Course Type	Course Code	Name of Course	L	T	P	Credit
OE	PHO403	ENERGY STORAGE TECHNOLOGIES	3	0	0	9

Course Objective
The students are expected to identify the new methodologies / technologies for effective storage of energy resources.
Learning Outcomes
1. To understand the need, importance of energy sector and scope of energy resources under Indian and global context. 2. To understand the various forms energy storage methods. 3. To understand the importance future energy storage technologies, like hydrogen energy storage, batteries.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1.	**Introduction**: Energy source and demand, Energy scenario of world and India, Classification of energy resources and reserves, Energy consumption pattern, Environmental impact of different resources of energy, Global and Indian energy scenario.	03	Students will learn about energy sources and its current utilization
2.	**Energy storage systems overview:** Scope of energy storage, needs and opportunities in energy storage, Technology overview and key disciplines, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors.	04	Students will learn about the overview about the energy storage technologies.
3.	**Thermal storage system:** Heat pumps, hot water storage tank, Solar thermal collector, Application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation of thermal energy storage systems.	06	Students will be familiar with the thermal storage systems.
4.	**Chemical storage system**: Concept of chemical storage of solar energy, Application of chemical energy storage system, Advantages and limitations of chemical energy storage, challenges, and future prospects of chemical storage systems.	08	In this topics, students will learn about chemical storage systems.
5.	**Electromagnetic storage systems:** Double layer capacitors with electrostatically charge storage, Superconducting magnetic energy storage (SMES), Concepts, Advantages and Limitation of electromagnetic energy storage systems, and future prospects of electrochemical storage systems.	05	In this unit, students will learn about the electromagnetic storage systems.
6.	**Electrochemical storage system: Batteries**, Working principle of battery, primary and secondary (flow) batteries, major battery chemistries and their voltages- Li-ion battery & Metal hydride battery vs. lead-acid battery. **Supercapacitors**, Working principle of supercapacitor, types of supercapacitors, difference between battery and supercapacitors, Introduction to Hybrid electrochemical supercapacitors, **Fuel cell**, Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery/supercapacitor systems.	09	Student will understand the various electrochemical storage systems, including, batteries, supercapacitors, and fuel cells.
7.	**Hydrogen Energy production and storage**: Thermal-Steam reformation, thermo chemical water splitting, gasification-pyrolysis, nuclear thermal catalytic and partial oxidation methods. Electrochemical Electrolysis, photo electro chemical method. general storage methods, compressed storage-composite cylinders, metal hydride storage, carbon-based materials for hydrogen storage. Hydrogen powered vehicles.	10	Students will learn hydrogen production and storage of materials, and Hydrogen power vehicles.
	Total	42	

Text Books:

1. Frank S. Barnes and Jonah G. Levine, Large Energy Storage Systems Handbook (Mechanical and Aerospace Engineering Series), CRC press (2011)
2. Ralph Zito, Energy storage: A new approach, Wiley (2010)
3. G. D. Rai - Non-Conventional Energy Sources, Khanna Publishers, 2013.

Reference Books:

1. Robert A. Huggins, Energy storage, Springer Science & Business Media (2010)
2. Pistoia, Gianfranco, and Boryann Liaw. Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost. Springer International Publishing AG, 2018
3. Renewable Energy Resources: Twidell & Weir, CRC Press, 2015.
4. Solar Energy, S.P. Sukhatme, Tata McGraw-Hill, 2017.
5. Non Conventional Energy Systems: K M. Mittal, A H Wheeler Publishing Co Ltd., 1999.
6. Renewable Energy Technologies: Ramesh & Kumar, Narosa publication, 2018.
7. Renewable energy sources and conversion technology by N.K. Bansal, M. Kleemann, & M. Heliss, Tata McGrawHill, 1990.