FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI

AFRICA CENTRE OF EXCELLENCE IN FUTURE ENERGIES AND ELECTROCHEMICAL SYSTEMS (ACE-FUELS)

Handbook for Master of Science (MSc) Degree Programme in Future Energies

ACE FUELS

Africa Centre of Excellence in Future Energies & Electrochemical Systems

ACE-FUELS: HANDBOOK FOR MSc PROGRAMMES

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PREAMBLE

Name of Centre	**African Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS)**
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A WELCOME MESSAGE FROM THE CENTRE LEADER

It is a great pleasure to welcome you to the Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) at the Federal University of Technology Owerri, Nigeria (FUTO). I hope that you find the information you require and gain a good grasp of the breadth and scope our activities in this programme-specific Handbook, which forms part of the information kit, accessible from the Students Resources link on the Centre website (https://acefuels-futo.org/resources/). Other very necessary information resources therein include the ACE-FUELS Sexual Harassment Policy, ACE-FUELS Scholarship Policy, Handbook for English Language Support Programme, Regulations Governing Postgraduate Studies in FUTO (including student discipline and misconduct, on-campus residency rules and regulations). I urge you to study and familiarize yourselves with the content of these information resources and to seek clarifications where necessary.

Right from inception, we have focused on building partnerships with national, regional and international knowledge networks, in order to evolve novel technologies and approaches, which optimally engage local and regional scientific talents, while linking global expertise. I thus have no doubt that our researchers and partners possess the expertise and experience to train you to become highly motivated and result-oriented postgraduate students, with capacity to deliver meaningful solutions to technological problems and needs of the society in a timely manner. We have involved our industry and sectoral stakeholders in design, implementation and evaluation of all Centre activities and to appropriately set up our education, training and research agendas, in order to optimally attain our goals of training industry-ready and entrepreneurial postgraduate students. I therefore encourage you all to take advantage of the academic and cultural diversity within FUTO to enrich your postgraduate experience.

We at ACE-FUELS are committed to your continued wellbeing and comfort and have assigned dedicated staff to provide academic, technical, administrative and social assistance to all students at all times. Phone and email contacts of the relevant officers have been provided in this Handbook to enable you always identify and reach the support personnel.

Welcome to ACE-FUELS @ FUTO! Welcome to our learning community!

Prof. Emeka E. Oguzie,
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1. GENERAL INFORMATION

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1.1 Key Contacts at ACE-FUELS

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Project Accountant	Ms. Ifeoma Mgbenu	ifeoma.mgbenu@futo.edu.ng	08035033588
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1.2 Students Welfare

In addition to top-rate teaching, learning and research facilities, we also provide adequate and comfortable workspace and accommodation (in University Hostels) for the students and adequate recreational facilities. We have put in place an efficient and professionally run international office, with support personnel, ready to meet the social and personal needs of the students. Indeed, all staff of the Centre are committed to promoting student welfare, with an effective student welfare programme in place, with developmental, preventive and remedial aspects. An orientation programme shall be organized within the first week for all newly admitted students, as part of the onboarding activities to familiarize them with the Centre and larger University community as well as impart general personal development and inter-personal and leadership skills necessary for positive co-existence in a multicultural environment. Regional students shall be encouraged to participate in all student activities and initiatives. The international office shall provide assistance related to obtaining visas and resident permits, when required, for incoming regional students, as well as provide assistance related to obtaining insurance, flight/transportation arrangements and pick up when required and provide accommodation (in University Hostels) for the students and adequate recreational facilities.

Students will be assigned Programme Advisors to provide personalized academic guidance and support, as well as familiarize the students with the academic regulations of the University. All student communications to the Centre Management shall be routed through the Programme Advisor, whereas communications to the University Management shall be routed through the Programme Adviser and the Centre Leader.

Students will also be assigned to research supervisors on registration. Supervisors will be matched to students based primarily on students' stated research interests and/or their participation in their research studies, although gender, background, or personal interests may also be considered. New incoming students will also be assigned as mentees to more experienced older student. In so doing, we shall adopt a strategy which places researchers and students with multiple levels of experience and education in research and education settings in a progressive mentoring structure that has a measurable impact on individuals at all levels.

1.3 Health & Wellbeing

Our University campus has a Department of Health Services and a medical centre, with pharmacy. Experienced counsellors are also available to provide confidential and professional support on personal, family, social, academic or other related matters. Emergency medical treatment is also available. With your student identity card, you will always be given attention.

1.4 Gender Issues

FUTO has an existing Institute of Women and Gender Development Studies, as well as strong gender policies to promote diversity and inclusion. The ACE-FUELS is adopting the FUTO gender policy that is sensitive to the needs of women with the ultimate goal as to achieve equity or equality. Such sensitivity entails searching, considering and accommodating social relations between women and men in their context, in any analysis of policy, planning and programming access to resources, opportunities and rewards of labour in terms of retention, position placement/rank, such as improved maternity condition with the objective of ensuring a positive impact on women and men and bridging gender disparities. Our University is committed to fostering an inclusive culture where equality is promoted and diversity is recognized. We also maintain a cordial working, learning and social environment in which the rights and dignity of all students are respected, irrespective of gender, tribe or religious beliefs. Any act of harassment or victimization is strongly regarded as unacceptable behaviour and is not tolerated in any form. The

ACE-FUELS Sexual Harassment Policy spells out mechanisms for enforcing laws that regulate and penalize all harmful cultural, religious and social gender-biased discriminatory practices, which reproduce or promote gender inequality. This will help to achieve equity and equality in employment opportunities and eliminate all discriminatory and abusive practices (on the grounds of sex, ethnicity, class, religion, age, disability, or marital status) against the employment or enrolment of women in the Center. The ACE-FUELS Sexual Harassment Policy is available on (https://acefuels-futo.org/resources/).

1.5 Scholarship and Research Policies

The ACE-FUELS Scholarship Policy establishes the framework for consideration and award of the Centre's portfolio of scholarships can be found on (https://acefuels-futo.org/resources/). The selection of scholarship recipients shall be merit-based, fair, transparent, gender-balanced, coherent and specified in the ACE-FUELS Scholarship Policy document. We have set out

organizational mechanisms to give special preferences to individuals with disabilities, economically disadvantaged people, students from fragile and conflict affected states, especially when considering scholarships and awards. For applicants with equivalent academic level, preference shall be given to candidates from less advantaged socio-economic backgrounds, those from fragile and conflict affected states and those with disabilities. Non-discriminatory clauses prohibiting exclusion on account of ethnic grouping, sex, place of birth or family origin or religion or political persuasion from studentship, employment or membership of anybody will be established. This will help to build a community devoid of discrimination, guaranteeing equal access to academic and research opportunities for all. Scholarship holders are expected to maintain high level of achievement in their studies and will be monitored against the relevant regulations throughout the tenure of the scholarship to ensure that their eligibility to hold the scholarship is maintained. The minimum scholarship requirements shall apply to all students who have been offered any form of scholarship by the Centre. Any student who falls below the specified minimum at the end of any given semester may have their scholarship withdrawn.

1.6 English Language Support Programme (ELSP)

All ACE-FUELS programmes shall be run in English language. English language appreciation courses are available under the ELSP at the FUTO Language Laboratory, for Regional/International students who do not speak English as first language. ELSP offers English language lessons, tutorials and interactive sessions to improve academic English language skills. The Handbook for the English Language Support Programme is available on (https://acefuels-futo.org/resources/).

1.7 Worship Centers

Our university campus accommodates diverse religious beliefs, has facilities for different religions, groups and services. Students have open access to chapels, meditation spaces and worship areas for many religious beliefs, with readiness to accommodate newer ones. There is zero tolerance for religious discrimination on campus.

1.8 Academic Calendar

The FUTO Academic Session begins each year in October, with the Harmattan Semester (October – February) and ends in August with the Rain Semester (April – August). The Academic Calendar for each new session is approved by the University Senate before the end of the preceding session.

1.9 Other University Resources

Some other relevant academic and administrative resources of the University available to students are listed in Table 2. Detailed information on these resources and more are freely available on the University website: https://futo.edu.ng/

Table 2. Some Relevant University Resources

Some Relevant Academic Centers and Units	Some Relevant Administrative Units
Centre for Research & International Development (CRID)	Anti-Corruption & Transparency Unit (ACTU)
Institute for Women, Gender & Development Studies (IWoGDS)	Council Matters Unit (CMU)
Academic Planning & Development Unit (APDU)	Estate and Works Unit
Intellectual Properties and Technological Transfer Office (IPTTO)	Information and Public Relations Unit (IPRU)
Pre-Degree Unit	Linkages and Advancement Unit (LAU)
Students Industrial Work Experience Scheme (SIWES)	Legal Matters Unit (LMU)
University Library (UL)	Physical Planning and Development Unit
University Computer Center (UCC)	Student Affairs Unit (SAU)
University Admission Office (UAO)	Quality Assurance Unit (QAU)
FUTO International Secondary School	Catering Unit (CU)
University Staff School (USS)	FUTO Bookshop
	FUTO Bus Unit
	FUTO Security Unit

2. INTRODUCTION TO ACE-FUELS @ FUTO

The Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) is established to fill a growing education, skills and information gap in the field of renewable and other clean energy sources within the sub region and in this way address the regional development challenge of poor availability and access to energy. Indeed, there is really no shortage of energy in the sub region, which has an abundance of renewable energy resources (solar, wind, biomass, hydrothermal, clean hydrocarbon). What is lacking is the requisite skilled human resources as well as the technological, educational, physical and economic infrastructures for efficient and inexpensive exploitation of the available resources, to effectively navigate this challenging and complicated transition from the conventional to clean energies. The Centre shall prioritize training, research and development, knowledge sharing and dissemination, community education, technical skills and capacity development, stakeholder engagement, industry partnerships, research translation and commercialization as its core functions. The Centre's functionality shall bear a national and regional outlook, which would ultimately facilitate development of local, national and regional capacities and competences.

The mission of ACE-FUELS Centre align perfectly with the mission of the Federal University of Technology Owerri; "...to operate practical and result-oriented programmes and training geared towards transforming the nation's economy from consumer-oriented to production-oriented, with a sound technological base. The initiative satisfies the energy priority of the New Partnership for Africa's Development (NEPAD), to fully utilize the opportunities that promote greenhouse gas mitigation, as well as the National Economic Empowerment and Development Strategies (NEEDS) on the development of power generation infrastructure. Moreover, energy is central to virtually all MDGs, as access to equitable and sustainable energy is a precursor to poverty reduction/eradication, wealth generation, good health services, women empowerment and enhancing literacy.

2.1 Centre Objectives:

ACE-FUELS is envisaged to:

1. Develop a critical mass of well-trained researchers to meet requirement of R&D professionals for clean energy and related high technology applications.
2. Initiate and support high end research, to extend knowledge beyond the existing practice in the industry.
3. Promote local content in research and innovations by initiating necessary value-driven industry-academia collaborations.
4. Partner with local content industry initiatives within the region to help develop competencies by providing bespoke work-based learning events, activities and tools in line with global best practices.
5. To set up standard laboratories, with facilities for multi-disciplinary research projects based on electrochemical and energy related technologies.

2.2 Centre Activities

An outline of the proposed activities of the Centre is given in **Table 1**; with six core activities through which the Centre relates to the outside world.

TABLE 1: Description of activities at ACE-FUELS Centre

ACTIVITY	STAKEHOLDERS	OUTPUT
Education	Researchers and Students for PhD, MSc, PGD and professional short courses	• Teaching, learning, research • Technical & entrepreneurial skills development • Institutional, national and regional capacity development • Revenue to the Centre
Research & development	Researchers, students, industry /sectoral partners	• Improved creativity & innovation. • Develop new processes & product lines • More efficient RE generation and deployment systems
Commercial Research & Laboratory Analysis	Researchers & students from different national & regional universities; Industries, Government agencies.	• Local, national & regional improvements in research quality • Improved research capacity and research output • Industrial contract testing & Revenue to the Centre
Products testing, standardization & certification	Industries, product developers, marketers, Regulatory Agencies	• Develop products/process standards • Product/market regulation & Consumer protection • Revenue to the Centre
Information dissemination	Consumers/general public; Government, Decision makers	• Wider acceptability/improved regulations promoting RE • Increased investments and businesses in RE • Improved patronage of the Centre & Revenue to the Centre
Technology and Knowledge transfer	Industries, product developers, marketers, Consumers/general public	• Research translation & start-ups • Commercialize new processes/products & Revenue to the Centre

EDUCATION AND TRAINING: ACE-FUELS shall achieve its core education mandate by strengthening/modifying the relevant existing programmes in our partner Departments in order to appropriately link science with technology, in line with the Centre's goals. The Partner Departments include:

- Chemistry
- Physics
- Electrical/Electronic Engineering
- Mechanical Engineering
- Petroleum Engineering
- Polymer and Textile Engineering
- Chemical Engineering
- Metallurgical and Materials Engineering
- Geology
- Biotechnology
- Microbiology
- Environmental Management

The Centre has also introduced novel, bespoke multidisciplinary PhD and MSc programmes related to the focus disciplines of the Centre.

1. MSc/PhD in Future Energies
2. MSc/PhD in Nanotechnology
3. MSc/PhD in Electrochemical Technology
4. MSc/PhD in Corrosion Technology

The Centre also offers the ACE-FUELS professional training and career development courses designed to enhance the practical skills, expertise and credentials of science and technology professionals, as well as ACE-FUELS Training and Skills Support Programme, designed to offer

hands-on training for young professionals without academic qualifications. The Centre has put in place incentives and facilities to attract and retain talented female students, as well as regional students. We shall strive to ensure that all our programmes have the highest national and international accreditation possible.
The Centre provides standard facilities for teaching, learning and capacity development, with exciting and interactive learning opportunities for optimal development of technical and entrepreneurial skills, in order to solve pressing problems hindering energy and technology availability and access. ACE-FUELS utilizes the existing OYLEX online learning management system (LMS) in FUTO, which is a highly intuitive tool for delivering online courses and education that supports the whole learning spectrum. This OYLEX LMS provides learner-centred instructions and access to resources. It serves as a support system to deliver quality lessons, conduct assessments and track/analyze performance, while fostering improved/enhanced student-instructor communication. Lesson contents can be accessed anytime and anywhere for personalized learning and standardization of materials.

RESEARCH: Research at FUTO is built around dedicated and multidisciplinary research units spread over nine (10) Schools and 52 Departments. Each of the Engineering and Science Departments has dedicated demonstration laboratories and research laboratories, providing facilities for undergraduate and postgraduate research. The Federal Ministry of Environment (FMEnv) recently accredited FUTO Environmental Laboratories to provide Environmental Laboratory Services. Many of our researchers work in research centres like the Centre for Energy & Power Systems Research (CEPSR), Centre for Nuclear Energy Studies & Training (CNEST) and a Centre for Industrial Studies (CIS). FUTO has established 4 key research priority areas (RPAs) that engage researchers in all Schools and Centres/Institutes in interdisciplinary research. Each area comprises a number of smaller research clusters. The relevant RPAs like Energy and Environment and Advanced Materials are directly linked to the mandate of ACE-FUELS as outlined in **Figure 1**.

All the national, regional and international institutions selected as partners on this project possess modern facilities, expertise, resources and data, as well as unique and outstanding capacity to immensely improve the scale and scope of research projects, thereby enhancing the capacity for innovation and new discoveries. There is therefore no doubt that our researchers and partners possess the expertise and experience to train highly motivated and result-oriented postgraduate students and to deliver meaningful solutions to technological problems and needs of the society in a timely manner, as envisaged within the framework of the proposed ACE-FUELS.

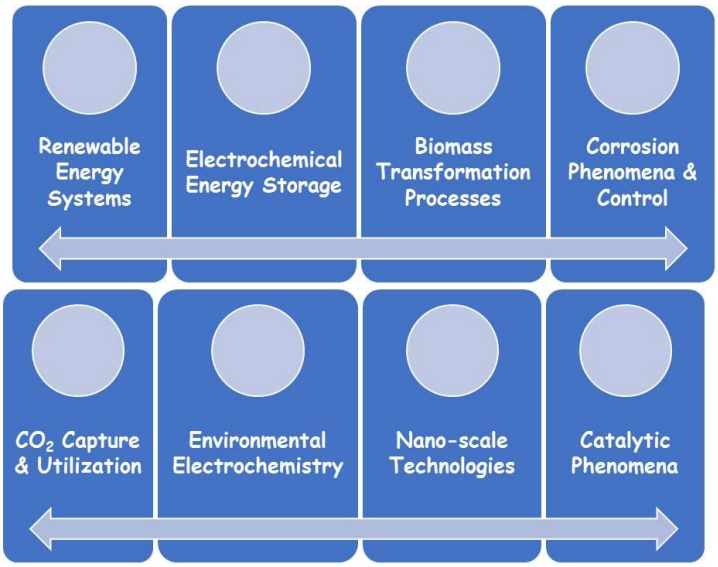

FIGURE 1: ACE-FUELS Research Priority Areas (RPAs)

PARTNERSHIPS: ACE-FUELS is partnering directly with 22 national, regional and international academic institutions for education and research collaborations in such areas as training, research and co-supervision, lecture delivery, access to facilities, joint workshops etc. We are as well partnering with 12 industrial/sectoral partners who partake in setting training and research agenda, and offer adjunctships, fellowships, student internship positions etc. The Centre has forged cooperation with broad-based national, regional and international knowledge networks like the Pan African Electrochemistry Network, Green Africa Innovation Network and recently the West African Centres of Excellence in Energy Network, to evolve novel technologies and approaches, which optimally engage local and regional scientific talents, while linking global expertise. ACE-FUELS programmes, processes and facilities shall be made to undergo relevant national and international accreditations as a means to extend acceptability and influence.

CONTRACT RESEARCH AND LABORATORY SERVICES: ACE-FUELS plan for contract research shall be to incorporate a Consultancy Unit, overseen by the Industry Liaison Officer. In this way, the Centre shall respond to tenders for contracts and consultancy services. Accordingly, the laboratories shall be configured to offer commercial laboratory testing and analytical services to researchers and students of other local, national and regional institutions as well as to government and private agencies. The Centre shall provide the research community with high quality research data on energy, electrochemical technologies and functional materials. Postgraduate students from other universities and research institutes from within and outside the country can apply for laboratory bench work at the Centre for a fee. The proposed Centre shall, through its Consultancy Unit, provide national and regional product testing, standardization and certification services to industry and thus assist in regulating the quality of products and services in the sector for more effective consumer protection.

3. PROGRAMME DESCRIPTION/STRUCTURE

Philosophy of the Programme

The philosophy of the Future Energies programme of the Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) at Federal University of Technology Owerri, is to inspire a new generation of highly skilled professionals, who will be able to develop novel technologies and new materials for efficient exploitation of the Africa's abundant energy resources and in this way address the regional development challenge of poor availability and access to energy.

Aim and Objectives

The primary goal in creating ACE-FUELS is to actively contribute towards the development and deployment of renewable and clean energy technologies in Nigeria and indeed Sub-Saharan Africa. In this way, the regional development challenge of poor availability and access to energy will be addressed. Thus, ACE-FUELS Future Energies programme is designed to:

(ii) Produce graduates of international standard, with appropriate knowledge and skills in their field of study, who will be highly employable, and also able to employ themselves.

(ii) Provide and expand access to relevant academic programmes that will impact on the local, regional, and international communities.

(iii) Develop a critical mass of well-trained researchers to meet requirement of R&D professionals for clean energy and related high technology applications.

(iv) Initiate and support high end research, to extend knowledge beyond the existing practice in the industry.

(v) Promote local content in research and innovations by initiating necessary value-driven industry-academia collaborations.

Mission/Vision: The ACE-FUELS Future Energies programme provides exceptional multidisciplinary training and research opportunities that will develop energy technologies of the future, integrate them into today's infrastructure, and examine their possible consequences for our society, economy, and environment.

FUTURE ENERGIES PROGRAMME OPTIONS (5 OPTIONS)

The MSc programme in Future Energies has five (5) possible areas of specialization and equips students with cutting-edge knowledge and skills in research, development, innovation in clean and renewable energy:

1. Solar Energy Specialization
2. Bioenergy Specialization
3. Clean Hydrocarbon Specialization
4. Geothermal Energy Specialization
5. Hydrogen Energy Specialization

The course takes an immersive approach to learning both the principles and practices of clean energy with much of the material based around examples and practical exercises. Students completing this course will have a firm, broad-based understanding of basic energy concepts, technologies and contemporary energy challenges and acquire knowledge for possible solutions to sustainable clean energy usage. They will develop and demonstrate broad-based expertise in renewable energy technologies, including identification, design, fabrication, characterization and utilization of clean energy technologies in diverse fields.

3.3 Programme Description

The ACE-FUELS MSc programme in Future Energies is designed as 18-month full-time courses. Students in the programme spend a 12-month period of learning, instruction and research on campus, at the end of which they submit their thesis and thereafter proceed for internship with any of the Center's several industry partners. The students undergo oral examination of their thesis at the end of the internship period.

The MSc programme of study is made up of three (3) essential modules of instruction:
(1) Mandatory Module
(2) Module of Specialization
(3) Project Module
The modules include lectures, tutorials, seminars, hands-on sessions as well as guest lectures by industry subject-matter experts.

3.4 Programme Structure

The ACE-FUELS MSc programme in Future Energies is structured into three (3) modules, totaling 55 credit units. Each credit unit corresponds to 15 hours of instruction.

MODULE 1:

Name	Credit Units	Duration
Mandatory Module	20	8 weeks

The Mandatory Module is made up of seven (7) carefully designed courses, aimed at providing comprehensive and broad-based education in the general area of the programme. All the contents of the Mandatory Module for the MSc FEM programme must be taken by all students enrolled in the programme, irrespective of area of interest or specialization.

MODULE 2:

Name	Credit Units	Duration
Module of Specialization	15	8 weeks

The Module of Specialization is more flexible and designed to offer courses that are most suited for each student's area of specialization and research interest. The Module is made up of three (3) fundamental courses in the area of specialization (9 Credit Units) and any three (3) courses from a list of elective courses (6 Credit Units).

MODULE 3:

Name	Credit Units	Duration
Project Module	20	36 weeks

In the Project Module, each student will be guided to undertake and complete an in-depth individual research project involving experimental, theoretical or computational studies in the area of interest. Each student will be guided by a principal supervisor and a co-supervisor who are academics and experts in the area. An industry-based supervisor may be included where necessary. The team of supervisors shall be assigned at the start of the programme and will work closely with the student all through the study period. The Project Module includes three (3) seminar sessions: Seminar I (Research Proposal); Seminar II (Progress Report); Seminar III (Final Report).

Internship Programme

Students who are successful in all three (3) modules and submit their draft thesis at the end of the 12-month period will proceed for Internship with an industry partner. The internship is to enable the student to integrate and function effectively, applying scientific knowledge and practice in an industrial setting, in conformity with laid down rules and regulations. Final oral examination of the thesis shall take place after successful completion of the internship programme.

3.5 Expectations from Students

(i) ***Research Publications:*** Each student is expected to co-author and publish at least one (1) article from their research work in a relevant Tier 1 peer-reviewed journal indexed by Thompson Reuters.

(ii) ***Presentations***: Each student is expected to attend and present papers (oral or poster) at a national/regional professional body conference.

(iii) ***Workshop/Seminar Participation:*** All students are expected to attend and participate in all workshops, seminars, guest lectures and other activities organized by the Center.

4. RESEARCH AND CAREER OPPORTUNITIES

4.1 MSc. FUTURE ENERGIES

Research Areas

Future Energies research areas focus on development of novel low-cost renewable energy technologies and devices for innovative and efficient exploitation of the region's abundant energy resources. This includes design and construction of solar, wind, hydro, marine and geothermal energy devices for efficient clean energy harvesting and storage. The solar energy research projects are based on improving design and performance of organic, inorganic, thin film, hybrid solar cells and 3-D printed solar cells, solar thermal systems, development of novel conducting polymers, semiconductors and nano-structured materials used in solar cells etc. Our hydro energy research projects are focused on development and domestication of the technology for small and micro hydro-turbine production using locally sourced materials. We are also interested in biomass conversion systems research with focus on improving the efficiency of biofuel, bioethanol and biogas production systems, microbial technologies for bio-energy production. Our research is also centred on developing efficient and inexpensive catalysts for the complex electrochemical conversion of carbohydrates for electricity generation using carbohydrate fuel cell and bio-fuel cells, with focus on starch-rich process water from cassava processing plants. In Future Energies research, we are also interested in field analysis and performance measurement of sustainable renewable energy systems; carbon capture and sequestration technologies; design and construction of bio-diesel and bio-oil production plants; next generation energy systems for domestic and industrial applications; modelling, simulation and optimization of renewable energy systems.

Career Opportunities

Career prospects in the renewable energy field are excellent. Energy plays a key role in the economy and environment. According to experts, there is a huge and growing demand for energy that is reliable, cheap and clean, with the potential to counter poverty and climate change. Renewable energy projects require a workforce with diverse background and skills-set. There are job opportunities for Materials Scientists, Engineers, Chemists, Ecologists, Biologists, Physicists, Geologists, Architects, Project Managers, Computer Scientists and Communication professionals. In fact, if you are looking for a stable job that pays well, a career in Future Energies is what you need.

5. ADMISSION REQUIREMENT/SELECTION PROCESS

5.1 ADMISSION REQUIREMENTS

The minimum admission requirement of the ACE-FUELS MSc programmes is a good Second-Class Honors degree in a relevant Science or Engineering discipline from a Nigerian university, or an equivalent qualification from Universities outside Nigeria.

5.2 SELECTION PROCESS

The selection process is mainly based on submission of the required application documents and fulfillment of the general application requirements. Applicants who fulfill these requirements will be scheduled for computer-based aptitude tests and interviews (either face to face or via Skype or phone). Applicants are rated using a scoring system based on the following criteria:

S/N	CRITERIA	SCORE
1	Research excellence	40
2	Motivation	15
3	Enthusiasm	10
4	Ability to take initiative & independency	20
5	Communication ability	15
	TOTAL	**100**

Candidates who score up to 60 points will be considered for admission into the programme. There are no restrictions based on age, gender, religion, nationality, ethnicity, disability or political orientation of the candidates.

Deadlines

Nomination and selection of MSc candidates take place only after the application deadline. Applicants will be notified of their application status no later than four (4) weeks after the application deadline. Candidates whose initial submissions meet the requirements will be invited for the phone interview and shall be informed of their final admission status within two (2) weeks.

Appeal & Redress

Unsuccessful candidates who believe they were unjustly evaluated due to discrimination based on gender, religion, age, ethnicity, nationality, disability, as well as procedural errors or other ethical issues, can appeal within two (2) weeks of receiving notification of their application status. An appeal committee will consider all such appeals within one (1) month.

6. COURSE OUTLINE/COURSE CONTENT

PREAMBLE

Even though hydrocarbons fuels remain abundant and relatively cheap in many aspects, concerns over their finite nature and environmental impact are compelling the global efforts to implement policies to accelerate transition to cleaner energy sources. With the energy and environmental landscape changing rapidly, investments are also being made in research to understand and attain the next steps. There is no doubt that science, technology and innovation (STI) will play a fundamental and critical role in this challenging transition to the clean energies of the future. Unfortunately, Nigeria and other Sub-Saharan African countries seem to lack sufficient skilled human resources as well as technological, educational, physical and economic infrastructures to effectively adapt STI for efficient exploitation of the abundant clean energy resources in the region.

The ACE-FUELS Future Energies programme provides exceptional multidisciplinary training and research opportunities that will develop energy technologies of the future, integrate them into today's infrastructure, and examine their possible consequences for our society, economy, and environment. Renewable energies have become the fastest growing industry in the world. It is also our goal to as well develop solutions for challenges presented by current energy systems, particularly as regards cleaner hydrocarbon production. Thus, students completing this course will have a firm, broad-based knowledge and skills to fill a growing education, skills and information gap in the field of clean energy and their high-level applications within the sub region.

PROGRAMME OUTCOMES

At the end of this postgraduate programme in Future Energies, the graduates should be able to:

1. Understand the Basic Energy Concepts, technologies and contemporary energy challenges and acquire knowledge for possible solutions to sustainable clean energy usage.
2. Develop and demonstrate broad-based expertise in renewable energy technologies, including identification, design, fabrication, characterization and utilization of clean energy technologies in diverse fields.
3. Demonstrate competence in responsible conduct of research, ability to critically analyze data as well as carry out design and manage research projects independently.
4. Develop effective oral and written skills.
5. Demonstrate ability to identify and respond to key innovation demands by recognizing and exploiting relevant sources of information for innovation.
6. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
7. Develop strategies and practices to manage the concerns and risks associated with widespread utilization of renewable energy devices.

6.1 MANDATORY MODULE

S/N	COURSE CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 801	Energy/Environmental Policy & Management	3	0	0	3
2	FEM 803	Future Energy Systems I	3	0	0	3
3	FEM 805	Future Energy Systems II	3	0	0	3
4	FEM 807	Future Energy Systems III	3	0	0	3
5	FEM 809	Local Solutions for Energy Access	3	0	0	3
6	REM 801	Research Methods & Innovation	2	1	0	3
7	MGT 805	Entrepreneurship	2	0	0	2
TOTAL			**20**			

(1) FUTURE ENERGY SYSTEMS (I, II, III)

This suite of courses forms the foundation of the Future Energies programme. It will provide course participants with an overview of Basic Energy Concepts, including the most significant renewable energy resources, concepts, technologies and challenges to overcome climate change and other sustainable development goals and an insight into the possible solutions to sustainable energy usage. Course participants will be able to recognize, understand and evaluate the different renewable energy resources available today and in the future, including their advantages and disadvantages.

FEM 803: FUTURE ENERGY SYSTEMS I

- Solar energy technologies
- Wind energy technologies
- Biomass energy technologies

Solar Energy Technologies

This course deals with the renewable energy systems which directly exploit the solar radiation received by the earth viz. solar photovoltaics (PV), solar thermal technologies. The course describes the fundamental mechanisms of solar energy conversion on solar cells, including the principles, manufacturing technologies, efficiencies, advantages and limitations of various PV cells. The optical and thermal parameters for solar thermal technologies are also considered with the basic heat transfer and thermodynamics principles that apply and the approaches for generating electrical power. The exploitation of these renewable energy systems in both large-scale power plants and in the urban, built infrastructure is considered. Topics include: Solar resource and solar radiation (the sun, solar radiation, solar spectral distribution, solar constant, solar insolation and position of the sun w.r.t surfaces on earth, solar time, AM 1.5 and irradiance, measurement of terrestrial solar radiation etc.). Advantages and disadvantages of solar energy. Photoelectric effect and concept of photons. Interaction of light with matter (absorptivity, reflectivity, transmittivity, emissivity etc). Principles of operation of PV cells; Manufacturing technologies of crystalline and thin film PV cells. Heat transfer and principles of solar thermal systems. Introduction to Solar collectors, Passive and active solar thermal systems, Solar drying, Solar distillation, solar cookers. The concepts of stand-alone and bulk solar thermal power generation systems

Wind Energy Technologies

This course deals with the harvesting of energy from wind. It addresses the availability of the resources, the types of systems and machines, their capabilities and limitations, the processes of setting up such systems, and their associated costs and environmental impacts. Wind energy, its potentials and its application to power generation. Advantages and disadvantages of wind energy. Wind resource and wind power; Wind power fundamentals, Wind generation, Wind power estimation. Wind turbine technology. History of wind power harnessing – windmills (wind machines in antiquity, Islamic civilization windmills, Medieval European windmills, Aegean & Mediterranean windmills, Dutch & European windmills, The American windmills). Overview of wind turbine components (Aerodynamic rotor, transmission system, generator, power electronics interface, control system).

Biomass Energy Technologies

The course considers the technical issues, economic feasibility and sustainability of bio-energy production in the African context. The focus of the course is in the integration of technical, economic and sustainability considerations into project development, to find practical, innovative, sustainable solutions for bio-energy production. The course will involve the development of a conceptual understanding of the conversion technologies for bio-energy and biofuels production, including biodiesel, biogas, ethanol, combustion, pyrolysis, gasification and electricity generation. Topics include: Biomass as a renewable energy source (Historical development & potential of bioenergy, biomass resources, Biomass properties, environmental impact of bioenergy, Economics of bioenergy). Biomass production and conversion: Photosynthesis (Basic concept of photosynthesis, light reaction for the photochemical oxidation of water, dark reaction for the synthesis of sugars, efficiency of photosynthesis). Biomass production (Natural factors, biomass yield, fossil input for biomass cultivation & harnessing, biomass logistics, environmental impacts of biomass cultivation, Economics of biomass production, major terrestrial biomass crops, aquatic biomass). Biomass conversion processes (Thermochemical conversion processes, biochemical conversion processes, chemical conversion processes). Utilization of biomass energy (Biofuels, electric power generation, heat production, chemical biorefinery). Advantages and disadvantages of biomass energy.

FEM 805: FUTURE ENERGY SYSTEMS II

- Hydropower technologies
- Geothermal technologies
- Ocean energy

Hydropower Technologies

Hydropower as renewable energy technology and its development: Components of Hydropower facilities. Classification of Hydroelectric power plants. Advantages and disadvantages of Hydropower. Hydrology and Hydraulics; Hydrological cycle; Hydrographs/ flow-duration curves. Hydraulic turbines: Basic principle, Turbine types and sizes; Degree of reaction, Turbine performance & selection. Applications of Hydropower.

Geothermal Technologies

Geology of geothermal regions: The Earth and its atmosphere; Active geothermal regions; Model of a hydrothermal geothermal resource, Other types of geothermal resources (Hot dry rock, geopressure, magma energy, deep hydrothermal). Exploration strategies and techniques: Objectives of an exploration programme; Phases of an exploration programme (literature survey, airborne survey, geologic survey, hydrologic survey, geochemical survey, geophysical survey). Applications of geothermal energy: Electricity generation; Industrial applications. Advantages and disadvantages of geothermal energy.

Ocean Energy/Marine Energy

The earth's oceans are huge sources of renewable energy. This course highlights different ocean energy resources and applicable conversion technologies. Ocean resource assessment and measurement strategies

will be addressed. Topics include: The idea of renewable energy from the ocean. Ocean activities: Waves, ocean currents, tides, salinity, temperature gradients. Tidal energy and technologies for exploitation of tidal energy: Tidal devices; turbine types, oscillating hydrofoils etc. Advantages and disadvantages of ocean energy.

FEM 807: FUTURE ENERGY SYSTEMS III

- Hybrid systems/energy mix
- Hydrogen and Green Hydrogen
- Renewable Energy storage systems
- Clean hydrocarbon/Carbon capture technologies

Hybrid Systems/Energy Mix

This course introduces established categories of hybrid systems and their application potentials, as well as provides insights in the fields of energy saving and smart utilization. Topics include: Hybrid power generation systems. Combined wind-solar systems. Hybrid thermal energy systems; combined solar-thermal and geothermal systems, Hybrid wind-diesel systems, PV-diesel systems and wind-PV-diesel systems etc. Techno-economic feasibility for energy saving systems. Main energy storage technologies. Environmental-social benefits of hybrid energy systems. New technologies for hybrid power systems. Energy and cost savings with hybrid power systems. Cogeneration systems

Hydrogen and Green Hydrogen

This module provides an initial understanding of hydrogen as an energy source, including the different techniques for commercial production and utilization of hydrogen. The students will understudy the theories and mechanisms of electrochemical production of hydrogen via water electrolysis/water splitting, including types of electrolysis and electrolyzers. The students will be introduced to the concept of electrochemical series and the interplay between electrochemical series and electrolytic processes.

Renewable Energy Storage

This course describes the need for renewable energy storage, as well as concepts and technologies used for storing energy from different sources. The course also highlights the technical and other considerations that guide energy storage options and sizes of grid connected and off-grid systems. Topics include: Energy storage technologies: Electrochemical storage systems (Lead-acid battery, lithium-ion battery, liquid metal battery, nickel-based battery, flow batteries). Mechanical storage systems (Pumped hydro storage system, flywheel storage system, compressed air storage). Thermal storage systems (Hot water storage, molten salt storage, latent heat storage). Electrical storage systems (Supercapacitors, superconducting magnetic energy storage). Hydrogen energy storage technology (Electrolysis with cryogenic storage). Multiple technologies for the storage of energy generated by wind power and other renewable sources. Introduction to the ProGeo system for storing electrical energy as methane chemical energy: an overview - Generating and storing energy in the ProGeo system - Research and development of model plants.

Carbon capture & sequestration

Introduction to Carbon capture & sequestration. Coal characteristics and combustion, power plants, engines, fundamentals of combustion, gas turbines, pollution. GHG emissions, GHG emissions reduction measures, Clean Development Mechanism (CDM). Fossil fuel power generation, power plants, power plant technologies. Membrane technology in the production of clean and renewable power. CO_2 capture technologies 1 - general overview. CO_2 capture technologies 2 - chemical and physical processes. Membranes for CO_2 capture and hydrogen production. Electrochemical reduction of CO_2 to fuels. Overview of market potential and technical barriers for membranes - Market potential and technical barriers for membranes for CO_2 capture and hydrogen production

FEM 809: LOCAL SOLUTIONS FOR ENERGY ACCESS

This multi-disciplinary, non-technical course aims to provide the Masters' level student with a framework to analyze the local/regional DRE sector, to assess its challenges and to offer potential solutions. It aims to give students an introduction to the big picture of energy access opportunities. If situated early on in a Masters' programme, the course aims to open options for career paths or entrepreneurship opportunities in the energy access sector.

FEM 801: ENERGY/ENVIRONMENTAL POLICY & MANAGEMENT

Socioeconomic (sustainability) aspects determining the selection of conventional and alternative fuel balance for energy generation. Renewable energy economics and financing (national, regional, international). Economic considerations (provision of fuel, revenue generation, project design & facility construction) and Financing considerations (institutional framework, financing approaches & sources, contracts & risk allocation). Financing and investment opportunities in renewable energy implementation. Environmental policy and practices (e.g. conservation, renewable energy, pollution prevention, recycling). Environmental regulations for renewable energy. Environmental Impact Assessment, Environmental Evaluation, Monitoring and Compliance. Environmental Management systems and the Total management systems including the ISO 9001 and 14000 standards series. Environmental impacts of diverse energy sources (solar, wind, biomass, geothermal, ocean, etc.) including beneficial and adverse impacts. Big data analytics for energy and environmental management.

REM 801: RESEARCH METHODS & INNOVATION (3 Units)

Fundamental concepts of scientific research. Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings. Using research productivity tools (statistical, referencing, research design, etc.). Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on research and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and entrepreneurship.

MGT 805: ENTREPRENEURSHIP (2 Units)

Fundamentals of starting and operating business in energy ecosystem. Dynamic role of entrepreneurship in the energy sector of the economy. Financial planning and control; Forms of ownership for startups; Strategic Marketing Planning; New Product or Service Development; Business Plan Creation; Types and theories of Innovation; Sources and Process of Innovation; Technological Entrepreneurs; Innovation Strategy & Systems; Managing Innovation and Intellectual Property; Funding Innovation and sustainable entrepreneurship.

6.2 MODULE OF SPECIALIZATION

There are five (5) areas of specialization in the MSc Future Energies programme:

6.2.1 Solar Energy Specialization

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 802	Solar thermal conversion systems and application	3	0	0	3
2	FEM 804	Photovoltaic solar energy conversion	3	0	0	3
3	FEM 806	Advanced photovoltaic systems	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 802: SOLAR THERMAL CONVERSION SYSTEMS AND APPLICATION
Solar radiation: Nature and measurement. Solar collection and thermal conversion. Solar collectors (flat-plate collectors, evacuated-tube collectors, concentrating collectors, Fresnel lens concentrators, heliostats). Solar thermal systems applications – Active & passive (heating – water& space; cooling & dehumidification; drying & distillation). Thermal energy storage. Economics of solar systems

FEM 804: PHOTOVOLTAIC SOLAR ENERGY CONVERSION
Types of solar cell/Generations of solar cells. First generation solar cells (crystalline Si, GaAs, Polycrystalline silicon solar cells). Second generation solar cells (Thin film solar cells – amorphous Si, microcrystalline Si, CdTe, $CuInSe_2$, $Cu(InGa)Se_2$, $Cu2ZnSnS_4$). Third generation solar cells (Nanocrystalline-based solar cells, polymer-based solar cells, dye-sensitized solar cells, concentrator solar cells, Tandem solar cells). Fourth generation solar cells (Hybrid or organic-inorganic solar cells). Next generation solar cells (Graded bandgap solar cells, Perovskite-based solar cells, Quantum dot solar cells, intermediate band solar cells, solar cells with up & down conversion, nano-structured solar cells e.g. with carbon nanotubes, grapheme etc.). Differences between solar cells, modules and panels (sizes and Efficiencies). Application of solar cell/modules/panels. Very low power application (such as in wrist watches, mobile phone, small torchlight, radios etc). Medium power application (such as in solar-operated cars, Street lighting, water pumping, household appliances etc). High Power and very high-power applications (as in stand-alone and grid-tied solar power plants). PV Economics: Cost of production, Cost of PV energy/Payback time, Feed-in tariff, Levelized cost etc.

FEM 806: ADVANCED PHOTOVOLTAIC SYSTEMS
Solar resource & irradiation data sources. Different solar PV technologies. Photo-voltaic panel: electrical characteristics, maximum power point, influence of shading & diffuse irradiation, etc. Photo-voltaic array: impact of positioning & tracking, string design and DC cable sizing, etc. Connection to the distribution grid: power electronics basics, earthing and circuit-breaker design, system sizing, AC cable sizing, South African regulations & standards. Financial viability: understanding tariffs, payback, etc.

6.2.2 Bioenergy Specialization

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 812	Bioenergy systems	3	0	0	3
2	FEM 814	Biofuels	3	0	0	3
3	FEM 816	Bioenergy & biotechnology	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 812: BIOENERGY SYSTEMS

Thermal power plants, heat energy and heat production (Biomass-based power & heat generation, biomass combustion power systems, biomass gasification power systems, biomass-fueled internal combustion engines & gas turbines, polygeneration of electricity, heat & chemicals, biomass boilers & heating systems). Biomass-based fuel cell systems (overview, biomass integrated gasification-solid oxide fuel cell systems, biomass integrated gasification-proton exchange membrane fuel cell systems, fuel cell systems fed with liquid biofuels, including ethanol, glycerol, butanol etc). Biorefineries (overview, energy inputs to basic biorefinery steps, biorefinery feedstock).

FEM 814: BIOFUELS

Biodiesel, bioethanol, methanol, biogas (Chemistry, feedstock, production process, uses). Fischer-Tropsch fuels (Overview, coal-to-liquid processes, gas–to-liquid processes, biomas-to-liquid processes). Thermochemical ethanol (Process chemistry, catalysts for ethanol synthesis, process design, energy, environmental & economic aspects). Dimethyl ether (DME) (Process chemistry, DME as energy carrier, production technology, DME from fossil fuels, DME from biomass, energy, environmental and economic aspects). Hydrogen (chemistry of hydrogen production, uses, storage, production methods, hydrogen from fossil fuels, hydrogen from water splitting, hydrogen from biomass gasification, hydrogen from electrochemical reforming of biofuels, biological hydrogen production, future hydrogen production processes, energy, environmental and economic aspects). Substituted natural gas (SNG) (Chemistry of methanation, natural gas as energy carrier, SNG production technology, SNG from coal, SNG from biomass gasification, energy, environmental and economic aspects).

FEM 816: BIO-ENERGY & BIOTECHNOLOGY

Biomass chemistry. Biomass for modern biotechnology applications. Biofuel suitability and feasibility of different applications. Advanced modern methods for biomass treatment and handling. Complex thermal biomass conversion (gasification, pyrolysis, liquefaction). Principles of biochemical biomass conversion. Environmental impact of biomass production and use. Bio-based fuel additives. Lignin conversion and levulinic acid and furfural conversion. Industrial Microbiology and biotechnology: Types and methods of optimization of products- substrate level, physiological level, genetic level. Process optimization, selection of appropriate substrates, computer aided optimization-Modelling and simulation for product optimization using Design expert software, Minitab, Sigma Plot, Ms Excel etc. metabolic and genetic engineering for improved yield. Genetically Modified Organisms, Merits and demerits.

6.2.3 Clean Hydrocarbon Energy Specialization

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 822	Introduction to membrane technology	3	0	0	3
2	FEM 824	Carbon capture & sequestration technologies	3	0	0	3
3	FEM 826	Membrane technologies for renewable energy applications	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 822: INTRODUCTION TO MEMBRANE TECHNOLOGY

Introduction – General Principles of Membrane Technology. Membrane Process – Overview of Membrane Process Unit operations. Membrane Materials and structure. Membrane Manufacturing techniques. Process Design – Membrane Module configurations and system design arrangement. Principles, Design and Application of Membrane Unit Processes. Reverse Osmosis, Ultrafiltration, Microfiltration, Dialysis, Electro dialysis, pervaporation, Gas Permeation, Liquid Membrane Process &Novel Membrane separation. membrane technology in the production of clean and renewable power; Overview of market potential and technical barriers for membranes

FEM 824: CARBON CAPTURE & SEQUESTRATION TECHNOLOGIES

Membranes for CO_2 capture and hydrogen production. Metal-organic frameworks as molecular gas cylinders for CO_2 capture. CO_2 capture technologies 3 – absorption. CO_2 capture technologies 4 – adsorption. CO_2 capture technologies 5 - membranes, cryogenic, looping cycles. CO_2 conditioning. CO_2 transport; different ways of CO_2 transport, CO_2 properties under transport conditions, impurities present in CO_2 streams from different generation/capture systems, effects of impurities on CO_2 compression and transport, risks associated with CO_2 transport. Market potential and technical barriers for membranes for CO_2 capture and hydrogen production.

FEM 826: MEMBRANE TECHNOLOGIES FOR RENEWABLE ENERGY APPLICATIONS

Introduction - Membrane applications in solar hydrogen production - Solar water electrolysis - Thermochemical water-splitting cycles - Solar membrane steam reforming. Membrane technologies for solar-hydrogen production. Membranes for biofuels production & processing. Membrane processes for biofuel separation, Membrane materials and fabrication, Membrane operations for gas and vapour separation. Membrane reactors for biofuels treatment. Membrane bioreactors Ceramic membrane preparation and applications.

6.2.4 Geothermal Energy Specialization

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 832	Geothermal reservoir engineering	3	0	0	3
2	FEM 834	Advanced geothermal drilling/completion technology	3	0	0	3
3	FEM 836	Geothermal production/power plants	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 862 - GEOTHERMAL RESERVOIR ENGINEERING

Geothermal reservoir types. Concepts of geothermal systems. Mathematical foundations of single and multi- phase flow in porous media. Analytical and numerical methods. Phase behavior. Well productivity index. Recovery factor. Simulation. Well Stimulation and engineered geothermal systems. Field Examples.

FEM 864 - ADVANCED GEOTHERMAL DRILLING/COMPLETION TECHNOLOGY

Drilling Concepts (Drilling the Limit, etc.). Drilling Optimization. Drilling Performance Analysis. Drill string Dynamics. Drilling Problems (Risk Analysis, Solutions). Under-Balanced Drilling. New Developments in Drilling Operations. Blow Out. Geothermal Drilling Technology. Well Design and Well Construction. Offshore Drilling (Well Design and Special Consideration). HPHT Wells, Horizontal and Extended Reach Wells, Multilaterals. Completion & Well Intervention. Case Studies.

FEM 866 - GEOTHERMAL PRODUCTION/POWER PLANTS

Introduction to integrated production systems. Review of reservoir inflow characterization. Single-phase and multi-phase flow modelling in wells. Flow assurance issues. Surface facilities. Production monitoring and optimization. Integrated field management. Geothermal power generating systems: single-flash steam plants; double-flash; steam plants; dry-steam plans; binary cycle power plants; advanced and hybrid systems. Field examples. Geothermal heat use without involving a power plant or a heat pump. Geothermal heat pumps. Use of spent fluids from geothermal power plants for direct use applications in so-called "cascaded" operation.

6.2.5 Hydrogen Energy Specialization

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 842	Hydrogen Production and Utilization Processes	3	0	0	3
2	FEM 844	Electrolyzers and Fuel Cell Technology	3	0	0	3
3	FEM 846	Hydrogen Economy	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 842: HYDROGEN PRODUCTION AND UTILIZATION PROCESSES

Hydrogen energy. Hydrogen production, storage, transport and distribution systems. Hydrogen production methods (steam-methane reforming, electrolysis, thermochemical cycles, photoelectrochemical hydrogen production, biological processes, etc), the hydrogen rainbow (gray, blue, green hydrogen, etc). R&D goals for hydrogen production. Technical and economic comparison of different production methods and global status, cost analysis. Hydrogen separation and purification. Hydrogen storage, physical-based storage (compressed gas, cryo/cold compressed, liquid hydrogen), material-based storage (adsorbents, metal hydrides, etc), novel materials for hydrogen storage. Tank types and designs for compressed hydrogen and liquid state hydrogen. Hydrogen storage challenges, R&D goals, technical targets for hydrogen storage, hydrogen storage materials database. Hydrogen utilization in energy, power generation, transportation, buildings, industry. Safety, regulations, codes and standards for hydrogen.

FEM 844: ELECTROLYZERS AND FUEL CELL TECHNOLOGY

Components of electrolytic cells and electrolyzers, configuration of electrolyzer stacks, different electrolyzer technologies (PEM, AEL, SOE, etc). Water splitting reaction mechanisms, electrodes and electrocatalysts for water splitting, challenges, R&D goals, technical targets. Introduction to fuel cell technology, structure and working of fuel cells, parts of a fuel cell, fuel cell systems, types of fuel cells (PEMFC, DMFC, AEFC, SOFC, regenerative FC, etc), their advantages and applications. Efficiency and performance and associated losses in fuel cells, R&D goals, technical targets. Transportation and stationary applications of fuel cells. Microbial fuel cells. Thermodynamic analysis of fuel cells.

FEM 846: HYDROGEN ECONOMY

Definition and basic principles of hydrogen economy. Hydrogen economy and technology roadmap. Global overview of the market potential for hydrogen. Importance of hydrogen economy. Challenges of hydrogen economy. Hydrogen value chains. Design and operation of hydrogen supply chains. Clean energy and hydrogen economy. Transition pathways for hydrogen energy. Energy transition pathways for green hydrogen in Sub Saharan Africa. The future of hydrogen (opportunities and challenges). Skilling the green hydrogen economy.

6.3 GENERAL ELECTIVE COURSES

S/N	COURSE CODE	COURSE TITLE	L	T	P	UNITS
1	CHM 824	Electrochemical Applications	2	0	0	2
2	ETM 801	Basic Electrochemistry	2	0	0	2
3	PTE 824	Introduction to Polymer Science	2	0	0	2
4	NTM 832	Nanotechnology for Energy Applications	2	0	0	2
5	NTM 834	Computational Modeling & Simulation Methods	2	0	0	2
6	MGT 801	Project Management Basics	2	0	0	2
7	MGT 803	Change Management	2	0	0	2
8	EVM 801	Climate Change	2	0	0	2
9	CHM 864	Statistical Thermodynamics	2	0	0	2
10	CHM 868	Applied Spectroscopy and Electrochemistry	2	0	0	2
11	FEM 842	Smart Grid Technology Overview	2	0	0	2
12	FEM 844	Fuels and Combustion	2	0	0	2
13	FEM 846	Renewable Energy Finance and Management	2	0	0	2
14	FEM 852	Finite Element Methods	2	0	0	2
15	FEM 854	Exergy Analysis	2	0	0	2
16	FEM 856	Rock Mechanics	2	0	0	2
17	FEM 844	Mini-grids: Planning and Design	2	0	0	2
18	FEM 852	Appliances for off-grid communities	2	0	0	2

CHM 824: ELECTROCHEMICAL APPLICATIONS (2 Units)

Electrochemical material evaluation principles for the choice of electrodes and electrochemical systems. Electroanalysis, Desalination, Demineralization, Electrodecantation and Electrofloatation as separation techniques in electrochemical industries. Polarography at rotating disc electrodes as an electroanalytical technique. Electrometallurgy and electro-refining in mineral processing. Electrosynthesis of key industrial chemicals: chlorine, sodium hydroxide, hydrogen peroxide, sodium perchlorate, aluminum, adiponitrile (used for making nylon-66) etc

ETM 801: BASIC ELECTROCHEMISTRY (2 Units)

Electrodes and cell reactions. Electrode kinetics. Interfaces, Interphases, Electrical double layers and electrode processes. Butler-Volmer equation. The electrode/solution interface at equilibrium. Polarization electrodics. Some technological aspects of electrodics.

PTE 824: INTRODUCTION TO POLYMER SCIENCE (2 Units)

Introduction to polymer science. Polymer synthesis: Step-growth polymerization, chain growth polymerization and controlled free radical polymerization. Molecular weight and molecular weight distribution. Mechanical property relationships: Visco-elastic properties and thermo-mechanical properties of polymers. Polymer morphology: Intermolecular forces, crystalline and amorphous phases, cross linking. Copolymers: Homopolymer, graft, alternating and random copolymers. Polymer density. Mechanical

properties: Strain, stress, toughness, modulus. Polymer gels. Thermal properties: Melting point, glass transition temperature, degradation, crystallization. Hydrophobic and hydrophilic properties. Electrical properties. Polymer characterization: Thermal gravimetric analysis (TGA), differential thermal analysis (DTA), differential scanning calorimetry (DSC), scanning electron microscopy (SEM) atomic force microscopy (AFM)Fourier transform infrared spectroscopy (FTIR), dielectric strength, surface resistivity.

NTM 832: NANOTECHNOLOGY FOR ENERGY APPLICATIONS (2 Units)

Introduction to Nano scale materials & nanotechnologies: synthesis, characterization, functionalization of nanomaterials**:** some applications and challenges. Energies and nanomaterials: Introduction; context and challenges dealing with energy; energy and power; production, storage, distribution (smart grids) and use of energy; some illustrations. Nanomaterials for solar energy applications: Semiconductors, Interaction of light with matter, solar cells basics. First to third generation solar cells, nanocrystalline-based solar cells, emerging thin film photovoltaic: organic solar cells, hybrid solar cells. Solar cooling and heating. Nanotechnology for bioenergy and biofuels production. Carbon-based nanomaterials in biofuel cells. Nanomaterials as heterogeneous catalysts in biorefineries for biomass conversion. Nanomaterials for energy storage applications. Nanoscale electrode materials.

NTM 834: COMPUTATIONAL MODELING & SIMULATION METHODS (2 Units)

Theory and application of computational methods for simulation of molecular properties and spectra as well as structural and bulk properties of matter. Ab Initio methods, Density Functional Theory methods, Hybrid Quantum / Classical methods. Energy functions and force fields, geometry optimization, normal mode analysis, and reaction--path techniques at the molecular level, and an introduction to the simulation of static and dynamic properties of organic and inorganic substances, chemical reactions and molecular spectroscopies via both Monte Carlo and molecular dynamics (MD) methodologies. Simulation laboratory exercises are compulsory to enable each student acquire skills for modern computational simulation software and complete the computational project in order to pass the course. The student will be able to derive, analyze, and utilize the computational software for molecular mechanics methods, ab initio methods, density functional theory methods, simulating molecular properties and thermodynamics properties, molecular reactions dynamics.

MGT 801: PROJECT MANAGEMENT BASICS (2 Units)

Project design and management cycle, Project Implementation Plan (PIP), Project Development strategies, Project Monitoring, Evaluation and Learning (MEL) and sustainability. Application of Theory of change approach to Energy project. Use of designated software for development of Project Management.

MGT 803: CHANGE MANAGEMENT (2 Units)

Introduction to change concepts and theories of change management. Methodologies and processes of change management. Dimensions of change. Pre-requisite for change. Resistance to Change. Change Management Strategy & Systems. Communicating & Implementing change. Change Failure.

EVM 801: CLIMATE CHANGE (2 Units)

Air pollution, global warming and climate change. Climate change modeling. Climate change mitigation. Climate change adaptation and planning. Discussions on recent technologies to combat global warming and abate climate change. Sustainable development goals. Corporate sustainability versus profitability.

CHM 864 STATISTICAL THERMODYNAMICS (2 Units)

Statistical mechanics vs. thermodynamics. Review of statistical concepts. Canonical and grand canonical ensembles. Entropy. General formulation of statistical thermodynamics. Fermi-Dirac, Bose-Einstein and

Boltzmann statistics. Quantum ideal gases. Specific heat of solids. Electrons in metals and semiconductors. Radiation: the photon gas

CHM 868 APPLIED SPECTROSCOPY AND ELECTROCHEMISTRY (2 Units)

This topic introduces advanced spectroscopy and electrochemistry. Studies in the area of spectroscopy will focus on the principles of and use of NMR, IR and mass spectrometry for chemical structure determination. Studies in electrochemistry will focus on the underlying principles, important examples of electrochemical reactions and expand to the analytical uses of electrochemistry in sensor technology. A considerable focus will be on the underlying theory of each technique along with instrumentation and sample requirements.

FEM 842: SMART GRID TECHNOLOGY OVERVIEW (2 Units)

This course will provide a broad overview of all components and technologies associated with, and connected to, the new Smart Grid. The field specific knowledge to be covered would be Renewable Energy Systems and characteristics. Grid code compliance. PV components and sizing. Storage components, e.g. batteries. Microgrids and power flow. Energy storage scheduling, load-frequency control and inter-area power flow. Network dynamics &stability. Economics of SG installations. Communications technology and selection. Applicable network codes & regulations, and power system modeling and simulation software.

FEM 844: FUELS AND COMBUSTION (2 Units)

Fundamentals of fuels and combustion technologies. Conventional fuels – properties (energy density, pollutant load, costs) and uses. Advantages and disadvantages of conventional fuels. Options for alternative fuels. Conventional and novel combustion method. Impact of continued hydro-carbon fuel use, and possibilities for a more sustainable future. Fuel handling of conventional and novel fuels; relevant codes and legislation such as DSEAR/ATEX and consider implications on fuel use in industry.

FEM 846: RENEWABLE ENERGY FINANCE AND Management (2 Units)

The basic renewable energy financial metrics. Economic justification and impact of renewable energy projects. Sustainability drivers for renewable energy business. Barriers to renewable energy project implementation. Existing opportunities for renewable energy implementation. Energy Project Management. Big Data Analytics - Data Acquisition and Validation, Data Integration, Calculations and Design work, Application of supporting Software. Energy Economics. Energy Law II: Joint Operation Agreements. Drilling Contracts and related agreements for energy supply subsurface activities.

FEM 852: FINITE ELEMENT METHODS (2 Units)

The main objective of the course is to provide a practical training in technological design using finite element methods. The course aims at introducing the fundamental principles of the modelling for statics and dynamics analyses, as well as for stress analysis. Significance and importance of finite element methods in tech design. Fundamentals of finite element methods for small displacement linear elastic analysis (statics). Non-linear finite element method. Use and mastery of commercial FE software (Abaqus). Application of FE methods in modeling steady-state and transient field problems. Model development and output data analysis & interpretation.

FEM 854: EXERGY ANALYSIS (2 Units)

Sustainability & efficiency (sustainable development, sustainability methods & metrics, thermodynamic approach to sustainability of efficiency). Thermodynamic Analysis of process (Mass & energy rate balances for a steady flow process – 1^{st} law of thermodynamics, quality of energy & materials, entropy & 2^{nd} law of thermodynamics, entropy production, entropy rate balance for a steady flow process, maximum work obtainable from a steady flow process). Exergy concept (Defining exergy, exergy reference environment, exergy versus energy, exergy of work & heat transfer, exergy of a stream of matter, physical exergy, chemical exergy). Exergetic evaluation of process & technologies (Exergy rate balance for a steady flow process,

internal & external exergy losses, exergetic efficiency performance, Economic & Ecological aspects of exergy). Renewability of biofuels (Application of cumulative exergy consumption of biofuels production, renewability indicators).

FEM 856: ROCK MECHANICS (2 Units)

Poroelastic theory: Hooke's law for dry rock, porous rock or non-porous rock, Biot's and Skepton's Coefficient. Borehole stability: Effect of mud weight on well stability, Rupture modes around a borehole. Sand production prediction: Sand production mechanisms, Theories to predict sanding tendencies. Hydraulic fracture design: Theory and calculation of hydraulic fracture. Concepts of fracture and its measurements. Fracture orientation & azimuth, Fracture area, Numerical modeling. Reservoir engineering applications: Depletion and effective stress, Compaction drive, Reservoir compaction and compressibility, Subsidence.

MTH 862: METHODS OF APPLIED MATHEMATICS (2 Units)

First and second order differential equations in the phase plane. Linear approximations at equilibrium points. Index of a point; limit cycles; averaging, regular and singular perturbation methods. Stability and Liapunov's method. Bifurcation. Basic ideas of calculus of variations. The Euler-Lagrange equations; eigenvalue problems. Applications to second and higher order differential and partial differential equations. Rayleigh-Ritz and Galerkin methods and discrete models.

FEM 844: MINI-GRIDS: PLANNING AND DESIGN

This multi-disciplinary course aims to provide the Masters' level student with a framework for understanding the mini-grid sector, enabling the graduate to assess its challenges and to offer potential solutions. After completion of the course, the students should be able to identify the most suitable mechanisms to promote and implement clean energy mini-grids in their countries.

The course will offer the following topics, suitable for non-technical students:

- Business models: demand creation, productive use, financing
- Mini-grid systems: generation, storage, DC technology
- Regulation & policy
- Demand assessment and community engagement
- Future options - grid integration vs DRE; smart mini-grids: peer to peer democratisation, digitalization.

FEM 852: APPLIANCES FOR OFFGRID COMMUNITIES

This multi-disciplinary, non-technical course aims to provide the Masters' level student with the knowledge and skills to contribute to the off-grid appliances sector by assessing its challenges and mapping potential innovative solutions in the context of technology readiness, market opportunities and local socio-economic nuances. If situated early on in a Masters' programme, the course could open options for further research, as well as career paths or entrepreneurship opportunities in the DRE appliances sector.

7. STAFFING

Staff involved in the Africa Center of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) are drawn from the partner Departments in FUTO, as well as from our academic and sectoral partners:

Name	Rank
Abdulwahab, Malik N.	Professor
Achumba, Ifeyinwa E.	Professor
Alisi, Chinwe S.	Professor
Enenebeaku, Conrad K.	Professor
Eya, Dominic D.	Professor
Ezema, Fabian I.	Professor
Ezeonu F.C.	Professor
Madu, Chinyere A.	Professor
Nkwocha, Edmund E.	Professor
Nweke C. O.	Professor
Ogbulie, Judeanthony N.	Professor
Ogoke, Iheanyi J.	Professor
Ogueke, Chika C.	Professor
Ogueke, Nnamdi V.	Professor
Oguzie, Emeka E	Professor
Okereke, Chikwendu N.	Professor
Onyekuru, Samuel O.	Professor
Opara, Alexander I.	Professor
Orji, Chikwendu E.	Professor
Owuamanam, Clifford I.	Professor
Azeez, Taofik O.	Reader
Ibeneme, Ikechukwu S.	Reader
Ike, Innocent S.	Reader
Iwuji, Samuel C.	Reader
Lawal, H. A.	Reader
Nwachukwu, Ikenna	Reader
Ogbulie, Toochukwu E.	Reader
Ohia, Nnaemeka P.	Reader
Okeoma, Kelechi	Reader
Ujowundu, Cosmas O.	Reader
Uzoije, Atulegwu P.	Reader
Aharanwa, Bibiana C.	Senior Lecturer
Akalezi, Christogonus O.	Senior Lecturer
Amangabara, Gordon T.	Senior Lecturer
Anyiam, Chioma K.	Senior Lecturer
Arukalam, Innocent O.	Senior Lecturer
Duru Ijeoma	Senior Lecturer
Echeme, Ibeawuchi I.	Senior Lecturer
Echendu, Obi K.	Senior Lecturer

Name	Rank
Ihugba, Okezie A.	Senior Lecturer
Ikerionwu, Charles	Senior Lecturer
Joe-Uzuegbu, Chijioke	Senior Lecturer
Mbamara, Uchenna S.	Senior Lecturer
Nwanonenyi, Simeon C.	Senior Lecturer
Nwogu, Ngozi C.	Senior Lecturer
Obiukwu, Osita O.	Senior Lecturer
Oguzie, Kanayo L.	Senior Lecturer
Onojo, O. J.	Senior Lecturer
Onyeachu, Ikenna B.	Senior Lecturer
Orga, Anselem C.	Senior Lecturer
Oze, Rita	Senior Lecturer
Ugwu, Kelechi E.	Senior Lecturer
Ulaeto, Sarah B.	Senior Lecturer
Verla, Evelyn N.	Senior Lecturer
Ayogu, Ignatius I.	Lecturer 1
Chidiebere, Arinze M.	Lecturer 1
Chijioke, Chinonye F.	Lecturer 1
Etim, Ini-ibehe N.	Lecturer 1
Njoku, Chigoziri N.	Lecturer 1
Ohajianya, Anthony	Lecturer 1
Okorondu, Justin N.	Lecturer 1
Ugochukwu, K. A.	Lecturer 1
Njoku, Demian I.	Lecturer 1
Ugochukwu, K. A.	Sectoral Partner
Uba Osigwe, Kelechi	Sectoral Partner
Ozumba, Chinyere	Sectoral Partner
Nwankwo Emeka	Sectoral Partner
Nzuruba, C.	Sectoral Partner
Udensi, Emmanuel	Sectoral Partner

8. ACE-FUELS CONTINUOUS ASSESSMENT

PREAMBLE

Assessment plays an important role in the process of learning and motivation and can reinforce the efficacy of teaching and learning to achieve set targets and expectations. A key goal of ACE-FUELS is to develop a critical mass of well-trained researchers to meet requirement of R&D professionals for clean energy and related high technology applications, as well as initiate and support high end research, to extend knowledge beyond the existing practice in the industry. Accordingly, the types of assessment tasks that we ask our students to do will determine how they will approach the learning task and what study behaviours they will use in order to achieve the learning and research objectives of the Centre.

Indeed, the nature of our assessment tasks will enable us gather relevant information about student performance or progress, or to determine student interests to make judgments about their learning process, in line with the Centre's goals. After receiving this information, lecturers can reflect on each student's level of achievement, as well as on specific inclinations of the group, to customize their teaching plans and nature of engagement with students.

ACE-FUELS student assessment is achieved through review exercises focused on research publications relevant to modules students have learned (this is in addition to tests and quizzes to be conducted in the course of module delivery). This approach is more reflective of the core objectives of our programmes. There is no doubt that conducting a literature review is an effective method for building knowledge in any field. Accordingly, the literature review exercises enable our students gain an understanding of the existing research and debates relevant to a particular topic or area of study, and to present that knowledge in the form of a written report. Therefore, effective review exercises is very vital for clarifying the state of knowledge, explaining apparent contradictions, identifying needed research, and even create a consensus where none existed before. The most direct benefit from writing a review is the confidence it builds from writing, thinking critically, assembling new hypotheses, and proposing future directions in the area of interest.

8.1 NATURE OF MSc ASSESSMENTS

(Mono Literature Review/Single Article Review)

MSc assessment for each compulsory course shall take the form of a Mono Review or Single Article Review, which comprises a concise summary of one specific research publication per course registered by the student. This is simply the careful summary of a particular research article selected by the lecturers taking the course.

- The idea is to get the students to read and summarize a research article in 2-3 pages.
- Lecturers in each course shall provide 1-5 papers for consideration by the students. Articles selected by lecturers in each course shall be uploaded on the Course page on the OYLEX platform. Students are at liberty to choose any one of the articles for review. All papers to be used in this regard must be of sufficient impact and published in Web of Science indexed journals, please. They could be papers authored by the lecturer or from the literature. If you must use your paper, please ensure it has direct relevance to your module and is published in a WOS-indexed journal.
- The students are given **a time interval** to conclude the review assignment for each course and submit for grading. **The review counts for 20% of the total score for each course.**

8.2 STRUCTURE OF THE MONO REVIEW

The review shall be a well-articulated 2–3-page summary of the article, highlighting the main finding of the study, the supporting arguments, and major points.

1. **Student details**
   Full Name
   Registration No.
   Degree of Study/Programme of Study
   Course code/Course title
2. Title of selected publication, authors and name of the journal.
3. **Preamble:** (Like an abstract) is a one paragraph summary of the highlights of your review. This is normally written after the review has been completed.
4. **Objectives/focus of the study:** You describe what you consider the key objectives and focus of the study presented in the paper.
5. **Approach/methodology:** You describe the approach and methodologies adopted in the study. Did the authors leave out any important steps or experiments that could better improve the study? What additional techniques would you recommend?
6. **Important results/findings:** Identify and briefly highlight what you consider to be the major findings and conclusion of the study. Suggest the relevance of the findings to the focus area of study. Identify any lapses or gaps in their conclusions.
7. **Conclusion:** Conclude your review by describing the contribution of the article to new knowledge in the subject area. Recommend what further studies are necessary to improve the relevance of the work. Comment on the suitability of the reference list. Did the authors cite current and relevant papers in the area? Identify and comment on the reference style adopted.

Benefits of writing a mono review

1) Students learn how to read and digest research publications
2) Students develop the critical skill of summarizing
3) Students develop the important skill of writing

9. EXAMINATION MISCONDUCT

Any student who has been found guilty of the examination misconduct listed hereunder shall on approval of the Senate and without prejudice to Section 16 of the Federal University of Technology Owerri Laws, serve the corresponding punishment as follows:

NATURE OF OFFENCES AND PRESCRIBED PUNISHMENTS

a	Any student caught with a piece of paper, GSM phone or gadgets containing relevant information pertaining to the examination.	Rustication for one (1) academic session
b	second offender for (a) above	Expulsion
c	Impersonation during examination	Expulsion of the student(s)
d	Fighting Examination Supervisor or Invigilator etc.	Expulsion
e	Unauthorized handling of examination question papers	Expulsion
f	Exchange of Answer booklets	Rustication for one (1) academic session
g	Exchange of materials in examination hall	As above
h	Collaborative copying	Rustication for one (1) academic session. Expel at a repeat of the office
i	Smuggling of question paper in or out of the examination hall	Rustication for one (1) academic session
j	Refusal to appeal before a panel	Rustication for one (1) academic session
k	Forging/altering result grades and signature of officials	Expulsion
l	Coming into the hall with a gun or any other dangerous weapon	Expulsion
m	Threatening a staff or members of their families verbally or in writing	Expulsion
n	Procuring and altering a medical certificate in order to obtain a deferment of examination	Rustication for one (1) academic session
o	Sorting/alteration of examination grades by whatever means	Rustication for one (1) academic session
p	Submission of forged registration materials, including add/drop card.	Rustication for one (1) academic session


ACE I FUELS