dana
Office Hours: Monday 3:00 – 5:00 pm in 3552 Dana and Wednesday 5:00 – 6:00 pm in 3552 Dana

Nate Hua, nhua@umich.edu

Optional Recitation: Tuesday 6:00 – 7:00 pm in 3552 Dana
Office Hours: Tuesday 7:00 – 8:00 pm in 3552 Dana and Wednesday 1:00 – 3:00 pm in 3012 Dana

DESCRIPTION

This course examines the production and consumption of energy from a systems perspective to accelerate sustainable energy transformations. 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 supply (resource extraction, conversion processes) and demand (end-uses) is covered. Strategies and interventions to address climate change and other sustainability challenges are explored in depth 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 SEAS, Engineering, Public Policy, Business, and other fields provide important perspectives useful for transforming energy systems to enhance sustainability.
LEARNING OBJECTIVES

- **Characterize current and future states** for energy supply and demand (trends, challenges, opportunities, projections) from technology, policy, business, and sustainability perspectives
  - Energy supply: fossil, nuclear, renewables (wind, solar, biomass, geothermal, tidal, wave)
  - Energy demand: mobility, commercial and residential buildings, industry
- **Develop energy models** for energy supply and demand technologies and sectors
  - Resource assessment and siting of renewable technologies
  - Energy systems analysis of end use sectors
- **Evaluate the sustainability performance** of the current and future energy systems, technologies and use patterns
  - Apply analytical tools (model life cycle energy, carbon emissions, levelized cost, cost of conserved energy, etc.) to explore technologies and pathways for a sustainable energy future
  - Examine alternative and disruptive technologies (e.g., connected and automated vehicles, smart buildings, energy storage)
- **Analyze strategy and policy** to promote sustainable energy transformations
  - Identify key business strategies and government policies influencing energy supply and demand
  - Recommend key market and policy levers for accelerating energy transformations

FORMAT

Learning in this course is facilitated through lecture, case studies and discussions, readings, in class exercises, assignments, field trips, 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. 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.

COURSE RESOURCES
1. **Course readings and other reference are available on Canvas**: [https://umich.instructure.com/](https://umich.instructure.com/)
2. **Key energy websites**:
   e. OpenEnergyInfo Gateway to world energy information/data: [http://en.openei.org/wiki/Main_Page](http://en.openei.org/wiki/Main_Page)
COURSE OUTLINE

Part A. Introduction and Energy Fundamentals
1. Sustainability challenges and opportunities (Sept 3)
2. Physics of energy (Sept 5)

Part B. Energy and Carbon Accounting
3. Energy accounting I: EIA convention (Sept 10)
4. Energy accounting II. LCA convention (Sept 12)
5. Energy growth analysis and carbon accounting (Sept 17)

Part C. Energy Supply
6. Fossil energy resources (Sept 19)
7. Electricity from fossil resources (Sept 24)
8. Electricity from nuclear fuels and other generating systems (Sept 26)
9. Electricity: Power Plant Economics and Regulation (Oct 1)

Part D. Energy Demand
10. Industrial and Commercial Sectors (Oct 3)
11. Residential Sector (Oct 8)
12. Transportation Sector (Oct 10)

MIDTERM (Oct 17)

Part E. Renewable Energy Technologies and Policy
13. Introduction renewable energy technologies and policy (Oct 22)
14. Wind energy (Oct 24)
15. Hydropower, Marine and Geothermal (Oct 29)
16. Solar energy (Oct 31)
17. Biomass: electricity (Nov 5)
18. Biomass: transport fuels (Nov 7)

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 12)
20. Building technologies and policy (Nov 14)
21. Storage technologies: electricity storage and carbon storage (sequestration) (Nov 19)

PART G. Course Synthesis
22. Climate science: global energy balance (Nov 21)
23. Climate mitigation and policy (Nov 26)
24. Term project posters (Dec 3 and 5)
25. Course review (Dec 10)
26. Optional review session: Q/A format (Dec 11; first study day)

FINAL EXAM (Dec 13)
PART A. INTRODUCTION AND ENERGY FUNDAMENTALS

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

Reading(*)

UN Sustainable Development Goals (SDG 7 – Energy)
https://sustainabledevelopment.un.org/sdg7
https://www.iea.org/woe/weomodel/sds/
Global Energy Assessment Toward a Sustainable Future Key Findings Summary for Policymakers Cambridge University Press xii – xviii.
Energy Technology Perspectives: Catalyzing Energy Transformations, Executive Summary. IEA 2017. (browse)
https://www.iea.org/publications/freepublications/publication/EnergyTechnologyPerspectives2017ExecutiveSummaryEnglishversion.pdf

References (**)
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
Tracking Progress:

NOTES:
(*) Readings are available on CANVAS both through PAGES and FILES/A. RESOURCES
(**) REFERENCES are not required readings; they are additional resources that may be useful.
Sept. 5  

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. 10  

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  
   EIA main glossary: http://www.eia.gov/tools/glossary/index.cfm

Sept. 12  

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/
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 2050 - Executive Summary
  https://www.eia.gov/outlooks/aeo/

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
  http://www.css.umich.edu/factsheets/us-energy-system-factsheet
- GHG Emission Factors:
- The Outlook for Energy A View to 2040 – Exxon Mobil

PART C. ENERGY SUPPLY

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
https://www.canadasoilsands.ca/en/what-are-the-oil-sands
USGS World Petroleum Assessment 2000 Executive Summary
Two perspectives on Fracking:
http://www2.epa.gov/hydraulicfracturing
http://www.marcellusprotest.org/

References
BP Statistical Review of World Energy
http://www.bp.com/statisticalreview
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.
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. 24

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
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?

References

Fukushima Daiichi Accident:


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

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:  
https://www.nrel.gov/analysis/tech-cost-dg.html

Levelized Cost of Electricity Calculator: https://www.nrel.gov/analysis/tech-lcoe.html


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

PART D. ENERGY DEMAND

Oct. 3  10. Industrial Sector


Readings


References

Chapter B4: Industrial Energy Consumption & Efficiency, Ross, M.
Advanced Manufacturing Office (DOE) http://energy.gov/eere/amo/advanced-manufacturing-office

Manufacturing Energy Consumption Survey (MECS) http://www.eia.doe.gov/emeu/mecs/contents.html


Oct. 3  10. Commercial Sector


Reading

Commercial Buildings Center for Sustainable Systems Factsheet http://css.umich.edu/factsheets/commercial-buildings-factsheet


References
Oct. 8

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


EERE Energy Savers: https://www.energy.gov/energysaver/energy-saver
(browse website)


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

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

References

Residential Energy Consumption Survey http://www.eia.doe.gov/emeu/recs/


“Home Energy Saver”, Developed by the Environmental Energy Technologies Division at Lawrence Berkeley National Laboratory http://hes.lbl.gov/

Chapter 8 Residential Energy, Ross, M.

Energy Star http://energystar.gov/

Residential Buildings Center for Sustainable Systems Factsheet http://css.umich.edu/factsheets/residential-buildings-factsheet


Oct. 10

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 (Autonomous Vehicles – disruptive technology)
Policy Options

Readings

Chapter 22: Transportation: Activity & Energy Use, Ross, M.
Personal Transportation Center for Sustainable Systems Factsheet (browse)
http://css.umich.edu/factsheets/personal-transportation-factsheet
Autonomous Vehicles Center for Sustainable Systems Factsheet (browse)
http://css.umich.edu/factsheets/autonomous-vehicles-factsheet

References

Transportation Energy Data Book – Oak Ridge National Laboratory
http://www-cta.ornl.gov/data/
Annual Urban Mobility Study, Texas Transportation Institute
http://mobility.tamu.edu/ums/
The Future of Transportation Electrification: Utility, Industry and Consumer Perspectives, Lawrence Berkeley National Laboratory August 2018
https://emp.lbl.gov/publications/future-transportation-electrification
Smog Formation - Ground Level Ozone US EPA Site
https://www.epa.gov/ozone-pollution
“Are e-scooters polluters? The environmental impacts of shared dockless electric scooters” https://iopscience.iop.org/article/10.1088/1748-9326/ab2da8

Oct. 14-15 Fall Study Break

Oct. 17 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://css.umich.edu/factsheets/us-renewable-energy-factsheet
NREL Renewable Electricity Futures Study website (browse)
https://www.nrel.gov/analysis/re-futures.html
National Renewable Energy Laboratory website (browse)
“Riding on the Experience Curve” Chapter 1 in Experience Curves for Energy Technology Policy OECD/IEA, 2000

Production Tax Credit and Extension (browse)

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

References

Interactive mapping tools from NREL: https://maps.nrel.gov/
Green Power Partnership: http://www.epa.gov/greenpower/
World Renewable Energy Network (WREN) website (browse)
http://www.wrenuk.co.uk/
Levelized Costs of Renewable Electricity
https://www.nrel.gov/analysis/tech-lcoe.html
Renewable Portfolio Standards map (See dsireusa.org site)
http://www.dsireusa.org/resources/detailed-summary-maps/
https://www.nrel.gov/docs/fy08osti/41409.pdf
Optimization Model for Distributed Power: HOMER
http://homerenergy.com/
Meta analyses of renewable energy technologies: NREL LCA harmonization project

Oct. 24

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.
Wind Energy Basics (EERE): (browse)
https://www.energy.gov/eere/wind/wind-energy-basics
Wind Technologies Market Report 2017 (DOE): (browse key findings)
13

References

Wind Energy Center for Sustainable Systems Factsheet
http://css.umich.edu/factsheets/wind-energy-factsheet

https://www.nrel.gov/docs/fy08osti/41869.pdf

Chapter 12 Wind Energy Systems, in Energy Systems Engineering Vanek and Albright
NREL Wind maps: http://www.nrel.gov/gis/wind.html
NREL Wind:
https://www.nrel.gov/wind/ (browse)
WINDEXchange (EERE): https://windexchange.energy.gov/
American Wind Energy Association: http://www.awea.org/

Oct. 29

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 Basics (EERE) browse
https://energy.gov/eere/geothermal/geothermal-basics

References

World Commission on Dams http://www.internationalrivers.org/node/348
DOE Hydropower Technologies Program (including technology overview)
https://www.energy.gov/eere/water/water-power-technologies-office
Geothermal Energy Center for Sustainable Systems Factsheet
http://css.umich.edu/factsheets/geothermal-energy-factsheet
Marine and Hydrokinetic Resource Assessment

Oct. 31

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

Readings

References

Photovoltaic Energy Factsheet
http://css.umich.edu/factsheets/photovoltaic-energy-factsheet
NREL PVWatts Calculator http://pvwatts.nrel.gov/
Chapter 10 Solar Photovoltaic Technologies, in Energy Systems Engineering Vanek and Albright (mirlyn online)
https://maps.nrel.gov/nsrdb-viewer/

Nov. 5

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

U.S. Billion-Ton Update: US DOE, July 2016 Executive Summary (PDF pages 21-33)
Wood-biomass-for-energy Forest Products Lab USFS 2004

References


Nov. 7

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.umich.edu/factsheets/biofuels-factsheet
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 Bioenergy Technologies Office:
https://www.energy.gov/eere/bioenergy
UK Renewable Fuels Agency Review of the Indirect Effects of Biofuels
http://webarchive.nationalarchives.gov.uk/20110407094507/renewablefuealsagency.gov.uk/reportsandpublications/reviewoftheindirecteffectsofbiofuels

PART F. OTHER EMERGING SUSTAINABLE ENERGY TECHNOLOGIES AND POLICY

Nov. 12 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
Hybrid and Plug-In Electric Vehicles Basics: (browse)
https://www.energy.gov/eere/electricvehicles/electric-vehicle-basics
Hydrogen Fuel Cell Vehicles Basics: (browse)
http://www.afdc.energy.gov/vehicles/fuel_cell.html

References


Nov 14

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 (browse site)
https://www.energy.gov/eere/buildings/building-technologies-office

Smart Buildings

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: https://www.dsireusa.org

LEDs (EERE): https://energy.gov/eere/ssl/solid-state-lighting

Solid State Lighting: LEDs and OLEDs 2015 IEEE
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7134817
Nov. 19  **21. Electricity Storage Technologies**
Batteries, Capacitors, Flywheels, Pumped Hydro

**Readings**


**References**

US Grid Energy Storage Center for Sustainable Systems Factsheet
[http://css.umich.edu/factsheets/us-grid-energy-storage-factsheet](http://css.umich.edu/factsheets/us-grid-energy-storage-factsheet)


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


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Nov. 19  **21. Carbon Sequestration and Utilization**
Five Sequestration Strategies: Biological (Terrestrial) Sequestration, Carbon Capture, Geologic Sequestration, Ocean Sequestration, Advanced Concepts Clean Coal?

**Readings**

DOE Sequestration Site


“Capturing carbon: Can it save us?” *C&ENews* February 25, 2019: 38-43

**References**


Chapter 7 Carbon Sequestration, Vanek and Albright

“Carbon Dioxide Capture and Storage” *IPCC Special Report* (Summary for Policymakers and Technical Summary)

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**PART G. COURSE SYNTHESIS**

Nov 21  **22. Climate Change I: Climate Change Science**
Earth’s Energy Balance
Greenhouse Effect
Greenhouse Gases
Feedback Mechanisms
Climate Deniers

**Reading**
references

fifth assessment reports of the intergovernmental panel on climate change (ipcc)
http://www.ipcc.ch/

inventory of greenhouse gas emissions and sinks (us epa)

ipcc, 2013: summary for policymakers. in: climate change 2013: the physical science basis. contribution of working group i to the fifth assessment report of the intergovernmental panel on climate change

ipcc, 2014: summary for policymakers. in: climate change 2014: impacts, adaptation, and vulnerability. part a: global and sectoral aspects. contribution of working group ii to the fifth assessment report of the intergovernmental panel on climate change

nov. 26

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

ipcc, 2014: summary for policymakers. in: climate change 2014: mitigation of climate change. contribution of working group iii to the fifth assessment report of the intergovernmental panel on climate change

pacala, s. and r. socolow “stabilization wedges: solving the climate problem for the next 50 years with current technologies” science (2004) 305: 968-972.

references

city of ann arbor: climate action plan

obama’s climate action plan:
https://obamawhitehouse.archives.gov/sites/default/files/image/president27sc climateactionplan.pdf

stern review on the economics of climate change executive summary
stern review executive_summary 2006.pdf

social cost of carbon – u.s. epa

us congress climate change history
http://www.c2es.org/content/congress-climate-history
EIA Country Analysis Briefs
http://www.eia.gov/beta/international/analysis.cfm
United Nations Framework Convention and Kyoto Protocol
http://unfccc.int/kyoto_protocol/items/2830.php/
State and Local Climate Energy Program (US EPA):
https://www.epa.gov/statelocalclimate

Nov. 28  Happy Thanksgiving! (no class)

Dec. 3  24. Term Project Presentations: Group I Posters
Dec. 5  24. Term Project Presentations: Group II Posters
Dec. 5  Individual Term Project Papers Due (Group I and II)
Dec. 10  25. Course Review
Dec 11  Optional Review: Q/A format (Dec 11 is the first study day)

Final Exam:  Friday, December 13  4:00 pm – 6:00 pm

COURSE REQUIREMENTS AND EVALUATION

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Class participation*</td>
<td>10%</td>
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<tr>
<td>Assignments</td>
<td>20%</td>
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<tr>
<td>Term Project</td>
<td>20%</td>
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<td>Mid-Term Exam</td>
<td>25%</td>
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<tr>
<td>Final Exam</td>
<td>25%</td>
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* Class participation: Attendance in class is required. 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.