SUSTAINABLE ENERGY SYSTEMS

(EAS 574/PUBPOL 519)
Fall Term 2018
SYLLABUS

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

Instructor Greg Keoleian
Peter M. Wege Professor of Sustainable Systems
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Professor, Civil and Environmental Engineering
Director, Center for Sustainable Systems
Office 3504 Dana Bldg.
Phone 764-3194
E-mail gregak@umich.edu
Office Hrs Tuesday and Thursday, 4:00 – 5:00 pm or by appointment

Graduate Ellen Abrams, egabrams@umich.edu
Student Instructors Optional Recitation: Wednesday 6:00 – 7:00 pm in 3552 Dana Bldg.
Office Hours: Fall A – Monday 1:30 – 3:30 pm in 1st floor Commons Dana Bldg. and Wednesday 5:00 – 6:00 pm in 3552 Dana; Fall B – Monday 11:30 am – 1:30 pm in 2560 Dana Bldg. and Wednesday 5:00 – 6:00 pm in 3552 Dana

Zicheng (Kevin) Bi, bizc@umich.edu
Optional Recitation: Tuesday 6:00 – 7:00 pm in 1006 Dana Bldg.
Office Hours: Tuesday 1:30 – 2:30 pm 3552 Dana and Tuesday 4:00 – 6:00 pm 3012 Dana (CSS).

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 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 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/
2. 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 4)
2. Physics of energy (Sept 6)

Part B. Energy and Carbon Accounting
3. Energy accounting I: EIA convention (Sept 11)
4. Energy accounting II. LCA convention (Sept 13)
5. Energy growth analysis and carbon accounting (Sept 18)

Part C. Energy Supply
6. Fossil energy resources (Sept 20)
7. Electricity from fossil resources (Sept 25)
8. Electricity from nuclear fuels and other generating systems (Sept 27)
9. Electricity: Power Plant Economics and Regulation (Oct 2)

Part D. Energy Demand
10. Industrial and Commercial Sectors (Oct 4)
11. Residential Sector (Oct 9)
12. Transportation Sector (Oct 11)

MIDTERM (Oct 18)

Part E. Renewable Energy Technologies and Policy
13. Introduction renewable energy technologies and policy (Oct 23)
14. Wind energy (Oct 25)
15. Hydropower, Marine and Geothermal (Oct 30)
16. Solar energy (Nov 1)
17. Biomass: electricity (Nov 6)
18. Biomass: transport fuels (Nov 8)

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 13)
20. Building technologies and policy (Nov 15)
21. Storage technologies: electricity storage and carbon storage (sequestration) (Nov 20)

PART G. Course Synthesis
22. Climate science: global energy balance (Nov 27)
23. Climate mitigation and policy (Nov 29)
24. Term project posters (Dec 4 and 6)
25. Course review (Dec 11)
26. Optional review session: Q/A format (Dec 12; first study day)

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

Sept. 4

   - 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)
  https://sustainabledevelopment.un.org/sdg7
- 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
- Progress Toward Sustainable Energy 2015

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. 6  

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

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PART B. ENERGY ANALYSIS AND CARBON ACCOUNTING

Sept. 11  

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. 13  

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 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](http://www.eia.doe.gov/emeu/aer/contents.html)  
EIA State Energy Profiles, [http://tonto.eia.doe.gov/state/](http://tonto.eia.doe.gov/state/)  
*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](http://www.css.umich.edu/factsheets/us-energy-system-factsheet)  
*The Outlook for Energy A View to 2040* – Exxon Mobil  

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**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  
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 Production

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. 25

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
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
   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. 4 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
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://css.umich.edu/factsheets/commercial-buildings-factsheet

References
Commercial Buildings Energy Consumption Survey
http://www.eia.doe.gov/emeu/cbecs/
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

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: www.energysavers.gov/ (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/
“Energy Efficiency for Buildings” Chapter 6 in Energy for Sustainability Technology,
“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
Oct. 11  **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
“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)
Smog Formation - Ground Level Ozone US EPA Site
https://www.epa.gov/ozone-pollution

Oct. 15-16  **Fall Study Break**

Oct. 18  **Midterm Exam (in class) Parts A, B, C, D.**
13. Introduction to Renewable Energy

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)
https://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 (browse)
http://energy.gov/savings/renewable-electricity-production-tax-credit-ptc
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/
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
https://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
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)
https://www.nrel.gov/docs/fy13osti/57963.pdf

Oct. 25

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)

References
Wind Energy Center for Sustainable Systems Factsheet
http://css.umich.edu/factsheets/wind-energy-factsheet
NREL Wind maps
http://www.nrel.gov/gis/wind.html
NREL Wind
https://www.nrel.gov/wind/ (browse)
WINDEnExchange (EERE)
https://windexchange.energy.gov/
American Wind Energy Association: http://www.awea.org/

Oct. 30

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)
http://www1.eere.energy.gov/water/index.html
Geothermal Energy Center for Sustainable Systems Factsheet
http://css.umich.edu/factsheets/geothermal-energy-factsheet
DOE 2011 Geothermal Technologies Workshop at Stanford (slides)
Marine and Hydrokinetic Resource Assessment

Nov. 1

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

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)
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. 6  **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  
*U.S. Billion-Ton 2016 Report Summary and Comparison to 2011*  

Nov. 8  **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](http://css.umich.edu/factsheets/biofuels-factsheet)  
Renewable Fuel Standards (RFS):  
[http://www.epa.gov/otaq/fuels/renewablefuels/index.htm](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

Wang, D, W May, H Huo “Life-cycle energy and greenhouse gas emission impacts of
Comparison of Algae to Other Bioenergy Feedstocks,” Environmental Science &
Fairless, D. Jatropha The little shrub that could maybe? Nature Vol 449|11 October
Fargione, J. J. Hill, D. Tilman, S. Polasky, P. Hawthorne “Land Clearing and the Biofuel
Carbon Debt”, / Scienceexpress (7 February 2008).
Searchinger, Timothy et al. 2008. Use of U.S. Croplands for Biofuels Increases
Greenhouse Gases through Emissions from Land-Use Change. Science 319:
1238-1240.
UK Renewable Fuels Agency Review of the Indirect Effects of Biofuels
http://webarchive.nationalarchives.gov.uk/20110407094507/renewablefuelsagency.gov.uk/reportsandpublications/reviewoftheindirecteffectsofbiofuels

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**PART F. OTHER EMERGING SUSTAINABLE ENERGY TECHNOLOGIES AND POLICY**

**Nov. 13**

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

305: 974-976.

**References**


The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model: [https://greet.es.anl.gov/]  


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**Nov 15**

**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)  

Smart Buildings  

US DOE Appliance Standards (browse site)  

US DOE Building Codes Program (browse site)  

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**References**

Consumer Energy Tax Credits  
[http://www.energy.gov/taxbreaks.htm](http://www.energy.gov/taxbreaks.htm)

LEDs (EERE): [https://energy.gov/eere/ssl/solid-state-lighting](https://energy.gov/eere/ssl/solid-state-lighting)  
Solid State Lighting: LEDs and OLEDs 2015 IEEE  

17
Nov. 20  **21. Electricity Storage Technologies**  
**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.  

Nov. 20  **21. Carbon Sequestration**  
**Readings**  
DOE Sequestration Site  

**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)  

Nov. 22  **Happy Thanksgiving! (no class)**

18
Nov 27  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/
   - Emissions of Greenhouse Gases in the United States (EIA)

Nov. 29  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

References
   - City of Ann Arbor: Climate Action Plan
   - Obama’s Climate Action Plan:
24. Term Project Presentations: Group I Posters

24. Term Project Presentations: Group II Posters

Individual Term Project Papers Due (Group I and II)

25. Course Review

Optional Review: Q/A format (Dec 12 is the first study day)

Final Exam: Thursday, December 13 1:30 pm – 3:30 pm

COURSE REQUIREMENTS AND EVALUATION

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Class participation*</td>
<td>10%</td>
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<tr>
<td>Assignments</td>
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<tr>
<td>Term Project</td>
<td>20%</td>
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<tr>
<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.