MODULE TITLE	**Energy Storage Technology**	**CREDIT VALUE**	**15**
MODULE CODE	**ENE3007**	**MODULE CONVENER**	**Prof Xiaohong Li (Coordinator)**

DURATION: TERM	**1**	**2**	**3**
DURATION: WEEKS		**12**	

Number of Students Taking Module (anticipated)	**30**

DESCRIPTION - summary of the module content

Renewable energy is expected to provide a central solution to our need for a sustainable fuel. However, major challenges presented by renewable energies, such as fluctuations in output, unavailability, and unpredictability, limit their popularity. As a solution to these problems, energy storage technology (EST) is growing in significance. EST is to convert/store energy and to release energy in a controlled fashion when required, which improves energy efficiency and stabilizes operation of electricity grid.
In this module students will obtain general understanding of a number of energy storage systems. Technologies such as mechanical energy storage system (e.g. pumped hydro, compressed air), hydrocarbon storage, lithium ion battery, redox flow battery, lead acid battery, hydrogen and fuel cells, and thermal energy storage will be studied in terms of principles of operation, characteristics, development progress and challenges.

AIMS - intentions of the module

The aim of this module is to introduce and evaluate major energy storage systems. Some key concepts, techniques and strategic choices will be explored including principles and fundamentals of EST, operation parameters, design consideration and system optimisation. In addition, cost effectiveness, environmental compatibility and energy/materials sustainability will be taken into consideration.

INTENDED LEARNING OUTCOMES (ILOs) (see assessment section below for how ILOs will be assessed)

On successful completion of this module, **you should be able to:**

Module Specific Skills and Knowledge:
Show knowledge, understanding, and ability to quantify the relative capacities and efficiencies of various types of energy storage technologies.
Apply the knowledge and understanding of energy storage systems to identify optimal energy storage solutions in varying application areas.
Understand key concept of battery design, e.g. redox couples, electrode materials, electrolyte, etc.
Compare various batteries in the light of characteristics such as open circuit potential, power density, energy efficiency and charge-discharge behaviour.
Understand redox flow battery (RFB): RFB concepts and principles, classification, timeline of its development, progress and remaining challenges.
Discipline Specific Skills and Knowledge:
Recognise existing and developing technologies for energy storage.
Describe the fundamentals of energy storage system.
Suggest an appropriate battery technology for a particular application.
Identify and size an energy storage system for a given application.
Personal and Key Transferable/ Employment Skills and Knowledge:
Demonstrate appropriate mathematical skills – taught in lectures, practiced through worksheets, assessed in assignment and in-class test.
Access the literature on energy storage technology and write reports on their development.
Appreciate an industrial perspective of technology development.
Plan and execute practical tests of energy storage equipment and critically analyse the results of tests.

SYLLABUS PLAN - summary of the structure and academic content of the module

Overview of energy storage technologies.
Hydrocarbon storage – storage of LPG, LNG and liquid fuels for strategic / security needs; design details for solution mined and excavated caverns; volume and pressure calculations for required energy storage capacity.
Hydrogen economy – hydrogen production, storage, infrastructure, safety, cost, environmental concerns.Carbon capture and storage – locations and types of suitable CCS reservoirs (notably North Sea); calculations for CCS capacity based on reservoir porosity, thickness, area and pressure.
Fundamentals of electrochemistry – electrochemical principles and reactions, electroanalytical techniques, factors affecting battery performance. Conventional batteries - lead acid, nickel-cadmium batteries, etc.
Advanced batteries - redox flow battery, lithium ion battery, sodium-sulphur battery.
Fuel cells - hydrogen fuel cell, direct-methanol fuel cell, molten carbonate fuel cell, solid oxide fuel cells, etc.

LEARNING AND TEACHING

LEARNING ACTIVITIES AND TEACHING METHODS (given in hours of study time)

Scheduled Learning & Teaching Activities	40.00	**Guided Independent Study**	110.00	**Placement / Study Abroad**	0.00

DETAILS OF LEARNING ACTIVITIES AND TEACHING METHODS

Category	Hours of study time	Description
Scheduled learning and teaching activities	40	Lectures with integrated tutorials
Guided independent study	110	Private study

ASSESSMENT

FORMATIVE ASSESSMENT - for feedback and development purposes; does not count towards module grade

Form of Assessment	Size of Assessment (e.g. duration/length)	ILOs Assessed	Feedback Method
Not applicable			

SUMMATIVE ASSESSMENT (% of credit)

Coursework	50	Written Exams	50	Practical Exams	0

DETAILS OF SUMMATIVE ASSESSMENT

Form of Assessment	% of Credit	Size of Assessment (e.g. duration/length)	ILOs Assessed	Feedback Method
Coursework: Energy storage design report	50	3000-word report including figures and tables	1,2,6,7,9,10,11,12	Written feedback
In class Test: Electrochemical energy storage	50	1.5 hours	1,3,4,5,7,8,10,11,13	Written feedback

DETAILS OF RE-ASSESSMENT (where required by referral or deferral)

Original Form of Assessment	Form of Re-assessment	ILOs Re-assessed	Time Scale for Re-reassessment
Summative assessment	Additional assessment	As above	August Ref/Def period

RE-ASSESSMENT NOTES

As above 1 piece of coursework 50% and 1 in class test 50%.

RESOURCES

INDICATIVE LEARNING RESOURCES - The following list is offered as an indication of the type & level of information that you are expected to consult. Further guidance will be provided by the Module Convener

Basic reading:
DOE/EPRI Electricity Storage Handbook, US Department of Energy
https://www.energy.gov/oe/activities/technology-development/energy-storage
European Energy Storage Technology Development Roadmap towards 2030
https://ease-storage.eu/wp-content/uploads/2015/10/EASE-EERA-recommendations-Roadmap-LR.pdf
International Energy Outlook 2019 with Projections to 2050
https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf from US Department of Energy (published in September 2019)
Energy Flow Chart 2018 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/818151/Energy_Flow_Chart_2018.pdf from Department for Business, Energy & Industrial Strategy (published 25 July 2019)
Digest of UK Energy Statistics (DUKES): Energy 2019
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/820637/Chapter_1.pdf from Department for Business, Energy & Industrial Strategy (last updated 25 July 2019)
Digest of UK Energy Statistics (DUKES): Renewable sources of energy 2019
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/840014/Chapter_6.pdf from Department for Business, Energy & Industrial Strategy (last updated 25 July 2019)

Reading list for this module:

Type	Author	Title	Edition	Publisher	Year	ISBN	Search
Set	Linden, D. & Reddy, T.B.	Handbook of Batteries	3rd	McGraw Hill	2003	0-07-135978-8	[Library]
Set	Sorensen, B.	Renewable energy conversion, transmission, and storage Part IX: High-quality energy storage	1st	Academic Press	2007	9780123742629	[Library]
Set	Pletcher, D.	A First Course in Electrode Processes	2nd	Cambridge:RSC	2009	9781847558930	[Library]
Set	Barnes, F.S. & Levine, J. G.	Large Energy Storage Systems Handbook	1st	CRC Press	2011	9781420086003	[Library]
Set	Sioshansi, F.P.	Smart Grid: Integrating Renewable, Distributed & Efficient Energy	1st	Oxford: Academic	2011	9780123864529	[Library]
Set	Ford, R.M. & Burns, R.M	Energy Storage Technologies for Power Grids and Electric Transportation	1st	Nova Science Publishers	2012	9781622573516	[Library]
Set	Demirel, Y.	Energy: Production, Conversion, Storage, Conservation, and Coupling	1st	London: Springer	2012	9781447123729	[Library]
Set	Zhang, J., Zhang, L., Liu, H., Sun, A. & Liu, R.	Electrochemical Technologies for Energy Storage and Conversion	1st	Weinheim: Wiley-VCH	2012	9783527328697	[Library]
Set	Sorenson, B.	Hydrogen and Fuel Cells: Emerging Technologies and Applications	2nd	Academic Press	2012	9780123877093	[Library]
Set	Grasman, S.E.	Hydrogen energy and vehicle systems		CRC Press	2013	9781439826812	[Library]
Set	Menictas, C., Skyllas-Kazacos, M. & Lim, T.M.	Advances in batteries for large- and medium-scale energy storage: Applications in power systems and electric vehicles	1st	Woodhead Publishing	2014	9781782420132/132	[Library]
Set	Du, P. & Lu, L.	Energy Storage to Smart Grids: Planning and Operation for Renewable and Variable Energy Sources	1st	Academic Press	2015	9780124104914	[Library]

CREDIT VALUE	15	ECTS VALUE	7.5
PRE-REQUISITE MODULES	CSM2318, CSM2188, CSM1037		
CO-REQUISITE MODULES			
NQF LEVEL (FHEQ)	6	AVAILABLE AS DISTANCE LEARNING	No
ORIGIN DATE	Thursday 06 July 2017	LAST REVISION DATE	Tuesday 02 February 2021
KEY WORDS SEARCH	Energy storage; mechanical energy storage, hydrocarbon storage; carbon capture and storage; electrochemical energy storage, batteries; hydrogen & fuel cells; thermal storage; hydrogen economy.		