NPRE 477
NPRE 498ESU
NPRE 498ESG
Energy Storage Engineering
Fall 2025

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.youtube.com/watch?v=M7hOpT0lPGI

Regrettably, some 3,278 colleges and universities across the USA have been impacted by the Covid-19 pandemic, with many temporarily closing their campuses and switching to online classes, affecting more than 22 million students.
To all and everyone we wish good health and well-being.

<table>
<tr><th>Number</th><th>Date Assigned</th><th>Due Date</th><th>Description</th></tr>
<tr><td>1</td><td>8/25</td><td>9/1</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

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.
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<tr><td>2</td><td>8/27</td><td>9/3</td><td>Reading Assignment</td></tr>
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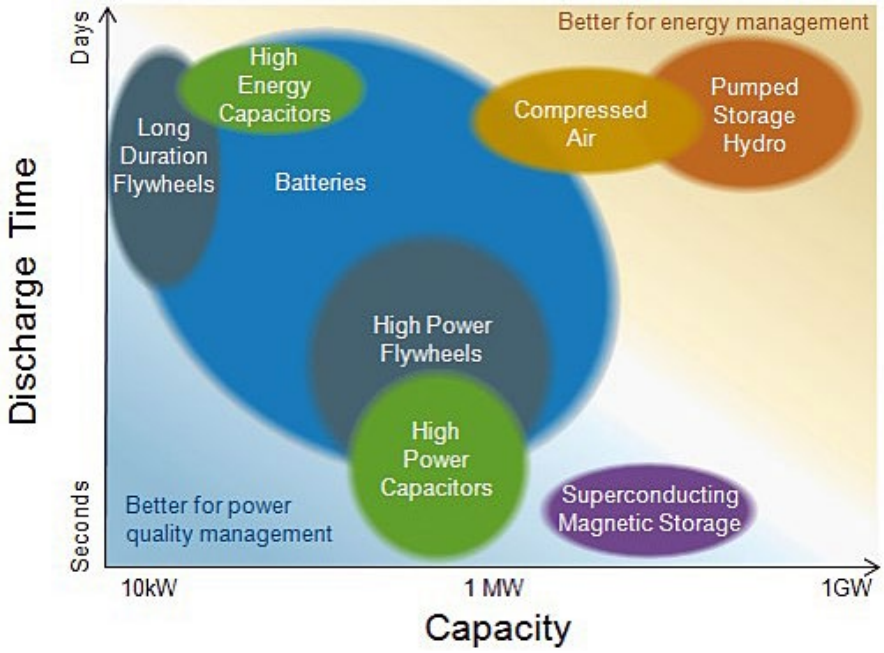
			Title-Preface **Written Assignment** Using the Ragone plot, compare the following energy storage options: 1. Pumped storage hydro, 2. Chemical Batteries.  Draw a diagram for the Internet of Things (IoT) envisioned for energy systems showing its components and the interconnections between them. Construct a table showing the allocation of electrical energy production, storage (pumped), export and use on a given day at two different times of the day. Use the links: Energy mix in electrical production, France **https://www.rte-france.com/en/eco2mix/eco2mix-mix-energetique-en** or: **https://www.rte-france.com/en/eco2mix/power-generation-energy-source**
3	8/**29**	9/**5**	**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 kW for an hour. If its efficiency is 60 percent, how long would it take to totally discharge it if it used to supply a load at 100 Watts?
4	9/3	9/10	**Reading Assignment** **Energy Storage Options** **Written Assignment**

<table>
<tr>
<td></td>
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<td>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>5</td>
<td>9/5</td>
<td>9/12</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 as a heat storage medium?

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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 rowspan="2">Project</th><th rowspan="2">Type</th><th rowspan="2">Storage medium</th><th rowspan="2">Cooling loop</th><th colspan="2">Nominal temperature [°C]</th></tr>
<tr><th>Cold</th><th>Hot</th></tr>
<tr><td>Irrigation Pump Coolidge, Arizona, USA</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>200</td><td>228</td></tr>
<tr><td>IEA-SSPS Almeria, Spain</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>225</td><td>295</td></tr>
<tr><td>SEGS I</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>240</td><td>307</td></tr>
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</td>
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Daggett, California, USA					
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

6	9/8	9/15	**Reading Assignment** **2. Solar Thermal Power and Energy Storage Historical Perspective** **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 [°C]	Hot [°C]
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
Nitrate salts, $NaNO_3$, KNO_3	265	585
Carbonate salts, Na_2CO_3	450	850
Liquid Na	270	530

7	9/10	9/17	**Reading Assignment** **3. Thermal Energy Storage** **4. Thermal Energy Storage with Solar Power Generation** **Written Assignment** Classify CSP plants according to their operational conditions. List the eutectic mixtures considered for thermal energy storage.

			Compare the heat capacities and heat of fusion of energy storage materials used in flat-plate solar collectors.
8	9/12	9/19	**Reading Assignment** **4. Thermal Energy Storage with Solar Power Generation** **Written Assignment** List then compare the options considered for Concentrated Solar Power Generation, CSP. List the reflecting materials used in CSP applications. Define the Concentration Ratio CR in solar CSP applications. List the types of tracking 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	9/15	9/22	**Reading Assignment** **5. Battery Technology** **Written Assignment** In the SI system of units, compare the units of the following figures of merits used to compare storage batteries: 1. Specific Energy, 2. Specific Power, 3. Energy Density, 4. Power density. Compare the different 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.
10	9/17	9/24	**Reading Assignment** **6. Electric Vehicles Technology** **Written Assignment** 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 indudtry? 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?
11	9/19	9/26	**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.
12	9/22	9/29	**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 (Faraday's constant) = 96,487 [Coulombs] or [Joules/Volt], n=2. What would the implication regarding cooling from the obtained different values? How many cells are needed for a 12-Volt battery? How many cells are needed for a 19-Volt battery?
13	9/24	9/29	**Reading Assignment** **7. Energy Hydrogenation and Decarbonization** **8. Steam Reforming** **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. Draw the cycle diagram for the steam reforming process for producing hydrogen from methane. Write the corresponding chemical reactions equations.
14	9/26	9/29	**Reading Assignment** **9. Carbon Dioxide Reforming** **Written Assignment** 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:

			$2nCO + nH_2 \xrightarrow[Fe]{} nCO_2 + ?$
	9/29		**First Midterm Exam**
15	10/1	10/8	**Reading Assignment** 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. **Written Assignment** Write a one-page summary of the paper listed in the Reading Assignment.
16	10/3	10/10	**Reading Assignment** **9. Carbon Dioxide Reforming** **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. In the Iodine-Sulfur (IS) high temperature thermochemical production of hydrogen, complete the following chemical reaction equations: $2H_2SO_4 \rightarrow ?+?+?$ $2I_2 + 2SO_2 + 4H_2O \rightarrow ?+?$ $4HI \rightarrow ?+?$ And the overall reaction: $2H_2O \rightarrow ?+?$ What compounds act as catalysts in the overall reaction?
17	**10/6**	**10/13**	**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.
18	**10/8**	**10/15**	**Reading Assignment** **12. The Hydrogen Economy** **15. Hydrogen Storage** **Written Assignment** 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.
19	**10/10**	**10/17**	**Reading Assignment** **17. Primary and Secondary Storage Batteries** **18. Battery Power Density, Life Cycle and Cost** **19. Nickel Cadmium and Lithium Ion Batteries**

			20. What makes a Sound Utility Storage Battery **Written Assignment** List the properties of a sound utility storage battery Compare the properties of: 1. Li ion batteries 2. Ni Cd batteries
20	10/13	10/20	**Reading assignment** **24. Carbon Capture and Storage** **Written Assignment** Draw a diagram of the Proposed Oxy-Combustion coal technology for the Meredosia FutureGen 2.0 project.
21	10/15	10/17	**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.
22	10/17	10/24	**Reading Assignment** **28. Pumped Storage Qattara Depression Solar Hydroelectric Power Generation** **29. Cryogenic Energy Storage** **30. Compressed Air Energy Storage** **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 advantages of the proposed approach in the paper to the earlier pumped energy storage project.
23	10/20	10/27	**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?

24	**10/22**	**10/29**	**Reading Assignment** **32.Sustainable Global Energy, Desertec Concept** **41. Algae Growth for Biodiesel Production** **36. Battery and Fuel Cell Aircraft** **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? 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.
25	10/24	10/31	**Reading Assignment** **35. Urea Power** **38. Run of River Hydroelectric Power** **51. Structural batteries** **52. Gravitational Potential Energy Storage** **53. Aerodynamic Solar Electric Vehicles** **54. Recycling Electrical Vehicles Batteries** **55. Flow Cell Batteries** **Written Assignment** 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. List the impediments to the use of urea as a source of hydrogen in fuel cells operation. Draw a diagram of a flow battery. List the advantages and disadvantages of flow batteries.
26	10/27	11/3	**Reading Assignment** **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.
27	10/29	11/3	**Reading Assignment** **13. High Voltage Direct Current for Power Transmission** **14. Smart Electrical Grid and Metering** **Written Assignment** If Power is given as: P=IV.

			Ohmic heating losses in conductors is $H=I^2R$ 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.
28	10/31	11/3	**Reading Assignment** **40. Natural Gas as a Bridge Fuel Toward Renewables** **Written Assignment** Write a one paragraph summary of the article: Magdi Ragheb, "Tight Natural Gas as a Bridge Fuel Toward Renewables," NBIZ Magazine, pp. 21-29, Winter 2011. List the additives added to the Hydraulic Fracturing fluids. List the environmental impacts and sustainability of the process of Hydraulic Fracturing (Fracking). Complete the equations describing the production of green diesel fuel from carbon dioxide and hydrogen. Synthesis gas is an equimolar mixture of CO and H_2. By adding H_2 to the reactant gas feed to establish the correct reactants ratio, it can be used to produce higher value products, most notably sulfur-free diesel using the Fischer-Tropsch process: $nCO+(2n+1)H_2 \rightarrow C_nH_{2n+2}+$ n?₂? It can also be used to produce methanol: $CO+2H_2 \rightarrow$??₂??
	11/3		**Second Midterm exam**
29	11/5	11/12	**Reading Assignment** **34. Safety Aspects of Thermal Energy Installations** **33. Electrochemical Supercapacitor** Dong Ok Kim, "Non-flammable Electrolytes for Li-ion batteries" pptx **Written Assignment** List the safety issues encountered in thermal solar installations. List the existing applications of supercapacitors. List the hazards encountered in the use of Li-ion batteries.
30	11/7	11/14	**Reading Assignment** **Ahmed Kazan, "Sodium ion batteries, availability, potential and comparison with other batteries" pptx** **Written Assignment** Compare Li-ion and Na-ion characteristics as to their safety and niche applications.

31	11/10	11/17	**Reading Assignment** **37. Metal Hydrides Alloys for Hydrogen Storage** **Written Assignment** Describe the Van't Hoff Equation in relation to metal hydrides energy storage.
32	11/12	11/19	**Reading Assignment** **39. Ultra Capacitors Electrostatic Energy Storage** **Written Assignment** List the existing applications of supercapacitors. Explain the role of graphene in the design of super capacitors. Compare super capacitors and chemical storage batteries.
33	11/14	11/24	**Reading Assignments** **49. Quantum Glass Battery** **50. Solid State Batteries** **45. Powerwall and Powerpack Tesla Batteries** **Written Assignments** Describe the perceived advantages of suggested solid state batteries. List the composition of glasses used in solid quantum glass batteries.
34	11/17	11/25	**Reading Assignments** **Ami Nicodemus, "Mitigating Risks in Compressed Hydrogen Energy Storage"** **46. Electrical Generation and Grid System Integration, pptx** **Written Assignment** Write a one-page summary of the power point presentation.
35	11/19	11/26	**Reading Assignment** **Gener Atienza, "Enhancing Frequency Stability using Flywheel Kinetic Energy Storage System", pptx** **Written Assignment** Write a one-page summary of the power point presentation.
36	11/21	11/28	**Reading Assignment** **Basathia, Binish Fatima Nuclear Hydrogen Production, pptx** **46. Electrical Generation and Grid System Integration** **Written Assignment** Write a one-page summary of the power point presentation. Draw a diagram of a compressed air storage system that can be used in conjunction with wind power generation.
37	12/1	12/8	**Reading Assignment** **Olivia Evans, "Road-way Kinetic Energy Harvesting; Piezoelectric, Hydraulic and Electromagnetic plates", pptx** **Raj Mohite, "Hydrogen Production using Nuclear Processes," pptx** **Written Assignment** Write a one-paragraph summary of each of the two power point presentations.
38	12/3	12/10	**Reading Assignment** **Anna Sako, "Interconnection of Batteries as distributed Energy Resources on the Electric**

			Distribution System", pptx **Written Assignment** Write a one-paragraph summary of each of the two power point presentations.
39	12/5	12/10	**Reading Assignment** Noor Ahmed, "Role of graphine in Ultra Capacitors Energy Storage."pptx Veeresh Chitradurga Gangadhara, "Ammonia NH3 as a possible hydrogen energy storage medium" pptx **Written Assignment** Write a one-paragraph summary of each of the two power point presentations.
40	12/8	12/10	**Reading Assignment** Selvin Tobar Taracena, "Solid State Storage Batteries, pptx Julian Herrera, "Hydrogen peroxide H2O2 as a hydrogen energy storage medium" pptx **Written Assignment** Write a one-paragraph summary of each of the two power point presentations.
41	12/10	12/18	**Reading Assignment** Albert Seo, "BuyancyEnergy Storage Systems", pptx **Written Assignment** Write a one-paragraph summary of of the power point presentation.
	12/18		**NPRE 498ES Fall 2025 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.