Imperial College London

MSc in Sustainable Energy Futures
Module specifications

securing our energy futures

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Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Legacy codes	DSS	OSS unit	CELCAT	Programme spec.	Local system(s)

Long title	Low Carbon Technologies
New long title	
New code	MECH70030
New short title	

Brief description of module *(approx. 600 chars.)*

The purpose of the module is to convey the fundamentals of modern/future energy systems in terms of their technical properties and economic and environmental impacts. Technologies/systems considered include solar photovoltaic electricity generation, wind and nuclear power. The module will also consider estimation of energy resources and demands along with the main sources of data and methods for analysis.

409 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N

HECOS codes

FHEQ level

Allocation of study hours

	Hours	
Lectures	27	
Group teaching	5.5	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled		*Incl. project supervision, fieldwork, external visits.*
Independent study	92.5	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term	Term 1	Other	

Ownership

Primary department	Energy Futures Lab
Additional teaching departments	Aeronautics
	Materials
	Chemical Engineering + Physics
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Rafael	Palacios
Topic Leader		Anna	Hankin
Topic Leader		Michael	Rushton
Lecturer		David	Woodhead
Lecturer		Jenny	Nelson
Lecturer		Philip	Sandwell
Lecturer		Piers	Barnes
Lecturer		Robin	Grimes

Learning and teaching

Module description

Learning outcomes

• Analyse the operating principles of photovoltaic solar cells and the role of materials in PV technology.
• Summarise the solar resource and solve simple problems in the design of solar systems to match that resource
• Recognise alternative useful ways of utilising solar energy, such as solar thermal and solar fuel
• Appraise the physics behind nuclear energy and reactor systems.
• Assess how nuclear power may be integrated into future sustainable energy systems by providing electricity and also process heat for industrial applications through co-generation.
• Evaluate alternative nuclear waste forms and which are appropriate for a given waste stream and predict the times over which radioactive materials remain a hazard.
• Analyse the operating principles of modern horizontal axis wind turbines.
• Calculate the energy potential of a wind turbine and understand the factors limiting the conversion efficiency of turbines.
• Perform, at a preliminary level, a wind farm site survey including resource assessment and incorporating economic and environmental factors.

Module content	• Nature of the solar resource • Photovoltaic materials • Physics of photovoltaic devices • Photovoltaic systems • Solar thermal, photoelectrochemical & PV recycling • Techno-economic analysis • A brief history of nuclear power. • Nuclear reactor physics. • Reactor systems, past, present and future. • The nuclear fuel cycle. • The issues of nuclear accidents and waste. • Nuclear co-generation. • Wind power distribution and wind turbine energy yield • Blade aerodynamics and the Betz Limit • Outline of turbine design • Electrical generators for wind turbines • Wind farm layout and wake effects • Offshore wind farms
Pattern of learning and teaching activities	The module will be taught in parallel with other autumn term modules. The solar, nuclear and wind components will be taught within three week blocks over the term. There will normally be one or two lectures each week with an associated weekly tutorial.
Learning and Teaching Approach	The module is delivered through lectures (during which the students are free to ask questions and are given small exercises to carry out on the spot) and interactive tutorials. Exercises are set to provide practice of applying key equations with support via a tutorial class. The wind coursework exercise is for assessment but help is provided via office hours with a GTA and on-line discussion.The nuclear component culminates in a day of group presentations - a key part of this are the question and answer sessions following each presentation which provides an opportunity for the entire class to enter a discussion on the issues raised, guided by the lecturers.
Assessment Strategy	This module presents opportunities for both formative and summative assessment. You will be formatively assessed through tutorial sessions. You will have additional opportunities to self-assess your learning via tutorial problem sheets. You will be summatively assessed by a written closed-book examination at the end of the module. The exam is specifically formulated to assess module learning outcomes. A wind coursework exercise is set to be worked on in small groups with outcomes assessed via a joint written report. A nuclear coursework exercise is set to be worked on in small groups with outcomes assessed via a group presentation.
Feedback	You will receive feedback on examinations in the form of an examination feedback report on the performance of the entire cohort. You will receive written and verbal feedback for the group coursework assignments. You will receive feedback on your performance whilst undertaking tutorial exercises, during which you will also receive instruction on the correct solution to tutorial problems.
Reading list	Handbook of Photovoltaic Science and Engineering, Antonio Luque, Steven Hegedus (2011) The Physics of Solar Cells, Jenny Nelson, Imperial College Press (2003) How to Drive a Nuclear Reactor, Colin Tucker The Fall and Rise of Nuclear Power in Britain, Simon Taylor An Atomic Empire: A Technical History of the Rise and Fall of the British Atomic Energy Programme, C.N. Hill Atomic Accidents: A History of Nuclear Meltdowns and Disasters: From the Ozark Mountains to Fukushima, James Mahaffey

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Module Specification

Basic details

			Earliest cohort	Latest cohort
UID		Cohorts covered		

Legacy codes	DSS	OSS unit	CELCAT	Programme spec.	Local system(s)

Long title: Methods for the Analysis of Energy Systems

New code: MECH70031

New short title:

Brief description of module *(approx. 600 chars.)*:

The purpose of the module is to provide students with a range of tools for the analysis of energy systems and resources from both technical/capability and environmental impact viewpoints. These will include thermodynamic methods for the analysis of energy systems with conventional thermal power plant and transport cycles used as case studies. The module also covers life cycle and scenario analysis, which is put into the context of Carbon Capture and Storage (CCS). Furthermore, the scientific computing component of the module introduces numerical methods to simulate energy systems using Python.

600 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit	HECOS codes
Credit value	5	10	N	

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	27	
Group teaching	16	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled		*Incl. project supervision, fieldwork, external visits.*
Independent study	82	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode: Taught/ Campus

Delivery term: Term 1

Other:

Other:

Ownership

Primary department	Energy Futures Lab
Additional teaching departments	Civil and Environmental Engineering
	Earth Science and Engineering
	Electrical and Electronic Engineering
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Graham	Hughes
Topic Leader		Anna	Korre
Topic Leader		Mark	Bruggemann
Lecturer		Sevket	Durucan
Lecturer		Fei	Teng

Learning and teaching

Module description

Learning outcomes	On successfully completing this module, you will be able to: • Assess the potential of energy systems from both a first law and second law perspective • Analyse the performance of common thermodynamic processes and cycles, and characterise their efficiency • Use life cycle analysis techniques to conduct whole life analyses of the impacts of energy systems and processes • Devise numerical models to analyse and simulate energy systems using Python • Apply the learned methodologies and techniques to industry relevant problems
Module content	• Introductory concepts and the First Law of Thermodynamics • Standard thermodynamic processes and cycles • Analysis techniques and examples • The Second Law of Thermodynamics and entropy • Industry perspective and case studies • Principles and Applications (Aggregates and minerals LCA; LCA of fossil fuels production and use; LCA of Li ion batteries for transport (production, use and recycling)) • LCA Allocation • Industrial decarbonisation, CO2 Capture and Storage • Energy, Water and Food Nexus • Systems of Equations and Data Representation • Numerical Differentiation and Integration • System Optimisation • Stochastic Optimisation
Learning and Teaching Approach	The material will be delivered primarily through large-class lectures introducing the key concepts and methods. Learning will be reinforced through self-paced tutorial question sheets completed individually or as part of small groups. Example solutions will also be supplied.

Assessment Strategy	Formative assessment will be available within the tutorials through the self-paced question sheets. The thermodynamics group coursework exercise includes a practical thermodynamic analysis and allows for a degree of self-directed exploration of the subject matter. The LCA and Scientific Computing individual assignments will draw on the techniques and approaches covered in the taught material.
Feedback	You will receive annotated and marked copies of your thermodynamics coursework report. These reports will be returned in conjunction with provision of general feedback comments to the whole cohort. You wil receive individual written feedback on your LCA and scientific computing coursework assignments.
Reading list	Cengel and Boles, Thermodynamics: An Engineering Approach – Chapters 1-3 are required pre-course reading

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Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Long title: Energy Economics and Policy

New code: | New short title:

Brief description of module *(approx. 600 chars.)*:

This module introduces students with engineering and physical science backgrounds to a selection of the key issues in energy economics and policy, emphasising how these topics must be considered closely with technology development initiatives in all sectors of the economy. It is expected that students would have the knowledge and skills to synthesise non-technical pathways to a net zero economy upon the completion of the module.

432 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	28	
Group teaching	4	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled		*Incl. project supervision, fieldwork, external visits.*
Independent study	93	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode: Taught/ Campus | Other:

Delivery term: Term 1 | Other:

Ownership

Primary department: Energy Futures Lab

Additional teaching departments: Centre of Environmental Policy; Business School

	Chemical Engineering
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Gbemi	Oluleye
Lecturer		Rob	Gross
Lecturer		Jim	Skea
Lecturer		Richard	Green
Lecturer		Iain	Staffell
Lecturer		Adam	Hawkes
Lecturer		Karen	Makuch
Lecturer		Milica	Fomicov
Lecturer		Joanne	Wade
Lecturer		Adam	Chase
Lecturer		Phil	Heptonstall
Lecturer		Richard	Hanna
Lecturer		John	Callaghan
Lecturer		James	Henderson

Learning and teaching

Module description

Learning outcomes	On successfully completing this module, you should be able to: •Evaluate the key non-technical issues that influence the design, operation, development, and transitions of energy systems in the UK, and internationally. •Identify the major non-technical issues that should be taken account of when achieving a climate related ambition.
Module content	The module is structured around the following thematic groups: •Policy •Economics and Markets •Sector-Specific applications - buildings, transport and industry •Coursework and Skills via Small Group Seminars
Learning and Teaching Approach	The module will be delivered primarily through large-class facilitative lectures introducing the key concepts and methods, supported by small group seminars. The content is presented via a combination of slides, whiteboard and visualizer. Learning will be reinforced through small group seminars.
Assessment Strategy	This module presents opportunities for both formative and summative assessment. Students will be formatively assessed through presentations given, and feedback on essays that will be submitted as part of the small group seminar. Specifically, Formative assessment is in four phases. Phase 1 is the receipt of a 1.5hr tutorial on writing essays, and detailed guidance notes. Phase 2 is feedback received during students presenations (the presentations are not assessed) - this involves a combination of peer feedback from other groups, and feedback from the seminar leader. Phase 3 will be feedback on content and depth provided from seminar group leaders to students upon receipt of their detailed essay outlines before final submission - students would have time to address the feedback before final submission of the essays. Phase 4 involves feedback given to students who attempt past exam questions during the revision class - the feedback would be from peers and the option convenor. Students have opportunities to self-assess their essays using the guide discussed during the introductory lecture. Students will be summatively assessed by a written essay and examination at the end of the module.

Feedback	Students will receive feedback on examinations in the form of an examination feedback report on the performance of the entire cohort. Students will also receive feedback on presentation, and essays using a feedback report. Further individual feedback will be available to students on request via this module's online feedback forum, through staff office hours and discussions with tutors.
Reading list	All background reading – it is not necessary to read them all! •Handbook of Energy Economics and Policy, 1st Edition, Alessandro Rubino Alessandro Sapio Massimo La Scala, Academic Press, 2021 •Energy Policy of the European Union, Schubert, Pollak & Kreutler, Palgrave Macmillan, 2016 •Net Zero by 2050, A Roadmap for the Global Energy Sector, IEA, 2021, Available from: https://iea.blob.core.windows.net/assets/beceb956-0dcf-4d73-89fe-1310e3046d68/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf •Policies for the Sixth Carbon Budget and Net Zero, 2020, https://www.theccc.org.uk/wp-content/uploads/2020/12/Policies-for-the-Sixth-Carbon-Budget-and-Net-Zero.pdf •IPCC, 2019: Summary for Policymakers Available from: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf •UK Energy Policy and the end of market fundamentalism, Rutledge & Wright, OUP, 2010 •Cambridge Centre for Smart Infrastructure and Construction 2020 - Flourishing Systems: https://www.cdbb.cam.ac.uk/files/flourishing-systems_final_digital.pdf

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Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Long title: Entrepreneurship Towards Zero Carbon Energy Systems

New code: MECH70033

New short title:

Brief description of module *(approx. 600 chars.)*:

This module covers entrepreneurship in the energy industry related to the transition to zero carbon energy systems, including both the industry's supply side and demand side. It is delivered somewhat in the style of a business school Master's programme (e.g. MBA) module, in content covering both theoretical and practical perspectives, and in delivery style putting an emphasis on class participation. The main aim is to equip students with key knowledge and skills that will be useful should they take up an entrepreneurial role (e.g. with a start-up company) at some point in their careers.

595 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	37	
Group teaching	0	*Incl. seminars, tutorials, problem classes.*
Lab/ practical	0	
Other scheduled	0	*Incl. project supervision, fieldwork, external visits.*
Independent study	88	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement	0	*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode: Taught/ Campus

Delivery term:

Other:

Other:

Ownership

Primary department: Energy Futures Lab

Additional teaching: Business School

departments	
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N

External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader	874351	John	Callaghan
Lecturer		Peter	Childs

Learning and teaching

Module description

Learning outcomes	On successful completion of the module, you will be able to: 1. Identify how entrepreneurship in the energy industry is similar to, and different than, entrepreneurship in other industries; 2.Assess key behaviours and actions of entrepreneurs as individuals, and understand how individual-level skills in entrepreneurship can be developed; 3. Present how ventures originate and develop either as independent start-up companies or as projects within corporations; 4. Apply a range of tools and techniques commonly used in entrepreneurship, e.g. as related to business planning and financial forecasting; 5. Assess the range, and relative advantages and disadvantages, of sources of finance for ventures; and 6. Analyse the challenges of growing ventures, including common causes of venture failure.
Module content	The module will cover the following main topics: 1. The meaning of entrepreneurship in context of the energy industry; 2. The energy entrepreneur as an individual; 3. The energy venture as, or within, an organisation; 4. Tools and techniques for energy entrepreneurs and ventures; 5. Entrepreneurial finance in energy; and 6. Energy venture development and growth.
Learning and Teaching Approach	The module will be delivered somewhat in the style of a business school Master's degree (e.g. MBA) course module. The class sessions will be highly participative, and you will be encouraged to continually contribute questions and answers, with the Module Leader sometimes 'cold calling' students. Some of the sessions will be orientated around written cases, which you must read and consider in advance of the sessions. There will be multiple opportunities for discussion with your fellow students, and part of the module's assessment is a group presentation which should be delivered in a practitioner style. However, class participation will not be graded.

Assessment Strategy	Your performance in the module will be assessed via i) an individual exam and ii) a group presentation. The exam and presentation are equally weighted, i.e. each will count for 50% of the module grade. The exam is intended to test your understanding of key concepts introduced in the module. The presentation, meanwhile, is an opportunity for you to demonstrate your abilities in researching, analysing, and communicating about an energy venture, applying what you have learned in the module to a real-life example. You will be formatively assessed and be offered feedback when submitting your group presentation venture proposal.
Feedback	All feedback will be provided in writing, and one-to-one discussion is offered for clarification purposes. For the exam, a score out of 50% will be provided to each student, and for the group presentation, comments and a score out of 50% will be provided to each group. Given the module's timing at the end of the autumn term, the comments and scores will be provided early in the spring term. Formative feedback will be provided during submission of proposals for ventures to cover in the group presentations and during preparation of the presentations by means of the coaching sessions.
Reading list	A reading list will be provided to you several weeks before the module starts. It will include the written cases, other required readings, and some optional/background materials (in written, audio, and video forms). All the readings will be available in electronic form via Blackboard. Example cases are: d.light, Harvard Business School, case 9-321-069 Elon Musk's Big Bets, Harvard Business School, case 9-717-431 KiOR: The Quest for Cellulosic Biofuels, Stanford Graduate School of Business, case E427.

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Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Long title: Urban Energy Systems

New code: | New short title:

Brief description of module *(approx. 600 chars.)*:

This module highlights the importance of cities as centres of energy service demand and as opportunities for improved efficiency, from both historical and contemporary perspectives. Key technologies for improved urban energy efficiency such as combined heat and power, smart controls, and others are introduced. You will also consider the practical difficulties encountered when trying to improve the energy efficiency of cities and apply optimisation modelling to urban energy systems.

486 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	17	
Group teaching	11	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled		*Incl. project supervision, fieldwork, external visits.*
Independent study	97	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode: Taught/ Campus | Other:

Delivery term: Term 2 | Other:

Ownership

Primary department: Energy Futures Lab

Additional teaching: Chemical Engineering

departments	
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Koen	Van Dam
Module Leader		Nilay	Shah
Lecturer		Paul	Rutter
Lecturer		Salvador	Acha
Lecturer		Edward	O'Dwyer
Lecturer		Sebastian	Maier
Lecturer		Peter	North
Lecturer		Chris	Mazur
Lecturer		Maria	Yliruka
Lecturer		Sara	Giarola

Learning and teaching

Module description

Learning outcomes	By the end of the module, students should be able to: •Analyse the contribution cities make to global energy demand (primary and final) and global energy-related greenhouse gas emissions; •Discuss major urbanisation trends and how this will affect future energy demand and environmental impacts; •Recommend examples of technologies to improve urban energy efficiency; •Design an energy strategy for a city using optimisation modelling; •Discuss some of the non-technical challenges facing cities that seek to improve their energy efficiency.
Module content	•Introduction to UES •History of UES •Technologies and Operational Aspects of UES •Decarbonising Real Estate •Modelling & Simulation of UES •Agent-based Modelling of UES •UES Planning for London •Smart and Sustainable Districts •Optimisation & AIMMS
Learning and Teaching Approach	The module will be delivered primarily through whole class lectures introducing the key concepts and methods, supported by a variety of delivery methods combining the traditional and the technological. In the second week of the module students will be supported via tutorials focused on the group coursework assignment.
Assessment Strategy	You will be summatively assessed by the submission of both a group and individual report which are directly linked to the learning outcomes.
Feedback	You will receive written feedback on the group and individual reports. You will also receive verbal whole class feedback on the assignments, with the opportunity to ask questions.

Reading list	The module is based on Urban Energy Systems: An Integrated Approach (2013, Earthscan), particularly chapters 2, 8, 9. It is available in the library and as an electronic text.

Quality assurance

Date of first approval	
Date of last revision	
Date of this approval	
Module leader	Koen Van Dam

Office use only

QA Lead	
Department staff	
Date of collection	
Date exported	
Date imported	

Imperial College London

Module Specification

Basic details

			Earliest cohort	Latest cohort
UID		Cohorts covered		
Long title	Synthetic Fuels			
New code	MECH70035	New short title		

Brief description of module *(approx. 600 chars.)*

This module is taught over two weeks, with one week focused on Bioenergy and one week on Hydrogen. In the Bioenergy week students will cover how raw biomass can be converted into 'drop-in' gaseous, liquid and solid energy carriers. There will also be a focus on two specific technological value chains for the delivery of synthetic fuels: anaerobic digestion for methane and CO2 production, and thermochemical / gasification derived syngas and hydrogen. In the Hydrogen week students will consider different approaches for producing hydrogen including those using fossil fuels compared to those using renewable energy. There will also be a focus on issues relating to storage, transportation and efficiency of hydrogen systems. Students will also undertake a deep dive into electrolysers and specific aspects of modelling hydrogen systems.

840 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit		
Credit value	5	10	N	HECOS codes	
FHEQ level	Level 7				

Allocation of study hours

	Hours	
Lectures	28	
Group teaching		*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled		*Incl. project supervision, fieldwork, external visits.*
Independent study	97	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term	Term 2	Other	

Ownership

Primary department	Energy Futures Lab
Additional teaching departments	Centre of Environmental Policy
	Chemistry
	Earth Science and Engineering
	Chemical Engineering
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Jem	Woods
Module Leader		Onesmus	Mwabonje
Module Leader	00154971	Anthony	Kucernak
Lecturer	01116102	Catalina	Pino-Muñoz
Lecturer		Mengzheng	Ouyang
Lecturer		Nilay	Shah
Lecturer		Goran	Strbac
Lecturer		Lee	Lynd
Lecturer		Marcos	Millan-Agorio
Lecturer		Chris	Cheeseman

Learning and teaching

Module description

Learning outcomes

On successfully completing this module, you will be able to:

• Consider the carbon intensity and sources of the different "Colours" of hydrogen, the different approaches used to produce hydrogen, the use of hydrogen in Industrial decarbonisation and the different storage/distribution routes for hydrogen.
• Discover the philosophy and approaches to modelling fuel cells and electrolysers and analyse the range of devices of low- and high-temperature electrolysers/fuel cells that can be used to produce hydrogen/generate electricity.
• Apply thermodynamic concepts to analyse performance of hydrogen systems and analyse cell and stack performance in terms of parameters such as volumetric power density, fuel utilisation and efficiencies.
• Evaluate two synthetic biofuel supply chains for the provision of bio-derived hydrogen and understand the range of technologies, in biological production, pre-conversion, conversion and end use, that can be deployed for the production of bio-hydrogen.
• Analyse how technologies can be applied along those supply chains and assess the impacts of the different technologies and biomass feedstocks, including bio-wastes.
• Assess fundamental resource constraints and opportunities and the value of Systems Thinking, including environmental and techno economics interactions, in the evaluation of bioenergy.
• Consider how carbon is captured by photosynthesis and how it can be used efficiently to produce bio-energy.
• Apply basic resource assessment and greenhouse gas / carbon emissions calculations to specified bioenergy supply / value chains.

Module content	• Benefits of a hydrogen economy and worldwide progress towards this goal. • Colours of hydrogen: Different approaches for producing hydrogen including those use using fossil fuels compared to those using renewable energy. • Different ways of storage hydrogen - as a gas or liquid of as a different sort of fuel (e.g. ammonia, methanol etc). transportation of hydrogen as a liquid hydrogen organic carrier. • Using renewable energy to produce hydrogen: Water electrolysis, photoelectrolysis, photocatalysis and thermochemical approaches for producing hydrogen including using nuclear heat. • How do you grow hydrogen distribution networks? • Electrolysers technologies and their operating principles; awareness and understanding of the physical processes controlling cell/stack performance as well as the main losses involved; and how fuel cells and electrolysers can be described using modelling tools to estimate performance and relevant efficiencies. • Assessing efficiency of hydrogen systems and specific aspects of modelling hydrogen systems • Electrolysers Modelling • Introduction to Bioenergy Systems • Advanced (2nd Generation) biological biomass conversion technologies • Advanced (2nd Generation) thermochemical biomass conversion technologies • Energy from Waste
Learning and Teaching Approach	The module will be delivered primarily through large-class lectures introducing the key concepts and methods, supported by a variety of delivery methods combining the traditional and the technological. This module is taught over two weeks, with one week focused on Bioenergy and one week on Hydrogen.
Assessment Strategy	This module will be summatively assessed through an in-class test and group presentation. There will be opportunities for formative assessment feedback via the module leaders and in the project support sessions.
Feedback	You will receive feedback on your performance whilst undertaking tutorial exercises, during which you will also receive instruction on the correct solution to tutorial problems. Group feedback will be available for the presentation sessions.
Reading list	“Land and bioenergy.” Chapter 9 in: Souza, G.M., Victoria, R., Joly, C and Verdade, L., (Eds.) Bioenergy and Sustainability, SCOPE (Scientific Committee on Problems of the Environment), Volume 72, ISBN: 978-2-9545557-0-6. BIOEN, BIOTA and PFPMCG, www.bioenfapesp.org/scopebioenergy. Woods, J., Lynd, L.R., Laser, M., Batistella, M., de Castro Victoria, D., Kline, K., Faaij, A.P.C. (2015) “Fuel Cell Systems explained”, J Larminie, A Dicks, Wiley.

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Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Long title: Data Science and Digitalisation in the Energy Sector

New code: | New short title:

Brief description of module *(approx. 600 chars.)*:

The module focuses on the role that data plays today in the energy domain. It will educate students on up-coming opportunities and challenges for the development of digitalised energy systems. It provides students with the most up-to-date knowledge on data science techniques, frameworks, and tools, with a specific application to power and electric mobility systems. It covers all aspects of data science: data collection and management; data analytics; data security and protection. It includes technical lectures, application use case seminars, and enlightening talks from industry experts.

595 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	18	
Group teaching	8	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled		*Incl. project supervision, fieldwork, external visits.*
Independent study	99	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term	Term 2	Other	

Ownership

Primary department: Energy Futures Lab

Additional teaching departments	Electrical and Electronic Engineering
	Business School
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Daphne	Tuncer
Lecturer		Fei	Teng
Lecturer		Aidan	Rhodes
Lecturer		Stefano	Moret
Lecturer		Raoul	Guiazon

Learning and teaching

Module description

Learning outcomes	•Acquire a broad awareness of the potential role of data science and digitalisation in energy system management and development; •Specify the types of applications that data science is being applied in the energy sector; •Consider the types of work that is taking place involving data science in the energy sector and the nexus role that data has across the energy sector and along value chains. •Develop a technical understanding of the main concepts of data science, including specialised terminology and standard techniques for the collection, processing, analysis and interpretation of data; •Assess the tools and frameworks used in professional environments in order to assist data science tasks.
Module content	The module covers the following topics: •Data science processes, frameworks, and tools •Data analytics techniques focusing on machine learning and optimisation •Data security and integrity •Digitalisation tools applied to the energy sector •Data management applied to the electric vehicle charging domain •Data management applied to power systems
Learning and Teaching Approach	The module is organised into 18 lectures. They include lectures covering technical content that are delivered by internal and external lecturers; lectures covering application use cases in the form of seminars; industry expert guest lectures in the form of enlightening talks. The course also includes coursework support sessions in order to assist students in the preparation of their project-based assignments. Some sessions are compulsory to attend in order to test progress. Students are encouraged to interact with the relevant speakers during all lecture and coursework support sessions, either directly or by email.
Assessment Strategy	The assessment is based on two components: •A group project that consists of a topic investigation associated with quantitative or qualitative analysis, findings reporting and formulation of recommendations. The outcome is delivered in the form of a 4 to 5 page report, and a presentation. The final mark is based on the quality of the submitted report and the quality of the presentation.

Feedback	Formative feedback will be provided during the module in the project support session to help students shape their assignment before it is submitted. Summative feedback will be provided at the end of the course. It covers how the assessment was carried out, and provides a breakdown between the group project and the individual exercise. For the group project, a personalised assessment is provided per group that identifies the strengths and weaknesses of each group work. For the individual assessment, a general marking grid is provided and feedbacks are indicated per grade range.
Reading list	‘Digitalisation of Energy’, Energy Futures Lab Briefing Paper H. V. Jagadish, "Big data and its technical challenges," Communications of the ACM, vol. 57, no. 7, pp. 86-94, 2014. E. Curry, "The big data value chain: definitions, concepts, and theoretical approaches," New horizons for a data-driven economy, Springer, Cham, pp. 29-37, 2016. T. H. Davenport, "Analytics 3.0," Harvard business review, vol. 91, no. 12, pp. 64-72, 2013.

Imperial College London

Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Long title: Energy Transmission and Storage

New code: | New short title:

Brief description of module *(approx. 600 chars.)*:

In the context of a low carbon energy system, this module presents the technologies, analysis and the challenges associated with transmission of electricity and gas, different forms of energy storage and demand response and their role in ensuring secure and affordable supply of clean power. The knowledge provided in this module includes how modern power and gas networks operate, what challenges are faced at the transmission level as large amounts of renewables are integrated into the system and how different forms of energy storage and demand response could help address some of these challenges.

602 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	26	
Group teaching	6	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled		*Incl. project supervision, fieldwork, external visits.*
Independent study	93	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term	Term 2	Other	

Ownership

Primary department: Energy Futures Lab

Additional teaching departments	Electrical and Electronic Engineering Mechanical Engineering Chemical Engineering
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Balarko	Chaudhuri
Lecturer		Goran	Strbac
Lecturer		Tim	Green
Lecturer		Marko	Aunedi
Lecturer		Jacqueline	Edge
Lecturer		Jamie	Speirs
Lecturer		Andy	Hadland

Learning and teaching

Module description

Learning outcomes	On successfully completing this module you should be able to: 1. Apply power flow analysis to study the steady-state behaviour of electric power transmission systems 2. Recognise the role of high voltage direct current transmission (HVDC) and flexible AC transmission systems (FACTS) technologies and evaluate the appropriate option in different contexts 3. Assess the transmission network issues towards large scale integration of wind power 4. Devise a vision for future distributed energy systems 5. Explain the operation of low inertia systems 6. Analyse the role of energy storage and demand response in low carbon energy systems and the technologies that could deliver it 7. Consider the role of gas in a low carbon future
Module content	Electric power transmission 1. Powerflow analysis 2. HVDC and FACTS 3. Transmission issues with high wind penetration 4. Distributed energy systems 5. Low inertia system Energy storage and demand response 1. Energy storage technologies 2. Demand response 3. System level impact of energy storage and demand reponse Role of gas in low carbon future
Pattern of learning and teaching activities	Two hours of lecture in the morning followed by two hours of tutorial or group exercise in the afternoon.
Learning and Teaching Approach	The module will be delivered primarily through lectures introducing the key concepts, technologies and analysis using the tradtional delivery methods. The content is presented via a combination of slides, whiteboard and visualizer. Learning will be reinforced through tutorial sessions and a group coursework exercise.

Assessment Strategy	This module presents opportunities for both formative and summative assessment. You will be summatively assessed by a group coursework exercise and written closed-book examination at the end of the module. The exam is specifically formulated to assess knowledge-based learning outcomes in addition to the other learning outcomes for the module. You will be formatively assessed by working through problem sheets in the tutorials. This formative work will inform both summative assessments.
Feedback	You will receive feedback on examinations in the form of an examination feedback report on the performance of the entire cohort. You will receive feedback on your coursework report as a group. You will receive feedback on your performance whilst undertaking tutorial exercises, during which you will also receive instruction on the correct solution to tutorial problems.
Reading list	1. J. J. Grainger, and W.D. Stevenson, Power system analysis. 1994, New York ; London: McGraw- Hill 2. J. Arrillaga, High voltage direct current transmission. 2nd ed. ed. 1998, London: Institution of Electrical Engineers 3. N.G. Hingorani, and L. Gyugyi, Understanding FACTS: concepts and technology of flexible AC transmission systems. 1999, New York: Institute of Electrical and Electronics Engineers 4. J. Newman, K.E.Thomas-Alyea, Electrochemical Systems, 3rd Edition, Wiley, New York, 2004 5. A.J.Bard and L.R.Faulkner, Electrochemical methods: fundamentals and applications, 2nd Edition, Wiley, New York, 2001 6. F.C.Walsh, A First Course in Electrochemical Engineering, 1993 7. A. Almansoori, and N. Shah, Design and Operation of a Future Hydrogen Supply Chain – Snapshot Model, Chemical Engineering Research and Design, 84(A6), 2006, page 423-438

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Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Long title: Sustainable Transport

New code: | New short title:

Brief description of module *(approx. 600 chars.)*:

Our transport systems are critical to our way of life. They enable the movement of people and goods, thereby enabling economic activity and development. Yet global greenhouse gas emissions due to transport are increasing and it degrades air quality in our cities. In this module, we will develop and understanding of how transport is linked to energy, climate change and air pollution. In addition to these core concepts, we will cover specific modes of transport (active travel, aviation, road and shipping) and innovations that are critical to making transport is more sustainable.

583 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	20	
Group teaching	16	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled	2	*Incl. project supervision, fieldwork, external visits.*
Independent study	87	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term	Term 2	Other	

Ownership

Primary department: Energy Futures Lab

Additional teaching departments	Civil and Environmental Engineering Centre of Environmental Policy + Aeronautics Mechanical Engineering + School of Public Health
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Marc	Stettler
Lecturer		Ricardo	Martinez-Botas
Lecturer		Nick	Molden
Lecturer		Jonathan	Morrison
Lecturer		George	Koudis
Lecturer		Tristan	Smith
Lecturer		Audrey	de Nazelle
Lecturer		Daniel	Ainalis
Lecturer		David	Green

Learning and teaching

Module description

Learning outcomes	On successfully completing this course unit, students will be able to: •Analyse the principle characteristics of land, air, and maritime transport and the key issues facing each in the context of Sustainable Energy •Quantify environmental impacts of transport, with an emphasis on climate and air quality impacts. •Evaluate and explain how alternative transport mode choices affect energy consumption and pollutant emissions. •Solve simple problems comparing the application of alternative transport systems to a given problem.
Module content	•Introduction to Sustainable Transport •Transport Emissions and Impacts •Low Carbon Transport Technologies •Real World Vehicle Emissions •Reducing Drag in Transport •Aviation •Shipping •Active Transport •Sustainable Road Freight •Air pollution exposure and health impacts •SEF Alumni Industry Roundtable
Learning and Teaching Approach	The module will be delivered primarily through whole class lectures introducing the key concepts and methods, supported by a variety of delivery methods. Throughout the module students will be supported via tutorials focused on the group coursework assignment.
Assessment Strategy	You will be summatively assessed by the completion of a group project, which includes both group and individually graded components, and an in-class test.
Feedback	You will receive written feedback on the group and individual reports. You will also receive verbal whole class feedback on the assignments, with the opportunity to ask questions.

Reading list	David J.C. MacKay. Sustainable Energy – without the hot air. UIT Cambridge, 2008. ISBN 978-0-9544529-3-3. Available free online from www.withouthotair.com Especially the following chapters: I.3 - https://www.withouthotair.com/c3/page_29.shtml II.20 - https://www.withouthotair.com/c20/page_118.shtml III.A - https://www.withouthotair.com/cA/page_254.shtml

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Module Specification

Basic details

UID		Cohorts covered	Earliest cohort	Latest cohort

Long title: Research Project

New code: MECH70038

New short title:

Brief description of module *(approx. 600 chars.)*:

Your project is the culmination of your postgraduate studies and constitutes a piece of individual research that must include some element of originality. We will provide you with a selection of projects proposed by potential supervisors working on sustainable energy research and drawn from across Imperial and industry. However, you can also propose your own research topic. In addition to completing a literature review and thesis, you will demonstrate your ability to communicate the results to a wider audience by creating a research poster and conference presentation. In the Autumn term you will take part in debates focusing on current energy issues. The intention is to use these sessions to develop skills which can be transferred to your project; critical analysis, assimilating knowledge and presenting a point of view. You will also take part in a series of research and consultancy workshops. These are designed to develop skills which will benefit you throughout the project, overall course and after graduating; group working, communication and personal effectiveness.

1085 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	45	90	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures		
Group teaching	40	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled	25	*Incl. project supervision, fieldwork, external visits.*
Independent study	1060	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	1125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? Rarely

Module delivery

Delivery mode: Taught/ Campus

Other:

Delivery term	Year-long	Other	

Ownership

Primary department	Energy Futures Lab
Additional teaching departments	
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N
External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Fei	Teng
Topic Leader		Mark	Workman

Learning and teaching

Module description

Learning outcomes	On successfully completing this module, you will be able to: • Demonstrate a unique contribution to an area of research interest. • Develop a research plan that encourages the application of originality/creativity, critical analysis, and investigation skills to a chosen research topic area. • Conduct a piece of independent research, set out in a project brief, within a defined timeframe and within available resources. • Interpret technical and scientific publications related to a research topic and demonstrate a critical attitude towards the results of others as well as their own. • Draw justified conclusions from the research data collected and communicate these findings effectively in written and oral formats. • Formulate and defend an argument in the energy debates, based on a critical appraisal of the available evidence. • Consider what constitutes clear communication and teamworking; and apply this in developing solutions to a variety of problems.

Module content	The project can focus on any research area relevant to sustainable energy and, to reflect the interdisciplinary nature of the course, supervisor(s) can be based in any academic department at Imperial. It is also possible to have external co-supervisors, but an Imperial supervisor must be attached to the project. The literature review relates to your proposed area of research and is undertaken in the Spring term, in parallel with the taught modules and submitted in the Spring break. Completion of the literature review assignment will help to establish the work already undertaken in the chosen research area. This should be up to 20 pages in length. The thesis is undertaken from the start of the Summer term and over the Summer break. This should be 50-80 pages in length and not more than 100 pages with appendices and references. The research undertaken in the thesis then forms part of the presentation and poster session at the student conference. A logbook is maintained throughout the literature review and research phase. In the Autumn term debates you will explore current energy issues. Previous debating topics have included, for example, the need for shale gas, concerns regarding social inequality and the importance of nuclear power in the transformation of our energy systems. For the research consultancy and project management workshops you will work through a series of learning periods comprising six interactive sessions of approximately three hours duration, and one, half-day experiential workshop. Learning will focus on non-technical / soft skills designed to introduce and develop effective teamwork, communications and personal effectiveness.
Learning and Teaching Approach	You will carry out the individual project under the supervision of a member of academic staff, with possible additional input from academic and industry co-supervisors. You will spend the majority of your time in self-directed study, reviewing literature, utilising theoretical, computational or experimental methods to complete your project objectives. Support will be provided through regular meetings with your supervisor(s), presenting your progress, discussing your findings and agreeing on future plans. In the debates the class will be divided into small groups. For each debate two groups will be assigned either the for or against position for the proposed motion. The whole class will be involved through participating as the debate audience and voting on the winning team. The research and consultancy project management workshops are highly interactive sessions, involving input from alumni and industry, based around developing a commercial presentation pitch.
Assessment Strategy	In the Autumn term the module is assessed through participation in energy debates and a group pitching exercise as part of the research and consultancy project management workshops. Formative assessment will take place during the course of the research. In research meetings with their supervisors, students will be required to report on progress towards deliverables and in discussion with their supervisor agree the next steps in the project. To aid student learning, the supervisor will provide verbal feedback on progress, and regular updates on any written work, which will give students ongoing feedback from which they can learn and progress. Summative assessment is in the form of the literature review in April and the thesis at the beginning of September. The final assessments are linked to our student conference in mid-September, where you will design a research poster and deliver individual and group presentations.
Feedback	You will receive written feedback on the literature review as well as more informal feedback from your supervisor(s) via regular supervision meetings throughout the research project process. Written feedback on the final thesis is also available after the publication of results.
Reading list	Material to be provided by research supervisors which may comprise peer-reviewed publications, lead research documents, specialist reports, previous MSc theses, PhD theses etc. Research methods for business students, Saunders, Lewis & Thornhill (650.072 SAU) Scientists Must Write, Robert Barras Knowledge is Beautiful, David McCandless