Northwestern | INSTITUTE FOR SUSTAINABILITY AND ENERGY

Course Syllabus – DRAFT
VERSION 1.4

ISEN 406 - Energy Efficiency and Sustainability Opportunities: Engineering, Design and Adoption

Northwestern University

Possible Instructors:
TBD
https://www.mccormick.northwestern.edu/research-faculty/directory/profiles/kulkarni-manohar.html
https://www.linkedin.com/in/craigsieben/
https://www.linkedin.com/in/sdentice/

Possible Guest Lecturers:
https://www.linkedin.com/in/vic-pisani-4344955/
https://www.linkedin.com/in/nbrod/
https://www.linkedin.com/in/tinambennett/

Class Assistant: TBD
Class Room: TBD
Class Timing: MSES Core Class, Spring Quarter (late March – early June, 10 weeks)

Course Synopsis:
This course aims to provide an understanding of the key concepts in energy efficiency (EE) and sustainability adoption. It will provide a basis for understanding energy bills, outline the role of codes and standards in building efficiency and provide information about the measures employed to increase energy efficiency. Topics covered will include auditing, design, technological advancements and adoption. The course will provide an overview of energy efficiency policies, while examining economic considerations such as incentives, consumer behavior and costs surrounding energy conservation measures.

Course Goals:
- **Understanding efficiency opportunities and ECMs**: This course will outline key tools used to assess the energy efficiency opportunities such as energy audits and thermodynamic tools/ methodology. In addition, students will become familiar with key Energy Conservation Measures (ECMs) and technological solutions for EE. Students will learn how measures vary for Residential or Commercial & Industrial (C&I) projects.
- **Learning energy efficiency policies, programs and laws**: Student will get an overview of the codes and standards, utility regulatory frameworks and government incentive programs that are important to improving energy efficiency. Content will include an overview of utility energy efficiency programs as well as independent standards and certifications relevant for driving energy efficiency.

- **Adoption of Efficiency & Managing Costs**: The class will learn how to interpret an energy bill and will understand the role of load shaping. The students will be exposed to program designs and the critical steps to drive behavior and adoption of efficiency solutions. Codes, rate structures and other tools used to drive take up will be discussed.

Grading/Assessment:

Grading will be based on the following rubric:

Component	Weight	Details	Due
Effort and Attendance	10%	Effort will be graded through attendance, class participation and pop quizzes on the readings for the day. This ensures that the readings are done and that students are engaged in work outside the classroom.	-
Quiz	20%	Conventional in class quiz based on the content. These will be declared beforehand and will focus on the theoretical frameworks explored in class. Questions may include definitions, analyses and multiple-choice responses. Questions may be asked from the required readings.	Week #3
Case Study Assignments	30%	Written, individual submissions. Students will be given a case study, which they will have to analyze using the methods learned in class. They will have to answer questions about product development, market readiness, strength of strategy and economic potential.	Weeks #5, 6,9
Final Paper	40%	Students will be randomly assigned one of four efficiency case examples and comment on the various aspects that drive efficiency adoption. Students will assess the current situation and propose the most important change to drive greater efficiency in their case, such as: • A multi-family apartment building in Chicago • An industrial facility in the Southeastern US • A single family home in Texas • A commercial high rise in Denver, CO Students will be expected to assess the EE opportunity (based on information provided), determine the likely measure adoption given today's market and they will propose at least one viable solution based on the prioritization principles, design strategies, standards / policies and technological solutions to improve EE for their case.	Week #10

		Papers will be assessed based on understanding of course concepts as well as on the quality of the solution proposed (including practicality of implementation and estimated cost to implement).	

Grading Policy:

- Grades will be assigned based on all the work you have completed during the semester following the traditional practice of A=90-100, B=80-89, C=70-79, D=60-69, F<60.

Letter Grade	Percentages	Letter Grade	Percentages
A	93 - 100 %	C+	77 - 79.9 %
A-	90 - 92.9 %	C	70 - 76.9 %
B+	87 - 89.9 %	D	60 - 69.9 %
B	83 - 86.9 %	F	< 60 %
B-	80 - 82.9%		

Course Readings:

This is a preliminary list of required readings. Instructor will specify selections from the following texts and will assign other articles.

- ACEEE. Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050. September 18, 2019[1]
- Martínez, Daniel M. *Energy Efficiency: Concepts and Calculations*. May 18, 2019.
- Mier, Mathias and Christoph Weissbart. Power markets in transition: decarbonization, energy efficiency, and short-term demand response. January 3, 2020.

Additional Readings:

- Patrick Leslie, Joshua Pearce, Rob Harrap, Sylvie Daniel (2012). "The application of smartphone technology to economic and environmental analysis of building energy conservation strategies"
- Bertagnolio, Stéphane; Lebrun, Jean (2008). "Simulation of a building and its HVAC system with an equation solver. Application to benchmarking"
- Benchmarking the energy efficiency of commercial buildings
- Answering behavioral questions about energy efficiency in buildings
- Behavior and Energy Policy

Further articles from the journal *Energy Policy* may be of value for this course.

[1] https://aceee.org/research-report/u1907

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CLASS OUTLINE

Weekly Topic	Description
1: Overview of efficiency & current state of markets	• Introduction to the scope of the course, modes of assessment • Overview of what EE + Conservation is, why it is necessary in the resource-strained world of today • Historical and current state of energy efficiency • Overview of key stakeholders in the efficiency marketplace
2: Understanding Energy Bills and the Grid	• Basic introduction of the grid and its relationship to energy efficiency (drawing on policy content to help understand who controls it and how). • Understanding an energy bill—what is its rate structure and what are the key differences between residential and C&I? • Understanding aspects of an energy bill such as peak demand limiting, power factor correction and their impacts. • Alternative rate structures and their potential impacts on EE: net metering analysis in the context of California and so on.
3: Energy Audits and Thermal Models	• Energy audits and thermal models as the first step to EE/Conservation • Introduction to energy audits: overview of the various types (IEA-EBC, ASHRAE), comparing residential and industrial audits • Basics of the building envelope and how R-value measurement works, ways of quantifying EE • Improvements in energy audits: technological advancements through smartphones, AI • Who conducts energy audits? Economic incentives of stakeholders such as public utilities, private utilities, state energy offices that conduct energy audits. • Audit accreditations: BPI, RESNET **FIELD VISIT (Ride along in small groups for efficiency audits)**
4: Introduction: Basic Areas and Methods for EE/Conservation	• *In-class discussion of audit ridealongs (Residential, C&I)* • Overview of the key areas that EE/Conservation tries to focus on, e.g. weatherization, lighting • Introduction to the basic technical solutions: sealing, LEDs, high efficiency HVAC, replacement and retrofitting of various components such as drives • Prioritization principles: economics (fuel cost/opex/rate design), environmental impact (decarbonization, resource intensity, etc) **QUIZ #1**

5: Key Residential ECMs	• Discussion of ECM cost effectiveness • Economic incentives for residential EE measures: government rebates and subsidies • Introduction to benchmarking: EnergySTAR certifications for homes • Replacement vs Retrofitting debate in the context of residential spaces Cost analysis using payback period as a metric • Weatherization and related government incentives • Challenges & opportunities in residential efficiency **CASE STUDY #1 – Role of weatherization programs in urban/suburban US**
6: Key C&I ECMs	• Overview of C&I cost / benefit • Economic incentives for industrial EE measures: government rebates and subsidies • Replacement vs Retrofitting in an industrial context • Behavioral energy efficiency in C&I • Top industries for efficiency opportunities • Challenges & opportunities in C&I efficiency • Codes & programs for C&I – how do they differ from residential • Other opportunities in C&I markets – time of use (TOU) pricing, load shaping, demand response (behavioral, auto DR) **CASE STUDY #2 – Large industrial example with assessment of economics, policy and key technologies deployed**
7: Designing an EE Solution: Consumer Adoption and Behavioral Design	• Non-cost factors influencing consumer adoption of desirable ECMs • Engagement challenges C&I and Residential • The role of data in behavioral measures and influencing participation in EE • Segment view of EE take up – why are some markets hard to engage? • Behavior-based Efficiency: We consider how to drive the market for building upgrades, as well as consider new approaches to behavioral response to information, benchmarking, and disclosure
8: Designing an EE Solution: Prioritization Principles	• Principles to be explored include decarbonization and resource intensity • Additional factors to be optimized include fuel costs, operational expenditure and capital expenditure. • Rate design as a policy-based method (as opposed to technological ECM) for achieving EE.

9: Policy Considerations: Federal Standards, Municipal Codes and Benchmarking	• Policies that impact energy efficiency: federal, state, federal and local • Leading building and equipment standards and certifications that drive efficiency (e.g. EnergyStar, LEED Platinum benchmark) • Exploring Chicago's EE policies as an example of regulation governing EE/Conservation FIELD VISIT - Chicago Area Regulation expert **CASE STUDY #3 – Impact of differences in local policy on EE**

10: Innovation & Integration in Energy Efficiency Markets	• Overview of recent changes and innovation in energy efficiency markets
	• Key Technologies & Models such as:
	  ○ Advanced Buildings and Services: Opportunities to build extremely low energy use homes and buildings cost-effectively, and how we can achieve their widespread adoption
	  ○ Intelligent Efficiency Systems: We look at the relationship of energy efficiency to the Smart Grid, with specific examination of grid connection to intelligent building technologies for efficiency and demand response
	  ○ Efficiency and the "Utility of the Future": How can energy efficiency programs integrate with renewables, electric vehicles, and distributed generation to minimize energy use and carbon emissions, and possible directions for new regulatory models.
	• Policy innovations
	• New financing models for efficiency (The Ohio State example, property tax financing of consumer efficiency improvements)
	• Innovation in program design, marketing and delivery
	
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