Northwestern | INSTITUTE FOR SUSTAINABILITY AND ENERGY

Course Syllabus – DRAFT

ISEN 431 Storage and Microgrids (0.5 credit)
Northwestern University

Course Synopsis: This course will cover the primary aspects of energy storage systems and microgrids. It will provide students with a high-level understanding of electrical storage technologies and microgrids and their key market applications.

Course Goals:

- Understand the core (hardware) technologies for storage and their characteristics
  - Develop an understanding of the operating principles of energy storage technologies— batteries, fuel cells, super capacitors
  - Components of batteries— cathode, anode, electrolyte materials.
  - Compare systems in terms of performance, life-cycle, efficiency, and capacity tradeoffs.
  - Explore other storage media such as Hydro, Thermal, Compressed-Air Energy Storage (CAES), Flywheels, etc.)
- Establish an understanding of microgrids and their function
  - Build knowledge in control systems and the purpose of microgrids
  - Review of power electronics interfaces: AC/DC and DC/AC converters
  - Ensure basic understanding of power architectures: centralized control and distributed control, primary, secondary and tertiary control
  - Introduce grid integration: methods, benefits, drawbacks.
- Develop the capability to assess opportunities to deploy storage and microgrids from an economic, technology and regulatory point of view
  - Analyze and discuss economic implications and key market applications for storage media and microgrids
  - Understand the core technology requirements to deploy storage and / or build a microgrid
  - Build a high-level understanding of policies and regulation that govern microgrids

Grading/Assessment:

Grading will be based on the following rubric:

Component	Weight	Details	Due
Effort and Attendance	20%	*Based on attendance and instructor assessment of preparations and participation in class; Instructor will use "warm call" method by listing names of those that he will call on at the beginning of class*	Ongoing

Response Papers	40%	*Papers that comment on that week's lecture topic(s). Papers will be 2-3 pages in length and will address question posed by the instructor (weekly basis x4)*	Weeks 1-4
Final Project	40%	Proposed a suitable location / design / market for a new microgrid. In an 8-10 page paper, explain: • Rationale for choosing this market or application • Explanation of expected value drivers / economic case • Overview of the regulatory environment and any key challenges or opportunities • (bulk of paper) Explanation of key technologies to deployed in your proposed microgrid and a deeper assessment of one key technology you would propose to include (e.g.)	Week 5

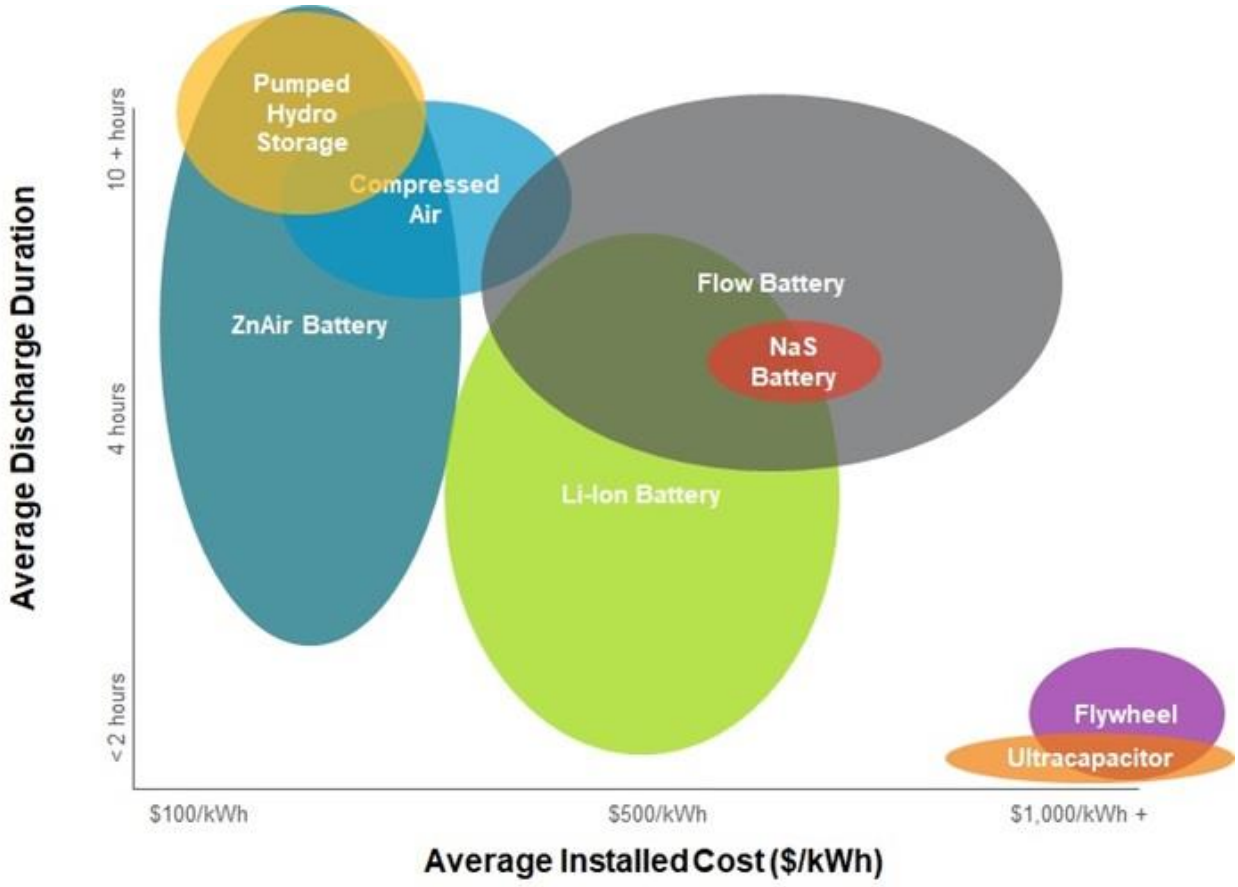
Grading Policy:

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%		

Required Course Materials:

- Huggins, Robert, *Energy Storage: Fundamentals, Materials, and Applications* (2016). Selection to be assigned
- Selected Lazard materials such as "Energy Storage Systems: Disrupting the Power Sector, Again[1]"
- P. Zhang, *Networked Microgrids.* Cambridge University Press 2020.
- Spector, Julian. "What Would It Take for the US to Become an Energy Storage Manufacturing Powerhouse?" *GTM*, Greentech Media, 13 Jan. 2020, www.greentechmedia.com/articles/read/can-the-us-claim-dominance-in-energy-storage-manufacturing.
- Lacey, Stephen et al., *The New Normal for the Grid: Batteries*, The Energy Gang. Green Tech Media 2019.
- Selected readings from Navigant Research (specific reports to be assigned by instructor)
  - https://www.navigantresearch.com/research-solutions/distributed-energy-storage
  - https://www.navigantresearch.com/research-solutions/microgrids



[1] https://microgridnews.com/energy-storage-disrupting-power-sector/

Source: Navigant Research

Additional Course Materials:

- Spector, Julian. "'Cheaper Than a Peaker': NextEra Inks Massive Wind+Solar+Storage Deal in Oklahoma", *GTM*. Greentech Media, 26 July 2019, www.greentechmedia.com/articles/read/nextera-inks-even-bigger-windsolarstorage-deal-with-oklahoma-cooperative#gs.yaljsn.
- Spector, Julian. "Dominion Energy Plans to Build 4 Storage Pilots and Study Them for 5 Years." *GTM*, Greentech Media, 7 Aug. 2019, www.greentechmedia.com/articles/read/dominion-energy-plans-to-build-four-storage-pilots-and-study-them-for-five-#gs.yaloay.
- Spector, Julian. "Can Newcomer Energy Vault Break the Curse of Mechanical Grid Storage?" *GTM*, Greentech Media, 14 Nov. 2018, www.greentechmedia.com/articles/read/energy-vault-stacks-concrete-blocks-to-store-energy#gs.yaltkp.
- John, Jeff St. "Energy Vault Lands $110M From SoftBank's Vision Fund for Gravity Storage." *GTM*, Greentech Media, 15 Aug. 2019, www.greentechmedia.com/articles/read/energy-vault-lands-110m-from-softbanks-vision-fund-for-gravity-energy-stora#gs.yaly99.
- Lacey, Stephen et al., *Watt It Takes: Form Energy's Mateo Jaramillo on His Mission to Build Long-Duration Batteries,* The Energy Gang. Green Tech Media 2019.

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CLASS OUTLINE

Weekly Topic	Description
1: *Introduction to course & Energy Storage Technology Basics*	• How do energy storage technologies operate? • Batteries • Fuel cells/Supercapacitors Response Paper #1: Discuss a material challenge or new opportunity with battery technology
2: *Assessing Storage Technologies + Key Market Applications*	• Overview of storage technologies: hydro, thermal, CAES etc. • What are the benefits/drawbacks of each)? What are the insights from a supply chain, performance/resilience, operating environment/flexibility & cost perspective? • How do each play a role in the US and global economy? Response Paper #2: Outline an ideal market or customer for deployment of battery technology
3: *Microgrids*	• What are microgrids and how do they work? • Microgrid power electronic interfaces Response Paper #3: Provide an assessment of the strengths and weaknesses of your "favorite" microgrid
4: *Microgrid Control and Integration*	• Microgrid architecture and control • Grid integration Response Paper #4: Discuss an emerging solution in microgrid software / control architecture
5: *Market Applications of Microgrids + Final Project Presentations*	• Where do microgrids fit into the US and global economy today? In the future? Final Project: Propose a microgrid including high level commentary on the economics & technology and a deeper assessment of a key technology you would propose to include (given the economics and policy environment)