School of
Engineering and Computer Science
Te Kura Mātai Pūkaha, Pūrorohiko

Prescription

This course will provide the students with insight into technologies to convert generated energy into useful fuels or power in the economy and society. It will specifically focus on bioenergy conversion processes, such as gasification, pyrolysis and torrefaction; chemical storage (solid-state and liquid batteries); and pumped and mechanical storage. For each technology platform the underlying physics and chemistry will be examined, with related practical experiments in the laboratory. The life cycle (sustainability) implications of the different,= technologies will also be explored, including manufacturing.

Course learning objectives

Students who pass this course will be able to:

1. Explain the scientific principles of different conversion and storage technology systems
2. Analyse the sustainability and efficiencies of the conversion and storage technology systems
3. Critically review an energy conversion or storage technology to identify the efficiency gains that can be achieved
4. Design and demonstrate through simulation and calculations an efficiency improvement to an energy storage configuration

Course content

The course consists of seven components. First, it provides students with the key concepts needed to understand energy storage, including the basic principles of enthalpy and entropy, and chemistry. Second, it provides a deeper understanding of different electrochemical storage platforms. Third, the approaches to thermal energy storage are explored, with a more detailed evaluation of the working of heat pumps. Fourth, the various bioenergy platforms are reviewed, as well as efficiency of conversions to different fuels. Fifth, the hydrogen value chain, as a possible energy vector, is discussed in greater depth. Sixth, the students are provided with a basic understanding of other storage alternatives relating to pumped and mechanical storage, and superconductors. Finally, options for system integration are investigated from a sustainability perspective.

Withdrawal from Course

Withdrawal dates and process:
https://www.wgtn.ac.nz/students/study/course-additions-withdrawals

Lecturers

Alan Brent (Coordinator)

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227 Alan MacDiarmid Building, Kelburn

Teaching Format

This course will be offered in-person and online. For students in Wellington, there will be a combination of in-person components and web/internet based resources. It will also be possible to take the course entirely online for those who cannot attend on campus, with all the components provided in-person also made available online.

During the trimester there are weekly contact lectures, tutorials, and laboratory sessions. Laboratory work will explore battery chemistry and performance, as well as the storage and generation of electricity using electrolysers and fuel cells.

Student feedback

Student feedback on University courses may be found at: http://www.cad.vuw.ac.nz/feedback/feedback_display.php

Dates (trimester, teaching & break dates)

- Teaching: 13 July 2020 - 18 October 2020
- Break: 17 August 2020 - 30 August 2020
- Exam period: 19 October 2020 - 25 October 2020

Class Times and Room Numbers

13 July 2020 - 16 August 2020

- **Monday** 09:00 - 09:50 – 403, Murphy, Kelburn
- **Wednesday** 09:00 - 09:50 – 403, Murphy, Kelburn

31 August 2020 - 18 October 2020

- **Monday** 09:00 - 09:50 – 403, Murphy, Kelburn
- **Wednesday** 09:00 - 09:50 – 403, Murphy, Kelburn

Other Classes

Laboratory sessions will be for less than 2 hours, but are available over 4 hours from 12h00 to 16h00 on Wednesdays in AM407.

Set Texts and Recommended Readings

Required

The course will use the set text below, available as an e-book.

Additional material is made available online, via Blackboard, to assist with understanding the various concepts and the current debate around the renewable energy technology systems, which include: webinars, explanation videos, and other resources. Journal papers are made available via Talis Aspire with specific case studies and academic literature that are discussed and/or from part of the tutorials. In some weeks students are required to identify relevant literature, as part of online discussions, through the University library.

- Robert A. Huggins (2016), *Energy Storage: Fundamentals, Materials and Applications.* Second edition, Springer.

Mandatory Course Requirements

In addition to achieving an overall pass mark of at least 50%, students must:

- Achieve an average of at least 40% on the assignments.
- Achieve an average of at least 40% for the tests.

If you believe that exceptional circumstances may prevent you from meeting the mandatory course requirements, contact the Course Coordinator for advice as soon as possible.

Assessment

Assessment Item	Due Date or Test Date	CLO(s)	Percentage
Battery storage system assignment (20 hours)	31 August 2020	CLO: 2,3	25%
Test 1 (2 hours)	2 September 2020	CLO: 1,2,3	20%
Test 2 (2 hours)	7 October 2020	CLO: 1,2,3	20%
Tutorial/laboratory exercises with a report on their learning (5 hours)	16 October 2020	CLO: 1,2,3	10%
Hydrogen storage system assignment (20 hours)	23 October 2020	CLO: 2,3,4	25%

Penalties

Work submitted late will be subject to a penalty of 10% of the total mark per day.

Extensions

Individual extensions will only be granted in exceptional personal circumstances, and should be negotiated with the course coordinator before the deadline whenever possible. Documentation (eg, medical certificate) may be required.

Submission & Return

All work must be submitted through the Blackboard submission system. Marks and comments will also be returned through the Blackboard marking system.

Workload

Although the workload varies from week to week, students are expected to spend approximately 10 to 12 hours per week on the course, to give a total of 150 hours study time. A plausible and approximate breakdown for these hours would be: lectures (2 hours); tutorials (1 hour); laboratories (2 hours); reading, review and online discussions (3 hours); and modelling and written assignments (3 hours).

Teaching Plan

Week 1

Lecture	▪ Fundamental concepts – enthalpy, entropy etc.
Tutorial	▪ Fundamental calculation exercises
Laboratory	▪ No lab in week 1

Week 2

Lecture	▪ Reversible chemical reactions ▪ Organic fuels
Tutorial	▪ Balancing chemical reactions ▪ Examples from the textbook
Laboratory	▪ OH&S briefing ▪ SCPS demonstrator

Week 3

Lecture	▪ Chemical storage – batteries, primary/secondary, redox flow, lithium
Tutorial	▪ Battery chemistry with SCPS
Laboratory	▪ Design assignment 1: Battery options for grid-scale systems for a wind farm. Prospects for longer time frames

Week 4

Lecture	▪ Battery efficiency/sustainability, BNEF view ▪ Hype vs reality
Tutorial	▪ Battery efficiency ▪ Calculations from textbook
Laboratory	▪ Modelling for assignment 1

Week 5

Lecture	▪ Thermal energy storage – sensible, latent. ▪ Molten salts, phase change materials ▪ Heat pumps (temperature / efficiency)
Tutorial	▪ Heat pump efficiency & COP
Laboratory	▪ Small packed bed experiment / demonstrator

Week 6

Lecture	▪ Bioenergy conversion – pyrolysis/torrefaction/gasification/biochar
Tutorial	▪ Guest lecture – Scion/BANZ
Laboratory	▪ Test 1: batteries, thermal storage, and heat pumps

Week 7

Lecture	▪	Gas to liquid synthesis (Fischer-Tropsch, MTG), methanation, ammonia synthesis
Tutorial	▪	Answers from Test 1
Laboratory	▪	Energy efficiency modelling - Coal vs NG

Week 8

Lecture	▪	Hydrogen – reforming, industrial use, compression electrolysis
Tutorial	▪	Japan carrier study
Laboratory	▪	Modelling efficiency of compression electrolysis

Week 9

Lecture	▪	Hydrogen – fuel cells, storage, transport, safety
Tutorial	▪	DoE review
Laboratory	▪	Fuel cell demo

Week 10

Lecture	▪	Hydrogen – applications & prospects
Tutorial	▪	Guest lecture - Hiringa
Laboratory	▪	Assignment 2: Energy efficiency of ammonia synthesis and usage

Week 11

Lecture	▪ Mechanical and pumped storage: compressed air, hydro (with the Onslow case), flywheels ▪ Electromagnetic storage
Tutorial	▪ Guest lecture: RRI superconductivity
Laboratory	▪ Test 2: bioenergy, GTL, hydrogen, mechanical and pumped storage

Week 12

Lecture	▪ Systems level and options analysis, including lifecycle and sustainability ▪ Review and wrap up
Tutorial	▪ Answers from Test 2
Laboratory	▪ Modelling for assignment 2

Communication of Additional Information

All online material for this course will be made available via Blackboard, which will also be used to facilitate discussions every week.

Links to General Course Information

- Academic Integrity and Plagiarism: https://www.wgtn.ac.nz/students/study/exams/integrity-plagiarism
- Academic Progress: https://www.wgtn.ac.nz/students/study/progress/academic-progess (including restrictions and non-engagement)
- Dates and deadlines: https://www.wgtn.ac.nz/students/study/dates
- Grades: https://www.wgtn.ac.nz/students/study/progress/grades
- Special passes: Refer to the Assessment Handbook, at https://www.wgtn.ac.nz/documents/policy/staff-policy/assessment-handbook.pdf
- Statutes and policies, e.g. Student Conduct Statute: https://www.wgtn.ac.nz/about/governance/strategy
- Student support: https://www.wgtn.ac.nz/students/support
- Students with disabilities: https://www.wgtn.ac.nz/st_services/disability/
- Student Charter: https://www.wgtn.ac.nz/learning-teaching/learning-partnerships/student-charter
- Terms and Conditions: https://www.wgtn.ac.nz/study/apply-enrol/terms-conditions/student-contract
- Turnitin: http://www.cad.vuw.ac.nz/wiki/index.php/Turnitin
- University structure: https://www.wgtn.ac.nz/about/governance/structure
- VUWSA: http://www.vuwsa.org.nz

Offering CRN: 30109

Points: 15
Prerequisites: ENGR 110 or 111; ENGR 121 (or MATH 141 and 151); ENGR 141 (or PHYS 114 and CHEM 114)
Duration: 13 July 2020 - 25 October 2020
Starts: Trimester 2
Campus: Kelburn