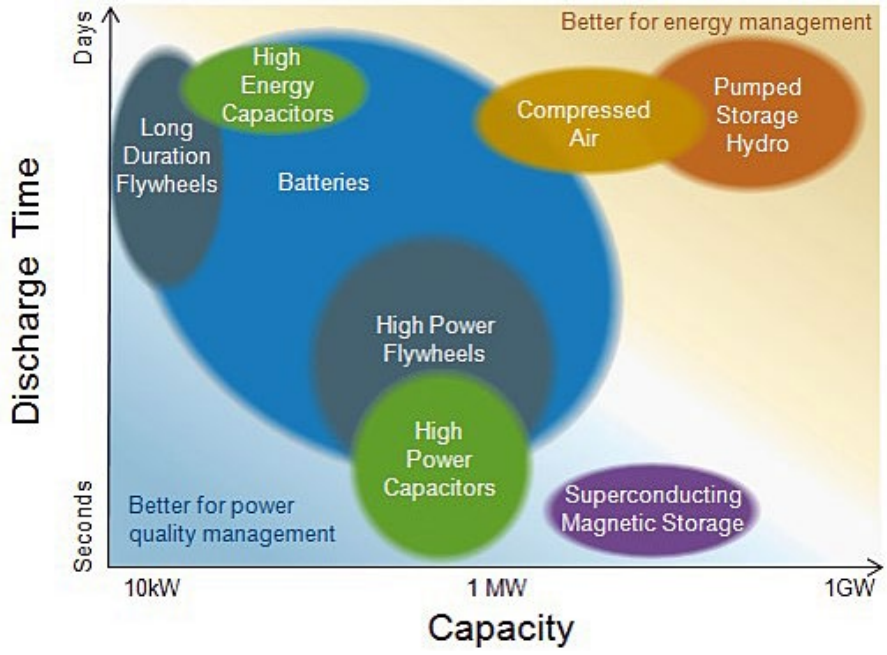
NPRE 498ESU
NPRE 498ESG
Energy Storage Engineering
Fall 2026

1. Please read the assigned-reading lecture-notes chapters.
2. Then answer the corresponding written assignment,
3. For questions about the assignments, please access the teaching assistants by email:
https://www.mragheb.com/NPRE%20402%20ME%20405%20Nuclear%20Power%20Engineering/talist.htm
4. Submit the corresponding written assignment through email to https://canvas.illinois.edu
5. Please use either the Word or pdf formats
6. In case of internet "rationing" (e. g. to health and government authorities), instability, or collapse through overload, please read the lecture notes and submit the corresponding assignments. Already-taken tests and submitted assignments would be used in assessing the final grade.

Threat of Nuclear War:
https://www.youtube.com/watch?v=HSC7Lp1nvx8

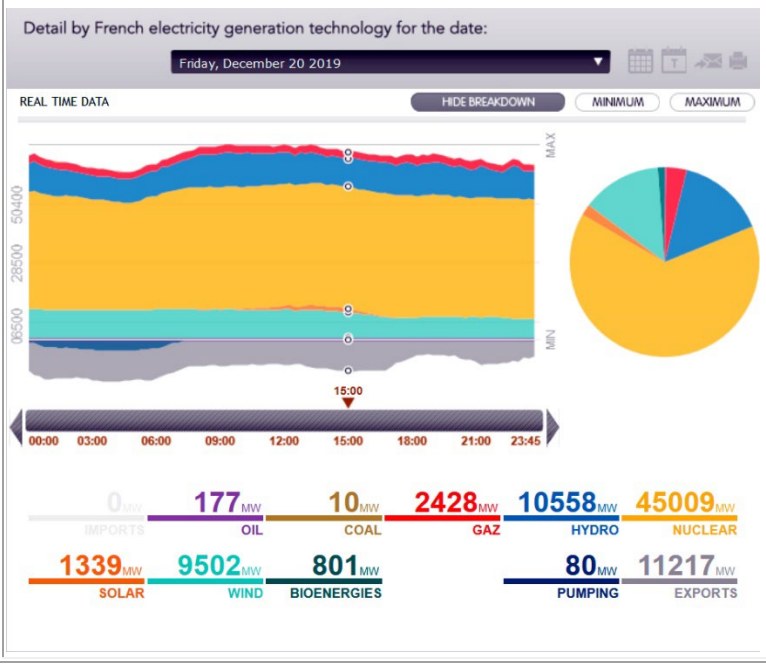
https://www.mragheb.com/Suggestions%20for%20New%20Students%20to%20Consider.pdf

Number	Date Assigned	Due Date	Description
1	8/24	9/31	**Reading Assignment** **Preface** **Written Assignment** Using the Ragone plot, compare the following energy storage options: 1. Pumped storage hydro, 2. Chemical Batteries. 

<table>
<tr><td></td><td></td><td></td><td>Using a Ragone plot version, compare the following energy storage options:
1. Chemical storage using Li-ion batteries,
2. Fuel cells using hydrogen as an energy carrier.</td></tr>
<tr><td>2</td><td>8/26</td><td>9/2</td><td>Reading Assignment
Preface
Written Assignment
Using the table, estimate the needed rated power for a solar or wind energy installation to provide the power needs for a family of four in different countries, assuming the presence of a capability to store the energy in battery banks, an overall conversion efficiency of 30 percent, and an intermittence (capacity) factor of 40 percent for both wind and solar.

<table>
<tr><th>Country</th><th>Energy consumption
[kWe.hr / (capita.year)]</th></tr>
<tr><td>USA</td><td>12,878</td></tr>
<tr><td>Japan</td><td>7,432</td></tr>
<tr><td>Switzerland</td><td>7,206</td></tr>
<tr><td>Germany</td><td>6,027</td></tr>
<tr><td>Hong Kong</td><td>4,847</td></tr>
<tr><td>China</td><td>1,899</td></tr>
</table>
capita: person</td></tr>
<tr><td>3</td><td>8/28</td><td>9/4</td><td>Reading Assignment
Preface
Written Assignment

Draw a diagram showing the components of the envisioned Smart Grid or Interner of Things IoT for electrical power generation.

Construct a table showing the allocation of electrical energy production, storage (pumped), export and use on a given day in France in MWe and in the percentage of each energy source.

</td></tr>
</table>

<table>
<tr>
<td>4</td>
<td>8/31</td>
<td>9/7</td>
<td>Reading Assignment
Introduction
Written Assignment
List the characteristics of a viable Energy Storage System.

List the perceived advantages of energy storage in conjunction with Renewable and Conventional Energy systems.

An electrical storage battery is charged from a power supply at 1 kWe for an hour.
If its efficiency is 60 percent, how long would it take to totally discharge it if it is used to supply a load at 100 Watts(e)?</td>
</tr>
<tr>
<td>5</td>
<td>9/2</td>
<td>9/9</td>
<td>Reading Assignment
Energy Storage Options
Written Assignment
List the main options under consideration to store energy.

To produce Hydrogen as an energy carrier, balance the thermo-chemical reactions used in the high temperature Iodine Sulfur (IS) hydrogen production process:
$2H_2SO_4 \rightarrow 2H_2O + ? + O_2$
$2I_2 + ? + 4H_2O \rightarrow 4HI + ?$
$4HI \rightarrow 2H_2 + ?$
_____
$2H_2O \rightarrow 2H_2 + ?$</td>
</tr>
<tr>
<td>6</td>
<td>9/4</td>
<td>9/16</td>
<td>Reading Assignment
2. Solar Thermal Power and Energy Storage Historical Perspective
Written Assignment
Henry E. Willsie identified the major weakness of all the previously built solar engines in their inability to overcome the intermittency problem of solar radiation. As an energy storage medium, he used large flat-plate collectors that heated water, which he kept warm all night in a large, insulated basin.

Identify the working medium that he used to extract the stored solar energy.

What was earlier pioneer Charles Tellier’ s choice?

What energy storage medium was used by Frank Shuman?</td>
</tr>
<tr>
<td>7</td>
<td>9/9</td>
<td>9/16</td>
<td>Reading Assignment
2. Solar Thermal Power and Energy Storage Historical Perspective
3. Thermal Energy Storage
Written Assignment
In the Concentrated Solar Power (CSP) projects shown in the following table, calculate the corresponding idealized Carnot Cycle efficiencies.
Rank the thermal energy storage media according to the achievable thermal cycle efficiency.

<table>
<tr><th>Project</th><th>Type</th><th>Storage medium</th><th>Cooling loop</th><th>Nominal temperature [°C]</th></tr>
</table>
</td>
</tr>
</table>

					Cold	Hot
Irrigation Pump Coolidge, Arizona, USA	Parabolic Trough	Oil	Oil	200	228
IEA-SSPS Almeria, Spain	Parabolic Trough	Oil	Oil	225	295
SEGS I Daggett, California, USA	Parabolic Trough	Oil	Oil	240	307
Solar One Barstow, California, USA	Central Receiver	Oil Sand Rock	Steam	224	304
CESA -1 Almeria, Spain	Central Receiver	Molten salt	Steam	220	340
THEMIS Targasonne, France	Central Receiver	Molten salt	Molten salt	250	450
Solar Two, Barstow, California, USA	Central Receiver	Molten salt	Molten salt	275	565

8 | 9/11 | 9/18

Reading Assignment

2. Solar Thermal Power and Energy Storage Historical Perspective

3. Thermal Energy Storage

Written Assignment

Calculate the theoretically achievable Carnot cycle efficiencies for the following liquid thermal energy storage media used in solar thermal applications

Storage medium	Operational Temperature	
	Cold [ºC]	Hot [ºC]
Mineral oil, liquid petroleum (alkanes, cyclic paraffins, petroleum jelly)	200	300
Synthetic oil, polyalphaolefin, synthetic esters, hydrocracked/hydroisomerized base oils.	250	350
Silicone oil, polymerized siloxanes, …Si-O-Si-O-Si…	300	400
Nitrite salts, KNO_2, $NaNO_2$	250	450

			<table><tr><td>Nitrate salts, $NaNO_3$, KNO_3</td><td>265</td><td>585</td></tr><tr><td>Carbonate salts, Na_2CO_3</td><td>450</td><td>850</td></tr><tr><td>Liquid Na</td><td>270</td><td>530</td></tr></table> List the reflecting materials used in CSP applications. List the choices of collector glazing materials in CSP applications. Draw a diagram showing the favored energy storage strategy in CSP applications.
9	9/14	9/21	**Reading Assignment** **4. Thermal Energy Storage with Solar Power Generation** **Written Assignment** List then compare the options considered for Concentrated Solar Power Generation, CSP. Define the Concentration Ratio CR in solar CSP applications. List the types of tracking in CSP applications.
10	9/16	9/23	**Reading Assignment** **7. Energy Hydrogenation and Decarbonization** **Written Assignment** Write down the two half equations and their combination describing the operation of a typical fuel cell.
11	9/18	9/25	**Reading Assignment** **7. Energy Hydrogenation and Decarbonization** **Written Assignment** Compare the voltages generated by a single fuel cell element when it is operated at: a. 20 °C, b. 100 °C. Use: $\Delta S = 163.2\ J/K$, $\Delta H = 285{,}800 J$, F (Farady's constant) = 96,487 [Coulombs] or [Joules/Volt], n=2. What would the implication regarding cooling from the obtained different values? How many full cells are needed for a 12-Volt battery? How many full cells are needed for a 19-Volt battery?
12	9/21	9/28	**Reading Assignment** **7. Energy Hydrogenation and Decarbonization** **Written Assignment** Plot the graph describing the energy requirement for the electrolysis method for hydrogen production. Discuss the effect on the overall process efficiency of: 1. Low temperature electrolysis, 2. High temperature electrolysis. As a potential use of hydrogen, write a summary of the paper:

			Rachel Beck and Magdi Ragheb, "Production of Carbon-Neutral Hydrocarbons From CO_2 and H_2 In Lieu of Carbon Capture and Storage (CCS)," 10th International Conference on "Role of Engineering Towards a Better Environment, RETBE14, Alexandria University, Faculty of Engineering, 15-17 December 2014.
13	9/23	9/28	**Reading Assignment** **5. Battery Technology** **6. Electric Vehicles Technology** **Written Assignment** Define the following battery storage figures of merit: **1**. Specific energy 2. Specific power 3. Energy density Explain the difference between: 1. Primary batteries 2. Secondary batteries Compare the different design options under consideration for a future fleet of Electrical Vehicles (EVs). Describe the different usages of battery storage technology in: 1. Hybrid Electric Vehicles, HEVs, 2. Plug-in Hybrid Electric Vehicles, PHEVs, 3. Electric Vehicles EVs.
14	9/25	9/28	**Reading Assignment** **6. Electric Vehicles Technology** **8. Steam Reforming** **Written Assignment** List three differences between ICE and EV propulsion. Write a paragraph about fuel cell driven vehicles. Compare the specific energy content of hydrogen and lithium-ion batteries. Compare the specific energy content of hydrogen and of lithium-ion batteries as energy storage media in automotive energy storage options. Compare a vehicle weight using hydrogen fuel cell vs. Li-ion batteries as a function of the attainable cruising range. What approach is favored for the heavy trucking industry? Compare the material compositions (in addition to Li) of the following Li -ion batteries: 1. LCO 2. NCA 3. LMO 4. NMC How do the LCO batteries differ from the other types?

			Briefly describe the steam reforming process for producing hydrogen.
	9/28	Monday	**First Midterm Exam, during class period**
15	9/30	10/7	**Reading Assignment** **10.** **High Temperature Water Electrolysis for Hydrogen Production** **11.** **Thermochemical Iodine Sulfur Process for Hydrogen Production** **Written Assignment** Draw the cycle diagram for the steam reforming process for producing hydrogen from methane. Draw the cycle diagram for he Iodine-Sulfur (IS) high temperature thermochemical production of hydrogen. What compounds act as catalysts in the overall reaction?
16	10/2	10/9	**Reading Assignment** **9.** **Carbon Dioxide Reforming** **12.** **The Hydrogen Economy** **Written Assignment** Draw the cycle diagram for the steam reforming process for producing hydrogen from methane. Write the corresponding chemical reactions equations. In the Fischer Tropsch industrial process carbon monoxide is reacted with hydrogen to synthesize hydrocarbons. The synthesis conditions are at 150 bar and 700 K in the presence of a catalyst. In the case of natural gas methane to liquids applications the suggested basic chemical reaction would be: $CH_4 + \frac{1}{2}O_2 \rightarrow 2H_2 + ?$ With Ni and Co used as catalysts, the following reaction would occur: $nCO + 2nH_2 \xrightarrow[Ni,Co]{} nH_2O + ?$ If, instead, a Fe catalyst is used the reaction proceeds as follows: $2nCO + nH_2 \xrightarrow[Fe]{} nCO_2 + ?$
17	10/5	10/12	**Reading Assignment** **32. Sustainable Global Energy, Desertec Concept** **13.** **High Voltage Direct Current for Power Transmission** **14. Smart Electrical Grid and Metering** **Written Assignment** In order to meet today‘s global power demand of 18,000 TWh / year, it would suffice to equip about three thousandths of the world’s deserts, an area of about 90,000 km^2 with solar collectors of solar thermal power plants. 1. Calculate the fraction of the area of the Sahara Desert that this area would cover. 2. What is the cost of covering the electrical demands of North Africa and the Middle East as well as 15 percent of Europe’s electricity by 2050 in dollars and euros? If Power is given as: P=IV. Ohmic heating losses in conductors is H=I^{2}R Prove that high voltage V transmission of power is needed to minimize the ohmic heating losses in the conductors’ wires.

			In what way does HVDC power transmission reduce the resistive heating losses compared with HVAC? Explain and sketch two diagrams showing the advantages of HVDC over HVAC for the long-distance conveyance of electrical power from the perspectives of: 1. Capital costs, 2. Transmission energy losses as ohmic heating and corona discharge.
18	10/7	10/14	**Reading Assignment** **26. Pumped Energy Storage** **27. Pumped Storage in Association with the Red Sea to Dead Sea Peace Canal** **Written Assignment** Consider a hydroelectric pumped energy storage facility producing power from stored sea water at a discharge rate of 39 m^3/sec from a height of 500 m. a) Calculate the theoretical rated power production of the station. b) For a conversion efficiency of 85 percent, what would be the effective electrical power generation? c) Calculate the potential yearly energy production in MWe.hrs.
19	10/9	10/16	**Reading Assignment** **28. Pumped Storage Qattara Depression Solar Hydroelectric Power Generation** **Written Assignment** Write a one-page summary of the paper: Patricia Weisensee and Magdi Ragheb, "Integrated Wind and Solar Qattara Depression Project with Pumped Storage as Part of Desertec," The Role of Engineering Towards a Better Environment, RETBE'12, 9th International Conference, Alexandria University, Faculty of Engineering, December 22-24, 2012. Power Point Presentation. Explain the economic advantages of the proposed approach in the paper to the earlier pumped energy storage project.
20	10/12	1/19	**Reading Assignment** **31. Kinetic Energy Flywheel Energy Storage** **Written Assignment** Consider a straight filament of length R and weight W rotating around a vertical spin axis with a rotational angular speed ω radians/sec. 1. Write the expression for the stored kinetic energy of the rotating element. 2. Derive the expression of its specific energy content. 3. What would happen to the stored kinetic energy if the rotational speed a) is doubled, b) is tripled. Use for the moment of inertia for a thin rod: $I = R^2W/3g$ What would be the choice material for the filament?
21	10/14	10/21	**Reading Assignment** **29. Cryogenic Energy Storage** **30. Compressed Air Energy Storage** **Written Assignment** Compare the energy input needs for the storage of Hydrogen in different forms: **Compressed Hydrogen**

			For the adiabatic compression of hydrogen, the compression energy in MJ/kg (1 M = 1,055 BTU) is: 47 MJ/kg, for 10,000 psi 36 MJ/kg, for 5,000 psi **Liquefied hydrogen** For cryogenic liquid hydrogen, the theoretical cooling energy expenditure is: 2.94 MJ/kg, for gas from 25 ºC to 20 K 0.45 MJ/kg, for gas to liquid at 20 K Total: 3.40 MJ/kg However, liquefaction involves a reverse Carnot Cycle efficiency of: $\eta_{\text{Reverse Carnot}} = \frac{Q_{extraction}}{Q_{rejection} - Q_{extraction}} = \frac{T_2 \Delta S}{T_1 \Delta S - T_2 \Delta S} = \frac{T_2}{T_1 - T_2}$ For liquefaction from T_1 = 25 ºC = 25 +273 K= 298 K to T_2 = 20 K, $\eta_{\text{Reverse Carnot}} = \frac{20}{(25+273)-20} = \frac{20}{298-20} = \frac{20}{278} = 0.0719 = 7.19\ percent$ This leads to actual liquefaction energies for a refrigeration efficiency of 7. percent of: Refrigeration energy = 3.4 / 0.0719 = 47.3 MJ/kg, for gas to liquid at 20 K Vaporization and warmup = 3.4 MJ/kg Total = ??? MJ/kg
22	10/16	10/23	**Reading Assignment** **12.** **The Hydrogen Economy** **15.** **Hydrogen Storage** **Written Assignment** List the methods considered for the storage of hydrogen. Give examples for the considered storage media.
23	10/19	10/26	**Reading Assignment** **17.** **Primary and Secondary Storage Batteries** **18.** **Battery Power Density, Life Cycle and Cost** **Written Assignment** List the properties of a sound utility storage battery Describe the main properties of $LaNi_5H_6$ as a hydrogen storage medium. List some chemical hydrides used in hydrogen energy storage. List some borohydrides used in hydrogen energy storage.
24	10/21	10/28	**Reading Assignment** **17.** **Primary and Secondary Storage Batteries** **24.** **Carbon Capture and Storage** **Written Assignment** Compare the properties of: 1. Li ion batteries

			2. Ni Cd batteries Draw a diagram of the Proposed Oxy-Combustion coal technology for the Meredosia FutureGen 2.0 project.
25	10/23	10/30	**Reading Assignment** **41. Algae Growth for Biodiesel Production** **36. Battery and Fuel Cell Aircraft** **51. Structural batteries** **52. Gravitational Potential Energy Storage** **53. Aerodynamic Solar Electric Vehicles** **48. Salt Gradient Solar Pond** **Trang Ha "Solar Pond for Desalination" pptx** **Written Assignment** List the applications of solar ponds for solar energy storage. Include a diagram of a proposed solar pond energy production cycle. Identify the perceived advantages of the contemplated aerodynamic and solar electric vehicles. Compare the electricity cost from gravitational potential energy storage to other energy storage choices. Search the internet and then write a short description of recent European or USA fuel cell powered aircraft. What are the perceived advantages of such a concept? List the contemplated future uses and algae growth research.
26	10/26	11/2	**Reading Assignment** **49. Quantum Glass Battery** **50. Solid State Batteries** **54. Recycling Electrical Vehicles Batteries** **55. Flow Cell Batteries** **Written Assignment** Describe the perceived advantages of suggested solid state batteries. List the composition of glasses used in solid quantum glass batteries. What are the main hazards encountered in recycling Li-ion batteries? Draw a diagram of a flow battery. List the advantages and disadvantages of flow batteries.
27	10/28	11/2	**Reading Assignment** **35. Urea Power** **33. Electrochemical Supercapacitor39. Ultra Capacitors Electrostatic Energy Storage** **39. Ultra Capacitors Electrostatic Energy Storage** **Written Assignment**

			The advantages and disadvantages of the use of supercapacitors in energy storage.
28	10/30	11/2	
	11/2	**Monday**	**Second Midterm Exam, during class period**
29	11/4	11/11	
30	11/6	11/13	
31	11/9	11/16	
32	11/11	11/18	
33	11/13	11/20	
34	11/16	11/30	
35	11/18	11/30	
36	11/20	11/230	
	11/23		Fall Break
	11/25		Fall Break
	11/27		Fall Break
37	11/30	12/7	
38	12/2	12/9	
39	12/4	12/9	
40	12/7	12/9	
	12/9	Last day classes	**Wed December 9, Final Exam during class period**
			~~**8:00-11:00 Wed December 16, Final Exam**~~

12Assignments Policy

Assignments will be turned in at the beginning of the class period, one week from the day they are assigned.
The first five minutes of the class period will be devoted for turning in, and returning graded assignments.
Late assignments will be assigned only a partial grade. Please try to submit them on time since once the assignments are graded and returned to the class, late assignments cannot be accepted any more.
If you are having difficulties with an assignment, you are encouraged to seek help from the teaching assistants (TAs) during their office hours. Questions may be emailed to TA's, but face-to-face interaction is more beneficial.
Although you are encouraged to consult with each other if you are having difficulties, you are kindly expected to submit work that shows your individual effort. Please do not submit a copy of another person's work as your own. Copies of other people's assignments are not conducive to learning, and are unacceptable.
For further information, please read the detailed assignments guidelines.