

**NPRE 477
NPRE 498ESU
NPRE 498ESG
Energy Storage Engineering
Fall 2024**

Online Temporary Alternative Coverage and access during Avian Influenza Type A Bird Flu H5N1, H5N2 or Covid-, MonkeyPox MPox and possible resurgence through mutations and variants or WHO anticipated Gain Of Function GOF research “Disease-X”

“H5N1 bird flu is widespread in wild birds worldwide and is causing outbreaks in poultry and U.S. dairy cows.”

<https://www.cdc.gov/flu/avianflu/avian-flu-summary.htm>

IgG4 Antibodies Induced by Repeated Vaccination May Generate Immune Tolerance to the SARS-CoV-2 Spike Protein

<https://pubmed.ncbi.nlm.nih.gov/37243095/>

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:

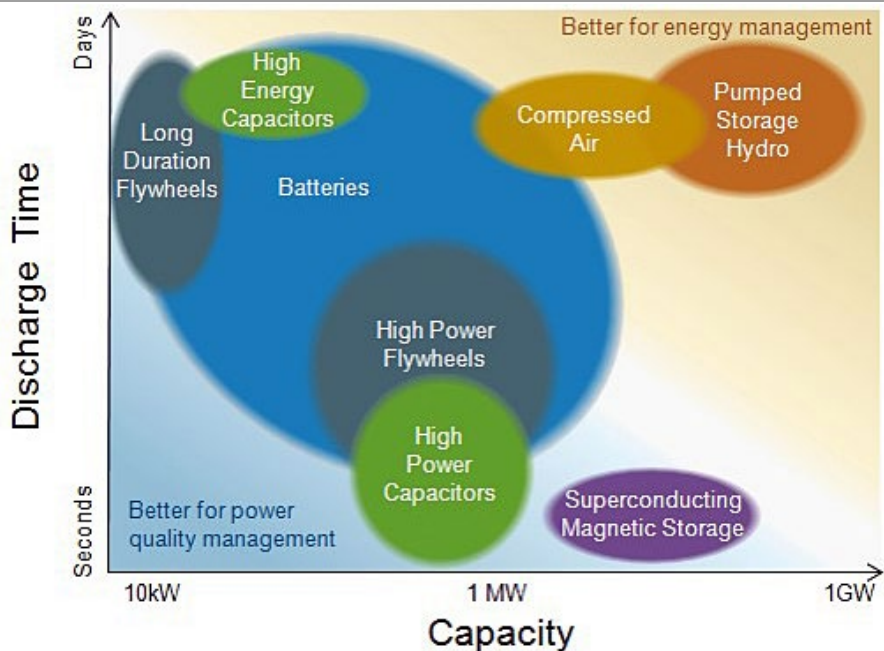
<https://www.youtube.com/watch?v=HSC7Lp1nvx8>

<https://www.youtube.com/watch?v=M7hOpT0IPGI>

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.

Number	Date Assigned	Due Date	Description
1	8/26	9/2	Reading Assignment Introduction Written Assignment



Using the Ragone plot, compare the following energy storage options:

1. Pumped storage hydro,
2. Chemical Batteries.

Country	Energy consumption [kWe.hr / (capita.year)]
USA	12,878
Japan	7,432
Switzerland	7,206
Germany	6,027
Hong Kong	4,847
China	1,899

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.

2	8/28	9/4	<p>Reading Assignment Introduction</p> <p>Written Assignment Draw a diagram for the Internet of Things (IoT) envisioned for energy systems showing its components and the interconnections between them.</p> <p>List the characteristics of a viable energy Storage System.</p> <p>List the perceived advantages of energy storage in conjunction with renewable and conventional Energy systems.</p> <p>An electrical storage battery is charged from a power supply at 1 kW for an hour.</p>
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			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?														
3	8/30	9/6	<p>Reading Assignment Title-Preface</p> <p>Written Assignment 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</p>														
4	9/4	9/11	<p>Reading Assignment Title-Preface</p> <p>Written Assignment To produce Hydrogen as an energy carrier, balance the thermos-chemical reactions used in the high temperature Iodine Sulfur (IS) hydrogen production process: $2H_2SO_4 \rightarrow 2H_2O + ? + O_2$ $2I_2 + ? + 4H_2O \rightarrow 4HI + ?$ $4HI \rightarrow 2H_2 + ?$</p> <hr/> $2H_2O \rightarrow 2H_2 + ?$														
			<p>In the simple pendulum without friction, energy that is stored as potential energy at the top of its stroke ($E_p = mgh$) is transformed into kinetic energy at the bottom of the stroke ($E_k = \frac{1}{2}mv^2$), then back as potential energy in a cyclic manner.</p> <p>1. For a stored potential energy of 1 joule what would be the speed v of a 1 kg pendulum at the bottom of its stroke? 2. To what height h will the pendulum rise at the highest point in its stroke?</p>														
5	9/6	9/13	<p>Reading Assignment 2. Solar Thermal Power and Energy Storage Historical Perspective</p> <p>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?</p> <p>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.</p> <table border="1"> <thead> <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> </thead> <tbody> <tr> <td>Irrigation Pump</td> <td>Parabolic Trough</td> <td>Oil</td> <td>Oil</td> <td>200</td> <td>228</td> </tr> </tbody> </table>	Project	Type	Storage medium	Cooling loop	Nominal temperature [°C]		Cold	Hot	Irrigation Pump	Parabolic Trough	Oil	Oil	200	228
Project	Type	Storage medium	Cooling loop					Nominal temperature [°C]									
				Cold	Hot												
Irrigation Pump	Parabolic Trough	Oil	Oil	200	228												

			Coolidge, Arizona, USA					
			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 Targassonne, France	Central Receiver	Molten salt	Molten salt	250	450
			Solar Two, Barstow, California, USA	Central Receiver	Molten salt	Molten salt	275	565

			<p>Reading Assignment Solar Thermal Power and Energy Storage Historical Perspective</p> <p>Written Assignment Calculate the theoretically achievable Carnot cycle efficiencies for the following liquid thermal energy storage media used in solar thermal applications</p>					
			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 ₂ CO ₃		450	850		
			Liquid Na		270	530		
6	9/9	9/16						
7	9/11	9/18	Reading Assignment					

			<p>3. Thermal Energy Storage</p> <p>4. Thermal Energy Storage with Solar Power Generation</p> <p>Written Assignment</p> <p>Classify CSP plants according to their operational conditions.</p> <p>List the eutectic mixtures considered for thermal energy storage.</p> <p>Compare the heat capacities and heat of fusion of energy storage materials used in flat-plate solar collectors.</p>
8	9/13	9/20	<p>Reading Assignment</p> <p>4. Thermal Energy Storage with Solar Power Generation</p> <p>Written Assignment</p> <p>List then compare the options considered for Concentrated Solar Power Generation, CSP.</p> <p>List the reflecting materials used in CSP applications.</p> <p>Define the Concentration Ratio CR in solar CSP applications.</p> <p>List the types of tracking in CSP applications.</p> <p>List the choices of collector glazing materials in CSP applications.</p> <p>Draw a diagram showing the favored energy storage strategy in CSP applications.</p>
9	9/16	9/23	<p>Reading Assignment</p> <p>5. Battery Technology</p> <p>Written Assignment</p> <p>In the SI system of units, compare the units of the following figures of merits used to compare storage batteries:</p> <ol style="list-style-type: none"> 1. Specific Energy, 2. Specific Power, 3. Energy Density, 4. Power density. <p>Compare the different options under consideration for a future fleet of Electrical Vehicles (EVs). Describe the different usages of battery storage technology in:</p> <ol style="list-style-type: none"> 1. Hybrid Electric Vehicles, HEVs, 2. Plug-in Hybrid Electric Vehicles, PHEVs, 3. Electric Vehicles EVs.
10	9/18	9/25	<p>Reading Assignment</p> <p>6. Electric Vehicles Technology</p> <p>Written Assignment</p> <p>Compare the specific energy content of hydrogen and of lithium-ion batteries as energy storage media in automotive energy storage options.</p> <p>Compare a vehicle weight using hydrogen fuel cell vs. Li-ion batteries as a function of the attainable cruising range.</p> <p>Compare the material compositions (in addition to Li) of the following Li-ion batteries:</p> <ol style="list-style-type: none"> 1. LCO 2. NCA

			<p>3. LMO 4. NMC</p> <p>How do the LCO batteries differ from the other types?</p>
11	9/20	9/27	<p>Reading Assignment 7. Energy Hydrogenation and Decarbonization</p> <p>Written Assignment Write down the two half equations and their combination describing the operation of a typical fuel cell.</p> <p>Compare the voltages generated by a single fuel cell element when it is operated at: a. 20 °C, b. 100 °C.</p> <p>Use: $\Delta S = 163.2 \text{ J / K}$, $\Delta H = 285,800 \text{ J}$, F (Farady's constant) = 96,487 [Coulombs] or [Joules/Volt], n=2.</p> <p>What would the implications regarding the obtained different values? How many cells are needed for a 12-Volt battery? How many cells are needed for a 19-Volt battery?</p>
12	9/23	9/30	<p>Reading Assignment 7. Energy Hydrogenation and Decarbonization 8. Steam Reforming</p> <p>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.</p> <p>Draw the cycle diagram for the steam reforming process for producing hydrogen from methane.</p>
13	9/25	9/30	<p>Reading Assignment 9. Carbon Dioxide Reforming 10. High Temperature Water Electrolysis for Hydrogen Production 11. Thermochemical Iodine Sulfur Process for Hydrogen Production</p> <p>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:</p> $CH_4 + \frac{1}{2}O_2 \rightarrow 2H_2 + ?$ <p>With Ni and Co used as catalysts, the following reaction would occur: $nCO + 2nH_2 \xrightarrow{Ni,Co} nH_2O + ?$</p> <p>If, instead, a Fe catalyst is used the reaction proceeds as follows:</p>

			$2nCO + nH_2 \xrightarrow{Fe} nCO_2 + ?$
14	9/27	9/30	<p>Reading Assignment 12. The Hydrogen Economy</p> <p>Written Assignment List the methods considered for the storage of hydrogen. Give examples for the considered storage media.</p> <p>To transmit a given amount of power $P = IV$, where V = voltage and I = current, show that high voltage V is needed to minimize the magnitude of the ohmic resistive heating losses: I^2R, where R is the resistance of the transmission line wire</p>
	First Midterm		Monday September 30
15	10/2	10/9	<p>Reading Assignment 13. High Voltage Direct Current for Power Transmission 14. Smart Electrical Grid and Metering</p> <p>Written Assignment In what way does HVDC power transmission reduce the resistive heating losses compared with HVAC?</p> <p>Explain and sketch two diagrams showing the advantages of HVDC over HVAC for the long-distance conveyance of electrical power from the perspectives of:</p> <ol style="list-style-type: none"> 1. Capital costs, 2. Transmission energy losses as ohmic heating and corona discharge.
16	10/4	10/11	<p>Reading Assignment 15. Hydrogen Storage</p> <p>Written Assignment List the methods under consideration for hydrogen storage.</p> <p>Hydrogen can be combined with carbon and stored as a hydrocarbon compound. Write a one-page summary of the paper: Rachel Beck and Magdi Ragheb, "Production of Carbon-Neutral Hydrocarbons From CO₂ and H₂ 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.</p>
17	10/7	10/14	<p>Reading Assignment 16. Metal Hydrides</p> <p>Written Assignment Describe the main properties of $LaNi_5H_6$ as a hydrogen storage medium.</p> <p>List some chemical hydrides used in hydrogen energy storage.</p> <p>List some borohydrides used in hydrogen energy storage.</p> <p>Draw a diagram of a system using a fuel cell in conjunction with a hydride storage system.</p>
18	10/9	10/16	<p>Reading Assignment 15. Hydrogen Storage</p>

			<p>24. Carbon Capture and Storage</p> <p>Written Assignment Describe the Van't Hoff Equation in relation to metal hydrides energy storage.</p> <hr/> <p>Compare the energy input needs for the storage of Hydrogen in different forms:</p> <p>Compressed Hydrogen For the adiabatic compression of hydrogen, the compression energy in MJ/kg (= 1,055 BTU) is: 47 MJ/kg, for 10,000 psi 36 MJ/kg, for 5,000 psi</p> <p>Liquefied hydrogen For cryogenic liquid hydrogen, the theoretical cooling energy expenditure is: 2.94 MJ/kg, for gas from 25 °C 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:</p> $\eta_{\text{Reverse Carnot}} = \frac{Q_{\text{extraction}}}{Q_{\text{rejection}} - Q_{\text{extraction}}} = \frac{T_2 \Delta S}{T_1 \Delta S - T_2 \Delta S} = \frac{T_2}{T_1 - T_2}$ <p>For liquefaction from $T_1 = 25 \text{ °C} = 25 + 273 \text{ K} = 298 \text{ K}$ to $T_2 = 20 \text{ K}$,</p> $\eta_{\text{Reverse Carnot}} = \frac{20}{(25 + 273) - 20} = \frac{20}{298 - 20} = \frac{20}{278} = 0.0719 = 7.19 \text{ percent}$ <p>This lead to actual liquefaction energies for a refrigeration efficiency of 7.19 percent of: Refrigeration energy = $3.4 / 0.0719 = 47.3 \text{ MJ/kg}$, for gas to liquid at 20 K Vaporization and warmup = 3.4 MJ/kg Total = ??? MJ/kg</p>
19	10/11	10/18	<p>Reading Assignment 26. Pumped Energy Storage 27. Pumped Storage in Association with the Red Sea to Dead Sea Peace Canal</p> <p>Written Assignment Consider a hydroelectric pumped energy storage facility producing power from stored sea water at a discharge rate of 39 m³/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 power generation? c) Calculate the potential yearly energy production in MW.hrs.</p>
20	10/14	10/21	<p>Reading Assignment 28. Pumped Storage Qattara Depression Solar Hydroelectric Power Generation</p> <p>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.</p>

			Explain the advantages of the proposed approach in the paper to the earlier pumped energy storage project.
21	10/16	10/23	
22	10/18	10/25	
23	10/21	10/28	
24	10/23	10/30	
25	10/25	11/1	
26	10/28	11/1	
27	11/30	11/1	
	Friday November 1st	11/1	First midterm exam during class period
28	11/3	11/10	

Assignments 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.