

Pro-Green Diploma
Energy Storage technologies PRGR606 – Spring/2018

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Overview of the Course

The course covers the fundamental principles of energy storage technologies, the main economics aspects of each technology and a case study analysis of a particular project. The technologies that will be discussed encompass solar power (solar chimneys, geothermal and Photovoltaic), chemical storage (biofuels, hydrogen), electrochemical (batteries), thermal (thermocline, molten salt, and ice storage), mechanical (compressed air storage, flywheel, and pumped hydroelectric energy), and electrical (super capacitors, and superconducting magnetic energy storage) and Hydropower (Tidal and waves) and wind power.

Credit Hours

2 crt.

Delivery Format

The course is delivered online through Moodle. Topics will be available weekly for student where an activity is assigned at the end of each. (<http://moodle.progrendiploma.com>).

Course Prerequisites

Basic calculus, circuit analysis, thermal and fluid science, physics, electronics, and economics

Course Goals

At the end of the course, students will:

1. Have a clear understanding of the need and the nature of the storage required in operating renewable energy systems.
2. Have a clear understanding of the different storage technologies currently in wide use within sustainable systems.

3. Be able to analyze and design a sustainable energy system with associated storage and assess its economics and technical operation.

Course Objectives

The objectives of this course are:

1. To provide students with the fundamental principles and devices and systems used to store energy resources in their different forms.
2. To help students understand how to determine the size of storage devices as affected by their operational nature and derive their basic economics attributes when associated with their applications.
3. To develop hands on experience in a study case of a renewable energy system involving storage whereby the students will use available software to design a sustainable energy system with associated storage and study how the storage size can affect the economics and the quality of operation.

Topics Covered

Topics Covered	Equivalent to 60 minute lectures
1. Introduction and history to renewable power generation and storage	2
2. Energy Storage services	3
3. Energy storage technologies: Mechanical (compressed air, hydropower, flywheels), electrical (Super-capacitors) and electrochemical (Batteries)	4
4. Solar Thermal and geothermal Power	4
5. Hydropower, tidal power and wave power	4
6. Biomass and fuel cells	4
7. Photovoltaic (PV) and wind Power	3
8. Energy storage impact, economics and society	2

Texts and Supplementary Materials

- Lecture Notes Published on Moodle
- **Text books** : John Andrews and Nick Jelley, Energy Science: Principles, technologies and Impacts (3rdEdition), Oxford University Press, 2017
- Ibrahim Emir Dinçer, Marc A. Rosen (2011), Thermal energy storage [electronic resource]: systems and applications, **Hoboken, N.J. : Wiley, 2011**
- Dhruv Bhatnagar and Verne Loose (2012): *Evaluating Utility Procured Electric Energy Storage Resources: A Perspective for State Electric Utility Regulators*, **Report No. SAND2012-9422, November, Sandia National Laboratories Albuquerque, New Mexico 87185 and Livermore, California 94550**

- Rastler, D. (2010). “*Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits*”, **Palo Alto, CA: Electric Power Research Institute.**
- Abbas A. Akhil, Georgianne Huff, Aileen B. Currier, Benjamin C. Kaun, Dan M. Rastler, Stella Bingqing Chen, Andrew L. Cotter, Dale T. Bradshaw, and William D. Gauntlett, *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA, SAND 2013-5131, SANDIA National Laboratory, 2013.*
- H. Y. Al-Ashkar, S. H. Karaki, M. Al-Hindi, and K. Abou-Ghali: “Modeling and Simulation of Solar Thermal Electric Energy and Water Production Systems”, Paper # 2013-3742, JPC/IECEC 2013 Conference, July 14-17, 2013.
- **The following energy research agencies websites:**
- http://global.oup.com/uk/orc/physics/andrews_jelley3e/
- http://www1.eere.energy.gov/vehiclesandfuels/technologies/energy_storage/index.html
- <http://storagealliance.org/about.html>
- <https://energy.gov/eere/vehicles/vehicle-technologies-office>
- <http://www.sandia.gov/ess/>
- http://energyenvironment.pnnl.gov/ei/energy_storage.asp
- <http://www.nrel.gov/vehiclesandfuels/energystorage/publications.html>

Technical Requirements

- Flash
- Java Runtime Environment
- Intermediate computer skills
- MATLAB
- HOMER
- Select-Tool

Professional Components

Technology: 50 %

System Modeling: 20 %

Sustainability and Economics: 30%

Grading Policy

The grades in this course break down as follows:

Discussion Forum	20 pts
Knowledge checks/exams	30 pts
Weekly Assignments	30 pts
Group Project	20 pts
Total Points	100 pts

Description of Course Requirements (assessments)

Case Study (40%), Quizzes/Exam (30%), Student Contribution (30%),
Students need to submit answering sheets for assignments and case studies per email or Moodle.

Discussion Forum

You will be assigned to do some discussions or answer open questions within a time limit that will be fixed after the end of each chapter. You will be guided to what to submit, when and within which frame of work (individual or group) when the chapter is published on Moodle.

Knowledge Checks

You will take quizzes (Knowledge checks) throughout the semester, all delivered via Moodle. These quizzes include multiple-choice questions and essay writing. The quiz content will be largely based on video lectures and readings.

Group Project

There will be one group project. Grading of this project will be on an "all or nothing" basis. The project will be a "brief" of a case or current event that relates to the chapters covered in the textbook. Your submission should be typed, single-spaced, with 1-inch margins and a 12-pt. font (no more than three pages).

Internet Etiquette

Netiquette (short for "network etiquette" or "Internet etiquette") is a set of social conventions that facilitate interaction over networks.

General Rules

1. Make your messages easier to read by making your paragraphs short and to the point.
2. TYPING IN ALL CAPS IS CONSIDERED SHOUTING ON THE INTERNET.
3. Messages in all lowercase letters can be difficult to read, instead, use normal capitalization.
4. *Asterisks* surrounding a word can be used to make a stronger point.

5. Be careful when using sarcasm and humor. Without face-to-face communications your joke may be viewed as criticism. When being humorous, use emoticons to express humor. (Tilt your head to the left to see the emoticon smile) :-) = happy face for humor

6. Never give your user ID or password to another person. System administrators that need to access your account for maintenance or to correct problems will have full privileges to your account.

Make-up Policy

Make up are made after proof of sickness or legal/family issues.

Tentative Schedule

Day/ Week	Topic	Activity	Due Date
Week 1: Feb 16- 23 Chapter I.	Introduction to energy science: demand, production, storage and trend	Individual research for power plants, renewable, storage systems available in the current living city	Feb. 23. 2018
Week 2: Feb. 23- Mar. 5 Chapter II.	Energy Storage services	Forum discussion: 1- mention bulk services of a lithium ion battery storage system. 2- estimate LCOE	Mar. 5. 2018
Week 3-4. Mar. 5- Mar. 14 Chapter III.	Energy storage technologies: compressed air, super-capacitors, conductors, flywheels and batteries	1-Assignments, 2- knowledge check	March 16
Week 4 and 5. Mar. 14- 28. Chapter IV.	Solar thermal and Geothermal	Assignments, forum, Knowledge check/Quiz	March 30
Week 6 and 7. Mar. 26 – April 9 Chapter V.	Hydropower, tidal and wave power	Assignment, case study.	April 10
Week 8-9. April 10-23 Chapter VI.	Biomass and fuel cells	Assignment, Forum discussion	April 23
Week 10-11. April 23- May. 4 Chapter VII.	Photovoltaic and wind power	assignments	May 5
Week 12. May.4- May 10 Chapter VIII.	Energy storage impact, economics and society	Forum discussion, Knowledge check/ Exam	May 17

