**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.

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| **Number** | **Date****Assigned** | **Due****Date** | **Description** |
| **1** | **8/25** | **9/1** | **Reading Assignment**[**Preface**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CTitle-Preface.pdf)**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.

|  |  |
| --- | --- |
| 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 |

capita: personUsing 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. |
| **2** | **8/27** | **9/3** | **Reading Assignment**[**Title-Preface**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CTitle-Preface.pdf)**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**](https://www.rte-france.com/en/eco2mix/eco2mix-mix-energetique-en)**or:**[**https://www.rte-france.com/en/eco2mix/power-generation-energy-source**](https://www.rte-france.com/en/eco2mix/power-generation-energy-source) |
| **3** | **8/29** | **9/5** | **Reading Assignment**[**Introduction**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CIntroduction.pdf)**Written AssignmentList 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**](https://www.mragheb.com/NPRE%20498ES%20Energy%20Storage%20Systems/Energy%20Storage%20Options.pdf)**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: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
| **5** | **9/5** | **9/12** | **Reading Assignment**[**2. Solar Thermal Power and Energy Storage Historical Perspective**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CSolar%20Thermal%20Power%20and%20Energy%20Storage%20Historical%20Perspective.pdf)**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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| **Reading Assignment**[**2. Solar Thermal Power and Energy Storage Historical Perspective**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CSolar%20Thermal%20Power%20and%20Energy%20Storage%20Historical%20Perspective.pdf)**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?**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.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Project | Type | Storage medium | Cooling loop | Nominal temperature[oC] |
| Cold | Hot |
| Irrigation PumpCoolidge, Arizona, USA | Parabolic Trough | Oil | Oil | 200 | 228 |
| IEA-SSPSAlmeria, Spain | Parabolic Trough | Oil | Oil | 225 | 295 |
| SEGS IDaggett, California, USA | Parabolic Trough | Oil | Oil | 240 | 307 |
| Solar OneBarstow, California, USA | Central Receiver | OilSandRock | Steam | 224 | 304 |
| CESA -1Almeria, Spain | Central Receiver | Molten salt | Steam | 220 | 340 |
| THEMISTargasonne, France | Central Receiver | Molten salt | Molten salt | 250 | 450 |
| Solar Two,Barstow, California, USA | Central Receiver | Molten salt | Molten salt | 275 | 565 |

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| **6** | **9/8** | **9/15** | **Reading Assignment**[**2. Solar Thermal Power and Energy Storage Historical Perspective**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CSolar%20Thermal%20Power%20and%20Energy%20Storage%20Historical%20Perspective.pdf)**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, KNO2, NaNO2 | 250 | 450 |
| Nitrate salts, NaNO3, KNO3 | 265 | 585 |
| Carbonate salts, Na2CO3 | 450 | 850 |
| Liquid Na | 270 | 530 |

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| **7** | **9/10** | **9/17** | **Reading Assignment**[**3. Thermal Energy Storage**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CThermal%20Energy%20Storage.pdf)**4**[**. Thermal Energy Storage with Solar Power Generation**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CThermal%20Energy%20Storage%20with%20Solar%20Power%20Generation.pdf)**Written AssignmentClassify 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**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CThermal%20Energy%20Storage%20with%20Solar%20Power%20Generation.pdf)**Written AssignmentList 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 Assignment5.** [**Battery Technology**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CBattery%20Technology.pdf)**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**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CElectric%20Vehicles%20Technology.pdf)**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 Assignment7.** [**Energy Hydrogenation and Decarbonization**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CEnergy%20hydrogenation%20and%20decarbonization.pdf)**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 Assignment7.** [**Energy Hydrogenation and Decarbonization**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CEnergy%20hydrogenation%20and%20decarbonization.pdf)**Written Assignment**Compare the voltages generated by a single fuel cell element when it is operated at:a. 20 oC,b. 100 oC.Use: , ,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 cells are needed for a 12-Volt battery?****How many cells are needed for a 19-Volt battery?** |
| **13** | **9/24** | **9/29** | **Reading Assignment7.** [**Energy Hydrogenation and Decarbonization**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CEnergy%20hydrogenation%20and%20decarbonization.pdf)[**8. Steam Reforming**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CSteam%20Reforming.pdf)**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**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CCarbon%20Dioxide%20Reforming.pdf)**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: With Ni and Co used as catalysts, the following reaction would occur:  If, instead, a Fe catalyst is used the reaction proceeds as follows:  |
|  | **9/29** |  | **First Midterm Exam** |
| **15** | **10/1** | **10/8** | **Reading Assignment**Rachel Beck and Magdi Ragheb, "[Production of Carbon-Neutral Hydrocarbons From CO2 and H2 In Lieu of Carbon Capture and Storage (CCS)](https://www.mragheb.com/Carbon%20Neutral%20Products.pdf)," 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 Assignment9.** [**Carbon Dioxide Reforming**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CCarbon%20Dioxide%20Reforming.pdf)**10.** [**High Temperature Water Electrolysis for Hydrogen Production**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CHigh%20Temperature%20Water%20Electrolysis%20for%20Hydrogen%20Production.pdf)**11.** [**Thermochemical Iodine Sulfur Process for Hydrogen Production**](file:///C%3A%5Cmragheb%5CNPRE%20498ES%20Energy%20Storage%20Systems%5CThermochemical%20Iodine%20Sulfur%20Process%20for%20Hydrogen%20Production.pdf) **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:And the overall reaction:What compounds act as catalysts in the overall reaction? |
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 **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.