Master of Science in Clean Energy Technologies

(2 years) [Sri Lanka Qualification Framework (SLQF) Level 10]

This degree programme consists of a **research project of one-year duration**, in addition to the taught courses of the Master of Clean Energy Technologies

Preamble

This programmes in Clean Energy Technologies are aimed at producing technically sound postgraduates to meet the growing demand in the field of Clean Energy Technologies, such as solar photovoltaic (PV), solar thermal, hydro energy, wind, bioenergy, etc.

This programme intends to produce highly skilled research and development workforce who could offer technical advice and assistance in Clean Energy Technologies, and enable them to get familiarized with different sources of clean energy and apply the relevant concepts in Physics, Chemistry, Engineering and other relevant fields in developing appropriate clean energy technologies. Students shall learn the most efficient and proper ways of energy production as they explore the relationships among work, power and energy and would be engaged in a wide variety of individual and group projects and laboratory activities that illustrate the inter-relationship between various forms of clean energy.

This multidisciplinary programmes will produce Master degree holders who are competent on applications of fundamental science and operating principles related to clean energy systems to authentic problems prevailing in the clean energy area. The industries in the field of Energy Technologies and, Academics and Professionals in Energy / Environment / Technology stream will also be benefited.

Objectives

- Get familiarized with different sources of clean energy
- Apply the relevant concepts in physics, chemistry, engineering and other relevant fields in developing appropriate clean energy technologies
- Learn the most efficient and proper ways of energy production
- Develop competency on applications of fundamental science and operating principles related to clean energy systems to authentic problems prevailing in the clean energy area
- Produce highly skilled Research and development workforce who could offer technical advice and assistance in Clean Energy Technologies

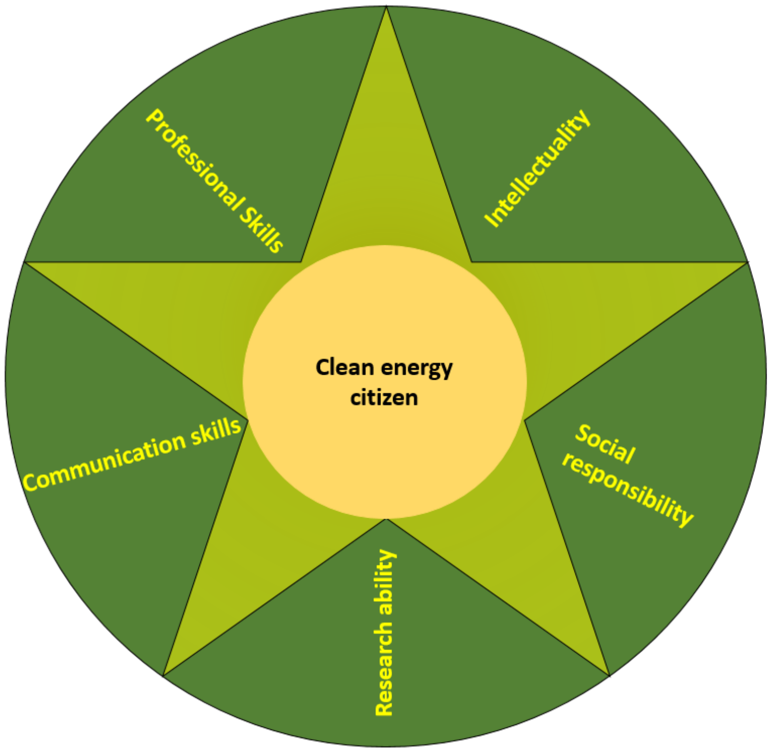
Eligibility requirement

Applicants seeking admission to this programme must have one of the following degrees / qualifications from a UGC recognized university:

- BSc Honours degree
- BSc degree in Engineering
- BTech Honours degree
- BSc General Degree and at least one year of proven research / professional experience in science / technology stream

Any other equivalent qualifications acceptable to the Board of Study in Physical Sciences of Faculty of Graduate Studies, University of Jaffna.

Graduate Profile



The desired profile of the MSc holder is depicted in the above figure, which encompasses intellectuality, research ability, social responsibility, professional, intra and inter specific skills with the following Generic and Subject specific attributes:

Generic Attributes

- conduct applied research, demonstrating a sound grasp of research methodology
- communicate effectively orally and in writing at an appropriate level to stakeholders
- plan and manage projects and work in international multidisciplinary teams reflecting on self and giving effective feedback to others
- stay abreast of relevant (inter)national developments in society, policy, and professional practice and to translate, develop and introduce these in an innovative manner to improve professional practice
- collaborate with interdisciplinary teams of research experts
- innovate and commercialize technology adhering to the Intellectual property rights policy of the university

Subject Specific Attributes

- apply the principles of clean energy technologies such as solar, biomass, wind, hydro energy to solve real life problems
- analyze clean energy technologies
- integrate clean energy into a flexible, distributed energy system
- analyze the social, environmental and economic effects of clean energy technologies
- incorporate socio-economic energy policy into clean energy systems development
- integrate technical knowledge and skills with strategic, and socio-economic issues
- analyze and improve the energy efficiency of production chains (implement innovations)
- use appropriate (mathematical) tools for modeling and analyzing problems relevant to clean energy systems
- perceive complexity associated with the energy transition

3.3 b (ii) Programme Learning Outcomes

Intended Learning Outcomes of this programme is categorized into Academic, Application-oriented, Context-oriented, Integrative, Communication and Professional development learning outcomes as follows:

Academic learning outcomes

- define the problem, employ specific research analysis methods and plan and conduct research on real-life non-routine problems
- translate a practical problem into questions in terms of a conceptual model, collect relevant data and translate the outcomes of the model into answers to the original problem.
- apply appropriate scientific methods and techniques, mathematics, economics and other sciences in energy systems design
- justify the ethical concerns in conducting research
- communicate findings in both written and oral form to the relevant stakeholders.
- Innovate and commercialize the output of the research and be a holder of intellectual property rights
- display a reflective attitude towards the possibilities and limitations of the scientific methods used and the development of a body of knowledge and, based on that make meaningful contributions to the energy debate

Application-oriented learning outcomes

- integrate clean energy sources (wind, solar [photovoltaic, thermal], hydro, biomass energy) into a flexible, distributed energy system
- apply the principles of integrated energy storage techniques to solve real life problems
- analyze and improve the energy efficiency of production chains (implement innovations)

Context-oriented learning outcomes

- apply knowledge and insights of the principles of a range of clean energy systems for optimal energy conversion
- design a (range of) clean energy system(s) for optimal energy conversion at a given location and for particular applications
- critically appraise codes of practice relevant to clean energy systems
- analyze economic and sustainability aspects of clean energy systems as well as technological considerations
- statistically assess clean energy resources at a specific location given appropriate data

Integrative learning outcomes:

- use appropriate mathematical methods for modeling and analyzing engineering problems relevant to clean energy systems
- use knowledge and understanding of the socio-economic impacts when introducing and using relevant technologies
- evaluate the profitability and competitiveness of clean energy projects in economic context

Professional and Communication development learning outcomes

- carry out tasks in a project environment
- participate effectively in an international, multidisciplinary team
- communicate effectively orally, visually and in writing at an appropriate level to stakeholders.
- elaborate the link between technological projects and strategic objectives to the management and other relevant stakeholders
- stay abreast of relevant (inter)national developments, trends and ideas in society, policy, and professional practice and its innovative improvement
- manage his / her own learning process and share expertise with peers and other experts during professional practice

PROGRAMME STRUCTURE

Duration : Two years
Course work : 40 Credits
Thesis Research : 20 Credits
Total : 60 Credits

The proposed MSc programme meets level 10 of the Sri Lanka Qualification Frame Work (SLQF, 2015); a 60 credits programme consisting of course work and a research project of 20 credits. It will be conducted over a period of twenty-four months (during weekends and/or weekdays), inclusive of minimum 08 months for the research project, with provision to exit at the end of second semester with taught master degree equivalent to level 9 of the SLQF.

The Course codes

A four-letter prefix followed by a 5-digit number is used to identify the course unit. The first digit of the five-digit number indicates the year of study. The next two digits indicate the course unit. The last two digits indicate the credit value of the course unit.

List of course units

Table I – Course units to be offered in the First Year

No.	Course code	Course Title	Contact hours		Notional hrs	No. of Credits
			Theory	Practical		
Semester 1						
1.	MCET 101 03	Essential science for Energy Technologies	45	-	150	03
2.	MCET 102 03	Wind Energy Technologies	30	-	100	02
3.	MCET 103 02	Instrumentation and Characterization Techniques	45	-	150	03
4.	MCET 104 03	Solar Energy Technologies	45	-	150	03
5.	MCET 105 03	Hydrogen Energy Technologies	45	-	150	03
6.	MCET 106 02	Lab based short projects [1,2]	-	-	200	02
Semester 2						
7.	MCET 107 02	Energy Storage Technologies	30	-	100	02
8.	MCET 108 02	Marine and Hydro Energy	30	-	100	02

		Technologies				
9.	MCET 109 02	Bioenergy Technologies	30	-	100	02
10.	MCET 110 03	Grid Integration of Clean Energy System	30	45	150	03
11.	MCET 111 02	Project Development and Management	30	-	100	02
12.	MCET 112 01	Industrial training in clean energy plants[2]	-	-	100	01
13.	MCET 113 02	Group research project [2]	-	-	200	02
Total						**30**

[1] to be conducted during first and second semester, [2] Independent learning

Table II – Course units to be offered in the Second Year

No.	Course code	Course Title	Contact hours		Notional hrs	No. of Credits
			Theory	Practical		
Semester 3						
14.	MCET 214 03	Nanomaterials for Energy Harvest and Storage	30	45	150	03
15.	MCET 215 03	Mathematical modelling for Clean energy technologies	15	90	150	03
16.	MCET 216 02	Critical review on a research topic	15	45	100	02
17.	MCET 217 02	Research Ethics, Proposal Writing and presentation	15	45	150	02
Semester 3 & 4						
18.	MCET 216 20	Research project [2]	-	-	2000	20
Sub-total						**30**
Total						**60**

[2] Independent learning

As per SLQF, one credit is considered equivalent to 50 notional learning hours for a taught course, laboratory studies course or field studies. In case of project and industrial training, including time allocated for assessments and in case of research, including time allocated for literature survey, one credit is considered equivalent to a minimum of 100 notional hours.

<table>
<tr><td colspan="4">Semester 1</td></tr>
<tr><td>Course Title</td><td colspan="3">Essential science for Energy Technologies</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 101 03</td></tr>
<tr><td>Credit value</td><td colspan="3">03</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>45</td><td>-</td><td>105</td></tr>
<tr><td>Objectives</td><td colspan="3">• Introduce crystal structures and interatomic forces
• Outline the fundamentals of semiconductors
• Introduce generator technologies and back emf
• Introduce basic concepts of thermodynamics related to energy conversion
• Familiarize with fluid dynamics
• Acquaint with heat transfer process
• Provide fundamentals of catalysis
• Familiarize with biological basics relevant to conversion of biomass to energy</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• Infer fundamentals of thermodynamics with respect to energy conversion
• Explain fundamentals of semiconductors
• Discuss generator technologies and back emf
• Comprehend principles of energy flow and fluid dynamics
• Identify different modes of heat transfer process
• Analyze thermal resistance for multimode heat transfer
• Show mechanism of catalysis
• Discuss metabolism of microbes in bioenergy production</td></tr>
<tr><td rowspan="6">Contents</td><td colspan="3">Crystal structure and Interatomic forces
Types of crystals, crystal structures, unit cells, FCC, BCC and HCP structures, crystal defects.
Inter-atomic forces: Molecules and binding forces, Van der Waals, ionic, covalent and metallic bonds.</td></tr>
<tr><td colspan="3">Fundamentals of Semiconductors
Valance band, conduction band, bandgap, Density of States, intrinsic carrier concentration, Fermi level, extrinsic semiconductors, p-n junction, depletion region, semiconducting polymers, HOMO and LUMO levels, doping.</td></tr>
<tr><td colspan="3">Basics of generator technology, back emf</td></tr>
<tr><td colspan="3">Thermodynamics
Basic concepts, zeroth law and temperature, energy interaction, first law, flow processes, second law, entropy and availability, combined first and second laws, gas power cycles: Carnot, Stirling, Brayton, Otto, diesel and duel cycles, vapour power cycles: Rankine cycle and improvements, refrigeration, psychrometry, role of thermodynamics in energy conversion</td></tr>
<tr><td colspan="3">Fluid dynamics
Equation of continuity, conservation of energy and momentum, energy flow, viscosity, forces on fluid element, uniform and non-uniform flow, flow patterns and Reynolds number, friction in the pipe flow and head lost, jet engine</td></tr>
<tr><td colspan="3">Heat transfer process
Modes of heat transfer, thermal resistance and circuit analysis for multimode</td></tr>
</table>

	heat transfer, properties of transparent materials, heat transfer by mass transport	
	Catalysis Heterogeneous and homogenous catalysis, mechanism for production of hydrogen, ammonia and methane, water splitting, carbon dioxide reduction	
	Metabolism of Microbes Microbial diversity, cell nutrients, enzymes, metabolic pathways, cell functions, stoichiometry of microbial growth and product formation	
Teaching and Learning Methods / Activities	Lectures Quizzes Assignments	
Evaluation	In-course assessments	30 %
	End of course examination	70 %
Recommended References	• Essentials of Energy Technology: Sources, Transport, Storage, Conservation, Jochen Fricke and Walter L. Borst, Wiley-VCH, 2013 (ISBN: 9783527334162) • Catalysis for Sustainable Energy Production, Pierluigi Barbaro, Claudio Bianchini (Eds.), Wiley-VCH, 2009 (ISBN: 9783527320950) • Catalysis for Alternative Energy Generation, László Guczi and András Erdôhelyi (Eds.), Springer, 2012 (ISBN: 9781461403432) • Bioprocess Engineering: Basic Concepts, Michael L. Shuler, Fikret Kargi and Matthew DeLisa, Prentice Hall, 2017 (ISBN: 9780137062706)	

Semester 1			
Course Title	**Wind Energy Technologies**		
Course Code	MCET 102 02		
Credit value	02		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	30	-	70
Objectives	• Introduce basic wind power calculations using fundamental physics concepts • Familiarize with wind energy technologies • Provide basics of generator technologies • Introduce reliability and quality of wind power generation • Introduce basic design of wind energy generation components • Provide civil engineering design aspects of wind tower		
Intended Learning Outcomes	• Calculate wind energy production from wind turbine • Describe types of wind energy generation technologies • Distinguish between technologies and rationale behind their evolution • Discuss about the quality of electric power produced from wind turbines • Design wind energy generation components • Explain the civil structural requirements and construction of a wind tower		
Contents	**History** Early wind power, technical development, advantages and disadvantages		
	Winds Physical background, energy content, variation in time and in space, geographical resource distribution, influence of terrain, measurement methods, statistical analysis		

	Turbine theory Free flow, principles of drag and lift, aerodynamics, design of turbine blades, horizontal and vertical axis wind turbines, Betz' and Glauert's turbine theories, the BEM method
	Power reliability/ quality, Grid-code (Wind energy related)
	Wind power generation technologies Fixed-Speed Induction Generator (FSIG), Variable Speed Wind Turbine (VST), Doubly-Fed Induction Generator (DFIG) and Full Converter Based
	Blade profile design, Computational Fluid Dynamics (CFD)
	Tower and foundation design
Teaching and Learning Methods / Activities	Lectures Mini-project Video-lectures Flipped classes
Evaluation	In-course assessments — 50 % End of course examination — 50 %
Recommended References	• Distributed Generation, N Jenkins, J.B. Ekanayake and G. Strbac, Institution of Engineering and Technology, 2010 (ISBN: 0863419585) • Wind Energy Generation: Modelling and Control, Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright and Mike Hughes, Wiley, 2009 (ISBN 978-0-470-71433-1)

Semester 1			
Course Title	**Instrumentation and Characterization techniques**		
Course Code	MCET 103 03		
Credit value	03		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	45	-	105
Objectives	• Introduce basic principles of materials characterization • Familiarize with selected materials characterization techniques • Acquaint with available methods for analyzing the data obtained using the above techniques		
Intended Learning Outcomes	• Explain principles of optical, microscopic, thermal and electrical techniques used in characterization of materials and devices • Identify appropriate technique for characterization of materials and devices for different applications • Solve practical problems in materials characterization utilizing appropriate techniques, skills, and modern analytical tools		
Contents	• **Introduction** Introduction to different material characterization techniques • **Optical analysis** Principle, Instrumentation, and Applications of - UV-Visible (UV) spectroscopy, - Fourier Transform-Infra Red (FT-IR), - Raman, - Photoluminescence (PL), and		

	- Transient Absorption Spectroscopy (TAS) • **Microscopic analysis** Principle, Instrumentation, and Applications of - Scanning Electron Microscopy (SEM), - Field Emission Scanning Electron Microscopy (FE-SEM), - Transmission Electron Microscopy (TEM), and - Atomic Force Microscopy (AFM) • **Structure analysis tools** Basic principle, instrumentation configuration, data interpretation, and quantification of - X-ray difractometer (XRD) - Energy-dispersive X-ray spectroscopy (EDX) - Neutron Powder Diffractometer - X-ray fluorescence spectrometer (XRF) - X-ray photon spectroscopy (XPS) and - Ultraviolet photon spectroscopy (UVPS) • **Thermal analysis** Principles and applications of - Differential thermal analysis (DTA), - Differential Scanning Calorimetry (DSC), and - Thermo-gravimetric analysis (TGA) • **Electrical analysis** Principles and applications of - Two and four probe - Kelvin probe - Hall Effect and - Magnetoresistance measurements.
Teaching and Learning Methods / Activities	• Lectures • Lab visit and demonstration • In-class Assignments
Evaluation	In-course assessments — 30 % End of course examination — 70 %
Recommended References	• Materials Characterization: Introduction to Microscopic and Spectroscopic Methods (2nd Ed.), Yang, L., Wiley, 2013 (ISBN: 978-3-527-33463-6) • Surface analysis: The principal techniques (2nd Ed.), Vickerman, J.C. and Gilmore, I., Wiley , 2009 (ISBN: 978-0-470-01764-7) • Characterization of materials, Kaufmann, E. N., Hoboken and N. J., John Wiley & Sons, 2003 (ISBN: 978-0-471-26882-6) • Thermal analysis of materials (1st Ed.), Speyer, R., CRC press, 1993 (ISBN 13: 978-0824789633, ISBN 10: 0824789636) • Materials Science and Technology: A Comprehensive Treatment/ Characterization of Materials (Materials Science & Technology), Cahn, R. W., Haasan and P., Kramer, E. J., Wiley-VCH, 1992 (ISBN 10: 3527268154, ISBN 13: 978-3527268153)

<table>
<tr><td colspan="4">Semester 1</td></tr>
<tr><td>Course Title</td><td colspan="3">Solar Energy Technologies</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 104 03</td></tr>
<tr><td>Credit value</td><td colspan="3">03</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>45</td><td>-</td><td>105</td></tr>
<tr><td>Objectives</td><td colspan="3">• Introduce basic concepts of solar energy technologies
• Describe existing solar energy strategies and frontier technology updates
• Familiarize with different types of solar Photovoltaic (PV) and thermal systems.</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• Recognize the necessity for solar energy technologies in the context of world energy demand
• Apply fundamental concepts of various solar energy technologies
• Discuss challenges in developing and operating different solar energy technologies
• Describe shading effect on the performance of solar cells
• Critically compare different solar energy technologies
• Distinguish between different PV technologies
• Evaluate solar Photovoltaic (PV) and thermal systems</td></tr>
<tr><td rowspan="8">Contents</td><td colspan="3">Solar spectrum
Electromagnetic spectrum, basic laws of radiation, Physics of the Sun, energy flux, solar constant for earth, Solar radiation on the earth surface, spectral energy distribution of solar radiation, Measurement of solar radiation: Pyranometer, Pyrheliometer.</td></tr>
<tr><td colspan="3">Solar cell performance
I-V characteristics of a solar cells, maximum power point, cell efficiency, fill factor, effect of irradiation and temperature, panel construction and power transmission</td></tr>
<tr><td colspan="3">Crystalline silicon solar cells
Working principle, fabrication process of crystalline and polycrystalline silicon solar cell, future research trends in silicon solar cell</td></tr>
<tr><td colspan="3">Thin film solar cells
Operational principles of a-Si, CdTe, CIGS and GaAs solar cells, Advantageous of CdTe solar cells over other thin film solar cells</td></tr>
<tr><td colspan="3">Nanostructured solar cells
Structure and operating principle organic solar cells, Plasmonic solar cell, Intermediate bandgap solar cell, Quantum dot sensitized solar cell, Up conversion & down conversion</td></tr>
<tr><td colspan="3">Effect of shading and remedial measures</td></tr>
<tr><td colspan="3">Computational modeling of solar cells: Optical & electrical stimulation of solar cell using commercial software (eg: VASP , PC1D, Lumerical FDTD, G-solver etc..)</td></tr>
<tr><td colspan="3">Advances in Solar Cell Manufacturing</td></tr>
</table>

	Concentrating solar power technology (CSP) Optical properties of concentrated light systems, Function and build-up of a CSP system, Overview of the different components and their functions. Examples of CSP-systems throughout the world.
	Solar thermal energy storage systems Design aspects of solar thermal energy harvesting and storage systems. Selection criteria of storage materials for heating and cooling applications, selection of heat transfer fluid for heating and cooling applications.
	Future Challenges in solar energy technologies
Teaching and Learning Methods / Activities	In – class Lectures Seminar presentation

Evaluation	In-course assessments	30 %
	End of course examination	70 %

Recommended References	• Solar Cells: Operating Principles, Technology, and System Applications, Green, M. A., Prentice Hall, 1981 (ISBN: 9780138222703) • Semiconductor Material and Device Characterization (2nd Ed.), Schroder, D., Wiley-Interscience, 1998 (ISBN: 9780471241393) • The Physics of Solar Cells. Nelson, J., Imperial College Press, 2003 (ISBN: 9781860943409) • Handbook of Photovoltaic Science and Engineering, Luque, A., and S. Hegedus (Eds.), John Wiley & Sons Ltd, 2003 (ISBN: 9780471491965). • Applied Photovoltaics. 2nd Ed., Routledge, Wenham, S., M. Green, et al. (Eds.), 2006 (ISBN: 9781844074013) • Fundamentals of Semiconductors: Physics and Materials Properties (3rd Ed.), Yu, P., and M. Cardona, Springer, 2004 (ISBN: 9783540413233) • Solar Energy Engineering, J. S. Hsieh, Prentice Hall • Solar Energy Engineering: Processes and Systems, Soteris A. Kalogirou, Academic Press, 2009

<table>
<tr><td colspan="4">Semester 1</td></tr>
<tr><td>Course Title</td><td colspan="3">Hydrogen Energy Technologies</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 105 03</td></tr>
<tr><td>Credit value</td><td colspan="3">03</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>45</td><td>-</td><td>105</td></tr>
<tr><td>Objectives</td><td colspan="3">• Summarize the principles of electrochemistry and thermodynamics behind the operation of a Fuel Cell
• Analyze different kinds of Fuel Cells and their respective applications
• Explain the functions of each components in a PEM (Proton Exchange Membrane) Fuel Cell and their design
• Assess the performance of a PEM Fuel Cell and the parameters influencing its degradation
• Establish a knowledge of hydrogen systems, storage, production and its application in fuel cells.</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• Compare different types of fuel cells in relation to specific applications and costs
• Identify the thermodynamic and electrochemical requirements for the operation of a fuel cell
• Discuss the performance evaluation and the degradation of PEM fuel cells
• Distinguish between the operational principles of a fuel cell and the water splitting
• Explain the chemical reaction concepts applied to hydrogen energy systems.
• Apply design tool for electrochemical, hydrogen power systems.</td></tr>
<tr><td rowspan="5">Contents</td><td colspan="3">Introduction to Hydrogen Energy Technologies
Basics of Fuel Cells, operational principle of a fuel cell and hydrogen Splitting</td></tr>
<tr><td colspan="3">Types of Fuel Cells
Proton Exchange Membrane (PEM) Fuel Cells, Solid-Oxide Fuel Cells (SOFCs), Direct Methanol Fuel Cells, Alkaline Fuel Cells, Phosphoric Acid Fuel Cells and Molten Carbonate Fuel Cells.
Operational principles, pros/cons in relation to various applications and cost analysis</td></tr>
<tr><td colspan="3">Proton Exchange Membrane (PEM) Fuel Cells
Components and characteristics, Membrane Electrode Assembly (MEA), Evaluation of performance, Voltage losses and their management</td></tr>
<tr><td colspan="3">Materials for PEM Fuel Cells
Electrolytes, Electrodes, Electro-catalysts, Gas Diffusion Layers (GDL) and Flow Fields</td></tr>
<tr><td colspan="3">Fuel Cell Thermodynamics and Electrochemistry
Basic thermodynamics related to the operation of a fuel cell, Reaction at</td></tr>
</table>

	electrodes, The cell reaction and potential, The variation of potential with pH and temperature, The determination of thermodynamic functions, Electrochemistry of PEM fuel cell,
	Applications of Fuel Cells Automotive, portable electronic and stationary applications
	Hydrogen Energy Hydrogen reforming technology, Hydrogen Storage, Hydrogen Production, Hydrogen economy.
	Water splitting Photoelectrolysis, structured materials for photoelectrochmical water splitting, Tandem photoelectrochemical cells for water splitting, Photocatlytic water splitting,
Teaching and Learning Methods / Activities	Lectures Laboratory work Home-work assignments

Evaluation	In-Course Assessments	30 %
	End of Course examination	70 %

Recommended References	• Fuel Cell - Fundamentals (3 rd Ed), Ryan O' Hayre, Suk-Won Cha, Whitney Colella and Fritz B. Prinz, Wiley, 2016 (ISBN 978-1119113805) • Fuel Cells - From Fundamentals to Applications, Supramaniam Srinivasan, Springer, 2006 (ISBN 978-0387251165) • Hydrogen and Fuel Cells: Emerging Technologies and Applications (2 nd Ed), Bent Sørensen, Elsevier Ltd, 2012 (ISBN 978-012387709-3) • Fuel Cells and Hydrogen: From Fundamentals to Applied Research, Viktor Hacker and Shigenori Mitsushima, Elsevier Ltd, 2018 (ISBN 978-0128114599) • Photoelectrochemical Water Splitting: Materials, Processes and Architectures (Energy and Environment Series), Hans-Joachim Lewerenz and Laurie Peter, RSC publishing, 2013 (ISBN 978-1849736473) • Photochemical Water Splitting: Materials and Applications, Neelu Chouhan, Ru-Shi Liu and Jiujun Zhang, CRC Press, 2017 (ISBN 978-1315279640)

Semester 1			
Course Title	**Laboratory based short projects**		
Course Code	MCET 106 02		
Credit value	02		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	-	-	200
Objectives	• Recall basic concepts associated with relevant characterization techniques • Familiarize with advanced experiments using the above techniques • Provide training in writing short project reports		
Intended Learning Outcomes	• Apply appropriate characterization techniques for real problems • Demonstrate range of materials characterization techniques, data analysis and reporting.		
Contents	Students are expected to perform at least ten of the following short projects independently using specified characterization techniques and submit respective short project reports. - Optical characterization of materials by UV-Vis spectroscopy - Carrier mobility of disordered materials by Time of flight technique - Band gap in semiconductors by Four-probe technique - Carrier concentration of semiconducting materials by Hall effect technique - External Quantum Efficiency measurement of solar cells - Current - Voltage characteristics of solar cells - Structural characterization of materials by XRD - Diffusion coefficient of materials by Impedance spectroscopy - Functional group identification by FTIR spectroscopy - AC Impedance Analysis of solar cells by Auto lab - Sheet resistance of conducting substrates by four probe method - Roughness factor of surface layers by Atomic Force Microscopy - Photoluminescence (PL) of hybrid sample by PL spectroscopy		
Learning Methods / Activities	• Laboratory Work • Writing short project reports		
Evaluation	In-course assessments (Laboratory project reports)		60 %
	End of course examination		40 %

Semester 2

No.	Course code	Course Title	Contact hours		Notional hrs	No. of Credits
			Lecture	Practical		
1.	MCET 107 02	Energy Storage Technologies	30	-	100	02
2.	MCET 108 02	Marine and Hydro Energy Technologies	30	-	100	02
3.	MCET 109 02	Bioenergy Technologies	30	-	100	02
4.	MCET 110 03	Grid Integration of Clean Energy System	30	45	150	03
5.	MCET 111 02	Project Development and Management	30	-	100	02
6.	MCET 112 01	Industrial training in clean energy plants[2]	-	-	100	01
7.	MCET 113 02	Group research project [2]	-	-	200	02

[1] to be conducted during first and second semester, [2] Independent learning

Semester 2			
Course Title	**Energy Storage Technologies**		
Course Code	MCET 107 02		
Credit Value	02		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	30	-	70
Objectives	• Assess different types of energy storage technologies • Explain the operational principle of a well-known secondary battery - Lithium-ion battery • Illustrate the importance of going beyond Lithium-ion batteries • Distinguish various types of super-capacitors and their performances • Discuss thermal and hydro energy storage technologies		
Intended Learning Outcomes	• Compare the practicality of different energy storage systems in the context of available resources • Distinguish between different types of battery chemistries • Introduce the basic operational principle of batteries and super-capacitors • Identify the relative costs, sustainability of each technology and the safety issues • Discuss various types of thermal and hydro energy storage technologies		
Contents	**Introduction to Energy Storage Technologies** Secondary batteries, super-capacitors, thermal and hydro energy storage technologies, high and low power high energy' storage devices		
	Components of a Battery Electrolytes, cathodes, anodes, separators and binders		

	Design and Operation of Major Battery Chemistries Lead-acid, metal-hydride and lithium-ion. Pros/cons of different chemistries, comparison of energy and power densities, cost analysis and charge/discharge characteristics	
	Different Types of Electrolyte Materials Aqueous and non-aqueous liquids, ceramics, gel-polymers, solid-polymers and ionic liquids	
	Different Types of Electrode Materials Graphite, hard-carbon, lithium cobalt oxide, lithium cobalt phosphate and so on.	
	Electrochemistry and Thermodynamics of Batteries Charge transfer at the electrode interfaces, cell resistance, ion diffusion, ion migration and capacity fade	
	Batteries Beyond Lithium-Ion Sodium-ion, sodium-sulfur, magnesium-ion and redox-flow batteries. Pros/cons and highlights on recent research and development of these new type of batteries	
	Applications of Different Types of Batteries Suitable battery types for automotive, portable electronic and stationary applications	
	Performance Evaluation of Batteries State of Health (SOH), State of Charge (SOC), State of Function (SOF) and Electrochemical Impedance Spectroscopic (EIS) evaluations. Safety issues (thermal runaway, short-circuiting and fire/explosion hazard) on batteries, battery management systems, second life of batteries	
	Introduction to super-capacitors Operational principle, different types of super-capacitors and specialty materials	
	Different Types of Materials for Thermal Energy Storage Phase change materials, organic liquids, thermal oils and molten salts	
Teaching and Learning Methods / Activities	Lectures Laboratory works Home-work assignments	
Evaluation	In-course assessments	30 %
	End of course examination	70 %
Recommended References	• Energy Storage - Fundamentals, Materials and Applications (2 nd Ed), Robert A. Huggins, Springer, 2016 (ISBN 978-3-319-21239-5) • Energy Storage, Gerard M. Crawley (Eds.), World Scientific, 2017 (ISBN 978-981-3208-95-7) • Modern Batteries - An Introduction to Electrochemical Power Sources (2 nd Ed) - Colin A. Vincent and Bruno Scrosati, Butterworth-Heinemann, 1997 (ISBN 0-340-66278-6)	

Semester 2			
Course Title	**Marine and Hydro Energy Technologies**		
Course Code	MCET 108 02		
Credit value	02		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	30	-	70
Objectives	• introduce underlying physics behind wave energy • explain wave energy technologies • explain types of wave energy technologies • introduce reliability and quality of wave power generation • provide basic design of wave energy generation components • introduce tidal power extraction • explain hydro energy technologies • provide basics of hydro power generator technologies • introduce reliability and quality of hydro power generation • provide basic design of hydro energy generation components		
Intended Learning Outcomes	• explain underlying concepts behind wave energy • discuss about the types of wave energy generation technologies • distinguish between technologies and rationale behind their evolution • design wave energy generation components • calculate and analysis of hydro energy production • describe types of hydro energy generation technologies • distinguish between technologies and rationale behind their evolution • design hydro energy generation components		
Contents	**Introduction** Simple amplitude wave theory; Finite amplitude wave theory		
	Wave properties Reflection, refraction, diffraction, energy transmission		
	Ocean waves: wave generation, wave energy and power, wave power extraction devices		
	Forces on submerged surfaces		
	Basics of wave harboring technology		
	Power reliability/ quality, Grid-code (Hydro energy related)		
	Hydro power generation technologies		
	Blade profile design, Computational Fluid Dynamics (CFD)		
	Tidal power: cause of tides, tidal power extraction		
Teaching and Learning Methods / Activities	Lectures Mini-project Video-lectures Flipped classes		
Evaluation	In-course assessments	50 %	
	End of course examination	50 %	
Recommended References	• Basic Coastal Engineering (3rd Ed), Sorensen R. M., Springer Publication, 2006 (ISBN: 0-387-23332-6 or 9780387233321) • Handbook of coastal and ocean engineering, Kim, Y. C., World Scientific Publishing Co. Pte Ltd, 2010 (ISBN: 981-281-929-0)		

<table>
<tr><td colspan="4">Semester 2</td></tr>
<tr><td>Course Title</td><td colspan="3">Bioenergy Technologies</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 109 02</td></tr>
<tr><td>Credit value</td><td colspan="3">02</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>30</td><td>-</td><td>70</td></tr>
<tr><td>Objectives</td><td colspan="3">• Define different types of biomass feedstock
• Familiarize with the existing and emerging bioenergy technologies
• Acquaint with available techniques for purification of biobased products
• Explain life cycle assessment of bioenergy systems</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• Identify potential biomass feedstock
• Discuss bioenergy technologies
• Relate appropriate separation techniques for various biobased products
• Asses life cycle of bioenergy systems</td></tr>
<tr><td rowspan="5">Contents</td><td colspan="3">Biomass feedstock
Harvested feedstock (1^{st}, 2^{nd} 3^{rd} and 4^{th} generation), residue feedstock (agricultural waste, forestry waste, farm waste, organic components of residential, commercial, institutional and industrial wastes)</td></tr>
<tr><td colspan="3">Biomass conversion technologies
Biochemical conversion (hydrolysis, enzyme & acid hydrolysis, fermentation, anaerobic digestion, transesterification), thermochemical conversion (combustion, gasification, pyrolysis, liquefaction), biorefineries, scaling up emerging technologies</td></tr>
<tr><td colspan="3">Bioseparation
Strategies to recover and purify products, separation of insoluble products (filtration, centrifugation, coagulation and flocculation), separation of soluble products (extraction, precipitation, reverse osmosis, adsorption, chromatography), purification (crystallization, drying)</td></tr>
<tr><td colspan="3">Impacts of bioenergy
Environmental, economic and social impacts, impact on use of land and other resources</td></tr>
<tr><td colspan="3">Life Cycle Assessment
Life cycle inventory, life cycle impact assessment, available tools, process optimization</td></tr>
<tr><td>Teaching and Learning Methods / Activities</td><td colspan="3">Lectures
Field visits
Take home assignments
Presentations</td></tr>
<tr><td rowspan="2">Evaluation</td><td>In-course assessments</td><td colspan="2">30 %</td></tr>
<tr><td>End of course examination</td><td colspan="2">70 %</td></tr>
<tr><td>Recommended References</td><td colspan="3">• Bioenergy: Principles and Applications, Yebo Li, and Samir Kumar Khanal, Wiley-Blackwell , 2016 (ISBN: 1118568311)
• Bioprocess Engineering: Basic Concepts, Michael L. Shuler, Fikret Kargi and Matthew DeLisa, Prentice Hall , 2017 (ISBN: 0137062702)</td></tr>
</table>

<table>
<tr><td colspan="4">Semester 2</td></tr>
<tr><td>Course Title</td><td colspan="3">Project development and management</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 111 02</td></tr>
<tr><td>Credit value</td><td colspan="3">02</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>30</td><td>-</td><td>70</td></tr>
<tr><td>Objectives</td><td colspan="3">• introduce the procedures to be followed in installing a project to develop and use a clean energy resource
• introduce managing and controlling a project
• provide techniques for effective resource allocation
• explain social, environmental safeguards and ethical responsibilities
• introduce options for project financing and financial management</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• appreciate the laws, regulations, guidelines and procedures to be followed in establishing a greenfield clean energy project
• prepare a project pre-feasibility study, and be able to develop the scope for detailed feasibility assessment and engineering designs
• assess options, prepare and manage project finances
• discuss techniques in planning, resource allocation, managing and controlling a project
• appreciate the need to respect social and environmental safeguards, ethical responsibilities</td></tr>
<tr><td rowspan="5">Contents</td><td colspan="3">Laws and regulations: Introduction to laws, regulations, guidelines and procedures to in Sri Lanka to facilitate and regulate energy source development and energy substitution/efficiency improvement, including Sustainable Energy Authority Act, Environmental Authority Act, Electricity Act, and regulations under such Acts, established procedures, case studies on procedures in other countries</td></tr>
<tr><td colspan="3">Project development cycle: reconnaissance, pre-feasibility study, feasibility study, decisions/decision tools, detailed engineering and costing, financing, procurement, project management, testing, commissioning, commercial operation, planning and execution of maintenance. Discussion on degree of confidence and accuracy in each pre-project study, go/no-go decisions, decision tools. Writing the scope of work/terms of reference, case studies of successes and failures in feasibility assessment</td></tr>
<tr><td colspan="3">Project Management: Definitions of projects; examples; importance of project management; project life cycle; project management process for a project; project integration management; project scope management; project time management; network diagrams to represent projects; network planning models; critical path method (CPM); project evaluation and review technique (PERT), introduction to scheduling tools (Ex: MS Project, Project Primavera);project risk management and project communication management, project quality management, procurement management and HR management. Hands-on exercises with scheduling tools</td></tr>
<tr><td colspan="3">Safeguards and Ethics: Social and environmental impact assessment, case studies</td></tr>
<tr><td colspan="3">Financial Accounting
Basic accounting procedures and concepts; bookkeeping, trial balance; profit and loss account; balance sheet; cash flow statement. Hands-on session on</td></tr>
</table>

	preparing a trial balance
	Entrepreneurship and Marketing Definition; Relevant economic, psychological and sociological theories of entrepreneurship; Characteristics and functions of an entrepreneur; Marketing environment; Product lifecycle; Consumer behavior; 4Ps.
	Energy policy implications and policy analysis Analysis of energy policies of various countries with respect to clean energy development, review of Sri Lanka Energy Policies and Strategies
Teaching and Learning Methods / Activities	Lectures Video-lectures Flipped classes
Evaluation	In-course assessments — 40 %
	End of course examination — 60 %
Recommended References	• The Art and Science of Corporate Investment Decisions (3rd Ed.), Titman and Martin, ISBN-10: 0133479528. • Data Analysis & Decision Making (5th Ed.), S. Albright and Wayne Winston, South-Western Cengage Learning, 2015. • Guide to the Project Management Body of Knowledge -PMBOK Guide (6th Ed.), Project Management Institute.

Semester 2			
Course Title	**Grid integration of clean energy systems**		
Course Code	MCET 110 03		
Credit value	03		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	30	45	75
Objectives	• provide an overall knowledge on how an electricity grid is planned and operated • introduce coordinated operation of energy resources in real-time grid operations • provide an overview of strengths and limitations of clean energy-based generation • introduce energy economics, costing and pricing, financial structuring of clean energy investments		
Intended Learning Outcomes	• describe electric power system planning and operations, including mini-grids and micro-grids • conduct reviews and calculations on grid demand forecasts for capacity and energy • discuss specific features of renewable energy resources, and how such features are integrated into grid operations planning • conduct economic assessment of clean energy technologies, financial structuring of a project and calculation of financial indices to assess bankability		

	• conduct electricity costing and pricing on each type of grid • describe energy policies in several countries, critical review of energy policies, ability to assess strengths and drawbacks	
Contents	**Types of Grids** The "grid", definition/topology of a public electricity grid, trans-national, national, and regional grids, concepts of mini-grids and micro-grids, ac and dc grids, interconnections, features of "strong" and "weak" grids, examples, possible roles of renewable energy in each type of grid. The connection code requirements, impact to the transmission and distribution networks (voltages issues, harmonic issues, etc.)	
	Electric power system operations The electric power system in real time operations, real and reactive power management, frequency and voltage management, demand-supply balance, examples and critical review of design and control philosophy of a power system, demand forecasting	
	Special features of electricity generation from clean energy technologies Intermittency, seasonality, geographic distribution, geographic dispersion, electro-mechanical features, and related probabilistic simulations/calculations, calculations on ancillary services	
	Power reliability/ quality, Grid-code, Power transmission, losses, remedies	
	Resource forecasting Wind, solar and hydropower forecasting techniques, limitations, and impacts on dispatch and spinning reserve, related technical and economic calculations	
	Energy economics: Economic comparison of clean energy technologies, mechanisms to encourage smaller developments, economic and financial modelling of clean energy projects	
	Power system economics Short-term demand forecasting, principles of economic dispatch, security constrained dispatch, electricity costing and pricing, capacity and energy costs of generation, and those of delivery, end-use customer pricing, subsidies and surcharges, case studies on Sri Lanka and elsewhere	
Teaching and Learning Methods / Activities	In-person lectures Assisted tutorials Classroom hands-on sessions (on financial structuring of clean energy projects and on electricity costing/pricing) Assignment: Mini-project Video-lectures Flipped classes	
Evaluation	In-course assessments	50 %
	End of course examination	50 %
Recommended References	• National Energy Policy and Strategies, Sri Lanka, 2008 • Renewable Energy Engineering, Nicholas Jenkins and Janaka Ekanayake, Cambridge University Press, 2017 (ISBN-13: 978-1107028487) • Renewable Energy Integration, Lawrence Jones, Academic Press, 2014 (ISBN: 978-0124079106)	

<table>
<tr><td colspan="4">Semester 2</td></tr>
<tr><td>Course Title</td><td colspan="3">Industrial training in clean energy plants</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 112 01</td></tr>
<tr><td>Credit value</td><td colspan="3">01</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>-</td><td>-</td><td>100</td></tr>
<tr><td>Objectives</td><td colspan="3">• Introduce installation of clean energy technologies</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• Explain installation of clean energy technologies</td></tr>
<tr><td rowspan="2">Contents</td><td colspan="3">Introduction to installation of clean energy technologies</td></tr>
<tr><td colspan="3">Industrial Visit: Visit a green field clean energy project, observe its installation, operation, etc.</td></tr>
<tr><td>Teaching and Learning Methods / Activities</td><td colspan="3">Lectures
Mini-project
Laboratory exercises</td></tr>
<tr><td rowspan="2">Evaluation</td><td colspan="2">In-course assessments</td><td>60 %</td></tr>
<tr><td colspan="2">End of course examination</td><td>40 %</td></tr>
</table>

<table>
<tr><td colspan="4">Semester 2</td></tr>
<tr><td>Title</td><td colspan="3">Group Research Project</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 213 02</td></tr>
<tr><td>Credit Value</td><td colspan="3">02</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>-</td><td>-</td><td>200</td></tr>
<tr><td>Objectives</td><td colspan="3">• Familiarize with one of the clean energy technologies
• Introduce pre-feasibility study of the identified clean energy technology
• Introduce the clean energy technology facility design</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• analyze one of the clean energy technologies
• perform a pre-feasibility study
• design a simple clean energy facility</td></tr>
<tr><td>Contents</td><td colspan="3">Analysis includes comparing different types of available designs/technologies in clean energy technologies.
Pre-feasibility study contains environmental, social, economic analysis, etc.
(Whatever the items required for a pre-feasible study should be covered.)</td></tr>
<tr><td>Learning Methods / Activities</td><td colspan="3">Group project</td></tr>
<tr><td rowspan="3">Evaluation</td><td colspan="2">Oral examination</td><td>30%</td></tr>
<tr><td colspan="2">Progress presentation</td><td>30%</td></tr>
<tr><td colspan="2">Project report</td><td>40%</td></tr>
</table>

No.	Course code	Course Title	Contact hours		Notional hrs	No. of Credits
			Theory	Practical		
Semester 3						
8.	MCET 214 03	Nanomaterials for Energy Harvest and Storage	30	45	150	03
15.	MCET 215 03	Mathematical modelling for Clean energy technologies	15	90	150	03
16.	MCET 216 02	Critical review on a research topic	15	45	100	02
17.	MCET 217 02	Research Ethics, Proposal Writing and presentation	15	45	150	02
Semester 3 & 4						
18.	MCET 216 20	Research project [2]	-	-	2000	20

[2] Independent learning

Semester 3			
Course Title	**Nanomaterials for Energy Harvest and Storage**		
Course Code	MCET 214 03		
Credit value	03		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	30	45	75
Objectives	• Define fundamental laws governing properties of nanomaterials • Provide hands on experience in various nanofabrication approaches • Explain growth of nanomaterials and fabrication of nanodevices. • Demonstrate application of nanotechnology in energy harvest and storage.		
Intended Learning Outcomes	• Classify the various properties of materials at nanoscale • Illustrate application of nanomaterials in energy harvest and storage • Distinguish bottom up and top down nanofabrication approaches • Design nanodevices using appropriate nanofabrication approaches		
Contents	**Physics of Low dimension** Length scales in modern solid-state physics, Dimensionality, Practical definition of dimensionality, Two-dimensional electron gas, One dimensional electron gas. **Properties of nanomaterials** **Optical,** Thermal, Magnetic, Structural, Mechanical and Chemical properties of Nanomaterials. Special attention to Carbon Nanomaterials: Fullerene, Single-walled carbon nanotubes and multiwall carbon nanotubes; Structure-property relationships, Physical properties, Applications. **Nanofabrication** **BOTTOM UP approaches** Chemical Synthesis: Self-assembly, Langmuir-Blodgett, Thin Film Growth or Deposition; Physical Vapour Deposition (PVD), Chemical Vapour Deposition (CVD);		

	Spin coating, Langmuir-Blodgett film deposition. Electrodeposition, Self-assembly, Chemical bath deposition, Spray pyrolyis, Theory of film growth: Production, Transport, Condensation, gas impingement, surface diffusion, Nucleation. Molecular Beam Epitaxy **TOP-DOWN Approaches:** Patterning –Lithography: Optical Lithography, E-beam Lithography; Film, Modification: Etching, Cutting, Grinding. **Nanomaterials and nanodevices for clean energy applications:** Operational function of and Applications of nanostructured Solar cells, Water splitting, Supramolecules (MOFs, COFs), Battery, super-capacitors
Teaching and Learning Methods / Activities	Lectures Laboratory work Group Assignment
Evaluation	In-course assessments — 30 % End of course examination — 70 %
Recommended References	• Nanotechnology for the Energy Challenge (2nd Ed.), Javier García-Martínez and Zhong Lin Wang (Eds.), 2013 (ISBN: 978-3-527-33380-6). • Linden's Handbook of Batteries, Fourth Edition, Thomas B. Reddy, 2011 (ISBN: 9780071624213) • Nanoparticles: From theory to applications (2nd Ed.), Edited by Gunter Schmid (Eds.), 2010 (ISBN: 978-3-527-32589-4). • Essentials of Nanotechnology, Jeremy Ramsden, 2009 (ISBN: 978-87-7681-418-2) • Nanostructures and Nanomaterials: Synthesis, Properties and Application GuoZhong Cao, 2004 (ISBN: 1-86094-415-9) • Lithium Batteries: Science and Technology, Nazri, Gholam-Abbas, Pistoia and Gianfranco (Eds.), 2003 (ISBN: 978-1-4020-7628-2). • Frank Owens and Charles Poole, The Physics and Chemistry of Nanosolids, John Willey, 2008 (ISBN 13: 978-0470067406, ISBN 12: 0470067403)

<table>
<tr><td colspan="4">Semester 3</td></tr>
<tr><td>Course Title</td><td colspan="3">Mathematical modeling for Clean Energy Technologies</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 215 03</td></tr>
<tr><td>Credit value</td><td colspan="3">03</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>15</td><td>90</td><td>45</td></tr>
<tr><td>Objectives</td><td colspan="3">• Familiarize with simple differential equations and solutions
• Introduce statistical modelling in clean energy applications
• Familiarize with the Matlab environment and learn how to edit, compile, and Run programs in Matlab</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• Formulate simple mathematical models using fundamental conservation laws
• Solve systems of differential equations numerically with several techniques of increasing accuracy
apply statistical theories to describe cleaner energy systems apply Matlab for data manipulation, data plotting, and programming</td></tr>
<tr><td rowspan="3">Contents</td><td colspan="3">Differential Equations and Solutions
Modelling with differential equations; First order equations, Higher Order Linear Ordinary Differential Equations, solution Methods</td></tr>
<tr><td colspan="3">Statistical modelling
Simple linear regression, least square estimation, coefficient of determination, multiple linear regression, categorical explanatory variables, sequential methods for model selection</td></tr>
<tr><td colspan="3">Introduction to Matlab
The Advantages of MATLAB, Disadvantages of MATLAB, The MATLAB Environment, Using MATLAB as a Calculator, Variables and Arrays, Creating and Initializing Variables in MATLAB, Built-in MATLAB Functions, Introduction to Plotting</td></tr>
<tr><td>Teaching and Learning Methods / Activities</td><td colspan="3">Lectures
Video-lectures
Flipped classes</td></tr>
<tr><td rowspan="2">Evaluation</td><td colspan="2">In-course assessments</td><td>40 %</td></tr>
<tr><td colspan="2">End of course examination</td><td>60 %</td></tr>
<tr><td>Recommended References</td><td colspan="3">MATLAB Programming with Applications, Stephen J. Chapman, Global Engineering, Cengage Learning, 2013 (ISBN: 9780495668077).
MATLAB Practical A Practical Introduction to Programming and Problem Solving, Elsevier by Stormy Attaway , Elsevier Butterworth-Hein, 2017 (ISBN: 9780128045251)</td></tr>
</table>

<table>
<tr><td colspan="4">Semester 3</td></tr>
<tr><td>Course Title</td><td colspan="3">Critical review on a Research topic</td></tr>
<tr><td>Course Code</td><td colspan="3">MCET 216 02</td></tr>
<tr><td>Credit value</td><td colspan="3">02</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>15</td><td>45</td><td>40</td></tr>
<tr><td>Objectives</td><td colspan="3">• Introduce the concepts of identifying and Managing bibliographies
• Provide hands on training in importing and retrieving literature using Bibliographic software
• Familiarize with reviewing the literature critically</td></tr>
<tr><td>Intended Learning Outcomes</td><td colspan="3">• Use bibliographic software competently
• Survey the relevant literature
• Review gathered literature critically</td></tr>
<tr><td>Contents</td><td colspan="3">Literature Survey and Bibliography
Familiarize with online databases, Identify relevant databases, search for relevant literature, download references from databases, Import downloaded references into Endnote / Reference manager library, Analyze the literature, Retrieved literature, insert references into the document and generate bibliography in required style.

Critical literature review
Students are required to carry out extensive literature survey on pre-assigned topics using e-resources and library, critically review gathered resources and submit a comprehensive report with Bibliography using Endnote/reference manager library and deliver an oral presentation.</td></tr>
<tr><td>Learning Methods / Activities</td><td colspan="3">• Lectures
• Assignment</td></tr>
<tr><td rowspan="2">Evaluation</td><td colspan="2">In course Assessments</td><td>40 %</td></tr>
<tr><td colspan="2">Review report with annotated bibliography</td><td>60 %</td></tr>
<tr><td>References</td><td colspan="3">• How to Write and Publish a Scientific Paper (6th Ed.), Day, R. A. and Barbara Gastel, 2006 (ISBN: 0-313-33040-9)

• A Scientific Approach to Scientific Writing, John B. and Martin. J., Springer New York, 2011 (ISBN 978-1-4419-9787-6)</td></tr>
</table>

Semester 3			
Course title	**Research Ethics, Proposal Writing and Presentation**		
Course Code	MCET 217 02		
Credit value	02		
Core/Optional	Core		
Hourly Breakdown	**Theory**	**Practical**	**Independent Learning**
	15	45	40
Objectives	• Create awareness on ethics in research and consequences of plagiarism • Explain fundamentals of effective scientific writing and presentation • Provide training on writing research proposals		
Intended Learning Outcomes	• Explain research ethics and consequences of plagiarism • Apply plagiarism detection software • Develop quality research proposals • Make effective scientific presentations		
Contents	**Research Ethics** Guiding Principles, Collection and storage of data, Data sharing, Research Publications and Dissemination, involvement in Research Supervision, Conflict of Interest, Intellectual Property and Ethical review **Plagiarism** Defining plagiarism in different contexts, Forms of Plagiarism, Copyright infringement and consequences of Plagiarism, Learning to avoid unintentional plagiarism, Observing plagiarism in articles (remote and online), Brute force approaches to plagiarism detection, Plagiarism detection software **Proposal writing and presentation** Interpretation and critical evaluation of results of published research; Formulation of a research problem: Concise literature review, justification, proposed research plan, Gantt chart, identification of resources, budgeting, etc.		
Learning Methods / Activities	Lectures Assignment: Plagiarism checking and reporting Case studies Presentations		
Evaluation	In-course assessments	50 %	
	End of course examination	50 %	
References	• How to Write and Publish a Scientific Paper (6th Ed.), Day. R. A., and Barbara Gastel.,2006 (ISBN: 0-313-33040-9) • A Scientific Approach to Scientific Writing, John B., and Martin. J., Springer (New York), 2011 (ISBN 978-1-4419-9787-6)		

Semester 3 and 4

No.	Course code	Course Unit Title	Notional hours	No. of Credits
18.	MCET 218 20	Research project	2000	20

Semester 3 and 4	
Title	**Research Project**
Course Code	MCET 218 20
Credit Value	20
Core/Optional	Core
Objectives	• Define researchable problems • Provide training to plan and conduct scientific research • Familiarize with different research methods • Develop relevant transferable skills
Intended Learning Outcomes	• Formulate research plan • Analyze scientific data • Compile written scientific reports
Contents	Each student is required to carry out a research study of twelve months duration in the field of clean energy technologies under the supervision of member(s) of the panel of academics. Students could also pursue research studies at institutions other than the University of Jaffna. Under such circumstances, the student is assigned with more than one supervisor; internal supervisor(s) from the panel of academics at the University of Jaffna and external supervisor(s) from the institution where the research project is carried out. On completion of the research study, each student is required to submit a dissertation and defend his/her dissertation in front of a panel of examiners appointed by the senate.
Learning Methods / Activities	Laboratory / Field work Writing dissertation Presentation
Evaluation	Dissertation Pass *Viva voce* Examination Pass

Programme Delivery and Learner Support System

The programme will be delivered using blended, student centered teaching and learning strategies with independent learning and judicious use of ICT and various teaching and learning aids.

The mode of programme delivery includes in-person and video lectures, quiz, in-class and take-home assignments, assisted tutorial, classroom hands-on session, flipped class, laboratory visit and demonstration, laboratory work, writing laboratory report, field visit, field work, seminar presentation, case study, mini-project, group project, research project and writing dissertation.

An efficient learner support system, such as well-equipped lecture halls and laboratories, resourceful library, computer room with ICT facilities, *etc*., is in place.

Further, guest lectures and workshops will be conducted during the study programme regularly.

Programme Assessment Procedure/Rules

Formative and summative examinations in the program:

Each course unit shall be evaluated with formative and summative assessment components: **in-course assessments** (based on quizzes, tutorials, assignments, field trips, etc.) and **end of course examination**, in which In-course Assessments carry a minimum of 30 %.

Exact nature of evaluation procedure of each course unit is provided in the detailed syllabus of the respective course units. 80 % attendance in theory and practical classes is mandatory to sit for the end of course examination.

Scheme of Grading (Grades/Grade Points/ Marks ranges):

Range of Marks	Grade	Grade Point Value (GPV)
85 -100	A^+	4.00
80 - 84	A	4.00
75-79	A^-	3.70
70-74	B^+	3.30
65-69	B	3.00
60-64	B^-	2.70
55-59	C^+	2.30
50-54	C	2.00
45-49	C^-	1.70
40-44	D^+	1.30
35-39	D	1.00
00-34	E	0.00

Calculation of Grade Point Average (GPA):

Overall Grade Point Average (OGPA) will be calculated as $\mathrm{OGPA} = \frac{\sum_i C_i G_i}{\sum_i C_i}$, where, C_i and G_i are the Credit value and the Grade Point value respectively of the i^{th} Course Unit.

Contribution by each semester to final GPA:

Each semester effectively carries 25% contribution to the final GPA. However, advanced laboratory practical course unit will be conducted in both first and second semesters, while research project will be conducted in both third and fourth semesters.

Contribution by in-plant training etc. to final GPA:

Out of 30 credits, the following course units contribute to in-plant training:

MCET 110 03 Grid Integration of Clean Energy System

MCET 112 01 Field work in clean energy plants

MCET 113 02 Group research project

Repeat / Make up examinations:

If a student is absent for an End of Course examination of a particular course unit for reasons acceptable to the University Senate, his/her result(s) will be recorded as WH (Withheld). He/she shall be permitted to sit for the examination at the next available opportunity and it will be considered as his/her first attempt.

If a student is absent for an End of Course examination of a course unit for reasons not acceptable to the University Senate or without giving a valid reason, his/her result(s) will be recorded as IC (Incomplete).

The student shall be allowed to sit the examination at the next available opportunity and the maximum grade obtainable is C.

A student will be permitted to repeat the End of Course examination twice only. The maximum period allowed to complete the MSc degree shall be four academic years.

Guidelines on group research project / proposal presentation and defense:

A group of students will be initially required to select a suitable project of their choice, carry out extensive literature survey and orally present the motivation, purpose and plan of the research work. If the project plan is acceptable, the student will be assigned a supervisor and allowed to carry out the proposed plan. Otherwise, the student will be asked to revise the project plan in consultation with an assigned supervisor. The students are expected to maintain a log book and consult the supervisor at least one hour per week throughout the project period. Also, they have to orally present the progress of their project regularly.

After successful completion of the group research project, the student is expected to submit a soft bound copy of the dissertation individually for evaluation. Later, they have to defend their dissertation individually in front of a panel of examiners. Finally, the students should submit 3 hard bound copies of the dissertation incorporating corrections, if any.

Guidelines on conduct of group research:

Each student is required to carry out a research study of three months duration in the field of clean energy technologies under the supervision of member(s) of the panel of academics.

Students could also pursue research studies at institutions other than the University of Jaffna. Under such circumstances, the student is assigned with more than one supervisor; internal supervisor(s) from the panel of academics at the University of Jaffna and external supervisor(s) from the institution where the research project is carried out.

Guidelines on comprehensive examination:
Research project will be evaluated by marking the dissertation and viva voce examination. The student must pass both examinations.

The **project supervisor** will award marks for items (i) – (vii) (**120 marks**) and a **second examiner** will also mark the items (ii) – (vii) (**80 marks**).

Criteria for evaluating the dissertation:

(i) Student performance and initiative (maximum marks available: 40 from project supervisor)

- Did the student possess required skills and initiative or did he/she need a lot of help and guidance?
- Did the student plan the project well?
- Was the student able to achieve more within the given time?
- How well did the student acquire new experimental, computational or theoretical skills?
- How well did the student handle any unexpected difficulties?

(ii) Presentation of the report (maximum marks available: 10 from each examiner)

- Is the report neat?
- Does the style conform to that of a scientific publication?
- Are the grammar and spelling good?
- Is the report divided into appropriate sections and subsections?
- Is the report presented in a logical order?
- Are the pages numbered?
- Are all figures and tables numbered and do they have appropriate captions?
- Is the quality of graphical and other figures good?
- Is a complete list of references given in a logical style at the end of the report?

(iii) Background to the work (maximum marks available : 10 from each examiner)

- Is the significance of the project explained? (What is the scientific importance of this work?)
- Has the project been placed in a wider context?
- Are there sufficient references with respect to related publications? Is there evidence of a successful literature survey?
- Is the specific objective of the project made clear?

(iv) Background theory (maximum marks available : 10 from each examiner)

- Is the theory discussed clearly and concisely, with all symbols explained?
- Is sufficient information provided for the reader to understand the theory to be applied?

(v) Methodology of the project (maximum marks available : 10 from each examiner)

- Are the techniques described adequately?
- In experimental work, are the equipment and sampling described?
- In theoretical and computational work, are the techniques used explained and justified?

(vi) Presentation and analysis of data (maximum marks available : 30 from each examiner)

- Are the results presented in a comprehensible manner?
- Is the quality of the results good?
- Is the quantity of the results sufficient?
- Are errors and uncertainties in the data and methods discussed adequately?
- Have any cross checks been made to verify the data?
- Have the data been checked against any similar data exist?

- Is the analysis appropriate?
- Are errors and uncertainties in the analysis discussed adequately?
- Have any cross checks been made to verify the methods used?
- Have the results been checked against any similar work reported?
- Could further conclusions have been drawn from the student's data?

(vii) Overall conclusions (maximum marks available : 10 from each examiner)

- Are the results summarized concisely?
- Are directions for future work suggested?

Guidelines on thesis defense examination:

On completion of the research study, each student is required to submit a dissertation and defend his/her research work in front of a panel of examiners appointed by the university senate.

Panel of Internal Resource Persons
(University of Jaffna)

Name	Qualification	Designation
Prof.K.Kandasamy	BSc Hons (Physics)(Cey), PhD (Keele, UK)	Emeritus Professor
Prof.P.Ravirajan	BSc Hons (Physics)(Jaffna), MSc (Pera), DIC, PhD (London, UK)	Senior Professor
Prof.A.Atputharajah	BSc Eng (Pera), PhD (Manchester, UK)	Professor
Prof.Ms.M.Senthilnanthanan	BSc Hons (Chemistry)(Jaffna), PhD (Leeds, UK)	Associate Professor
Dr.T.Thiruvaran	BSc Eng (Pera), PhD (UNSW, Australia)	Senior Lecturer(Gr I)
Dr.K.VIgnarooban	BSc Hons (Physics)(Jaffna), MPhil (Pera), PhD (Cincinnati, USA)	Senior Lecturer(Gr I)
Dr.T.Pathmathas	BSc Hons (Physics)(Jaffna), MSc (Pera), PhD (Cape Town, SA	Senior Lecturer(Gr II)
Dr.Ms.S.Ubenthiran	BSc Hons (Physics)(Jaffna), PhD (Malaya, Malasiya)	Senior Lecturer(Gr II)
Dr A.Thevakaran	BSc Hons (Physics)(Jaffna), PhD (Colombo)	Senior Lecturer(Gr II)
Dr.G.Sashikesh	BSc Hons (Chemistry)(Jaffna), PhD (Oxford, UK)	Senior Lecturer(Gr II)
Dr.Ms.R.Shivatharsiny	BSc Hons (Chemistry)(Jaffna), MS, PhD (South Dakota, USA)	Senior Lecturer(Gr II)
Dr.A.Anburuvel	BSc Eng (Pera), PhD (Hokkaido, Japan)	Senior Lecturer(Gr I)
Dr.D.N.Subramanium	BSc Eng (Mora), PhD (QUT, Australia)	Senior Lecturer(Gr II)
Dr.B.Ketheesan	BSc Eng (Pera), MS PhD (NMSU, USA)	Senior Lecturer(Gr II)
Dr.M.Thanihaichelvan	BSc Eng (Annah), MSc (East London, UK)	Lecturer
Mr.S.Senthuran	BSc Hons (Physics)(Jaffna), MSc(Belfast, UK)	Lecturer
Mr.K.Prashanthan	BSc Hons (Physics)(Jaffna), MSc(ICL, UK)	Lecturer

Panel of External Resource Persons

Name	Qualification	Designation and Affiliation
Prof.V.Dhayalan	BSc Hons, MSc, PhD (Bergen, Norway)	Faculty of Engineering and Science, Western Norway University of Applied Sciences, Norway
Prof. Alfred A. Christy	BSc Hons (Chemistry) (Pera), PhD (Bergen, Norway)	Faculty of Engineering & Science, University of Agder, Norway

Prof. Lakshman Dissanayake	BSc Hons (Physics)(Cey), PhD (Indiana, USA)	Research Professor, National Institute of Fundamental Studies, Kandy
Prof. Gamini Rajapakshe	BSc Hons (Chemistry)(Pera), DIC, PhD(London)	Senior Professor in Chemistry, University of Peradeniya
Prof. J.B. Ekanayake	BSc Eng (Pera), PhD (Manchester, UK)	Senior Professor in Electrical and Electronic Engineering, University of Peradeniya
Prof. Talal Rahman	BSc Hons, MSc, PhD (Bergen)	Faculty of Engineering and Science, Western Norway University of Applied Sciences, Norway
Prof. Reggie Davidraju	BSc Hons, MSc (Trondheim) PhD (Narvik)	Electrical and Computer Engineering University of Stavanger, Norway
Mr. Balashankar Gulendran	BSc Hons, MSc (Trondheim)	Senior Instrument & SAS Engineer BP RAE Project, Aker Solutions, Norway
Dr. Vajeeston Ponniah	BSc Hons, MSc (India) PhD (Oslo)	Department of Chemistry, University of Oslo, NORWAY
Prof. N. Muthukumarasamy	BSc Hons, MSc, PhD (India)	Department of Physics, Coimbatore Institute of Technology, India

Fee structure

Fees	**Per Student (Rs.)**		**Per Student (Rs.)**
	Year 1	**Year 2**	**Total (2 years)**
Tuition Fee	150,000.00	50,000.00	200,000.00
Registration Fee	6,000.00	4,000.00	10,000.00
Library fee	2,000.00	0.00	2,000.00
Laboratory fee – Non refundable	25,000.00	90,000.00	115,000.00
Examination fees	12,000.00	4,000.00	16,000.00
Use of Computer Lab	3,000.00	1,000.00	4,000.00
Other Fees (please specify each) Statement and Result sheet	2,000.00	1,000.00	3,000.00
Total	**200,000.00**	**150,000.00**	**350,000.00**
Repeat Examination per Course			3,000.00

The tuition fee can be paid in full or in two installments (50% at the registration and 50% at the beginning of the second semester) or in three installments (40% at the registration, 30% after 4 months from the date of registration and 30% after 8 months from the date of registration).