FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI

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

Handbook for Doctor of Philosophy (PhD) Degree Programmes

(updated 01/25)

ACE FUELS
Africa Center of Excellence in Future Energies & Electrochemical Systems

ACE-FUELS: HANDBOOK FOR PhD 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/students-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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Student Representative	Mr. John Anyanwu	john.anyanwu@acefuels-futo.org	09031975124

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 to 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/students-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/students-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/students-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) Institute for Women, Gender & Development Studies (IWoGDS) Academic Planning & Development Unit (APDU) Intellectual Properties and Technological Transfer Office (IPTTO) Pre-Degree Unit Students Industrial Work Experience Scheme (SIWES) University Library (UL) University Computer Center (UCC) University Admission Office (UAO) FUTO International Secondary School University Staff School (USS)	Anti-Corruption & Transparency Unit (ACTU) Council Matters Unit (CMU) Estate and Works Unit Information and Public Relations Unit (IPRU) Linkages and Advancement Unit (LAU) Legal Matters Unit (LMU) Physical Planning and Development Unit Student Affairs Unit (SAU) Quality Assurance Unit (QAU) Catering Unit (CU) 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
5. MSc Energy Management and Entrepreneurship

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.

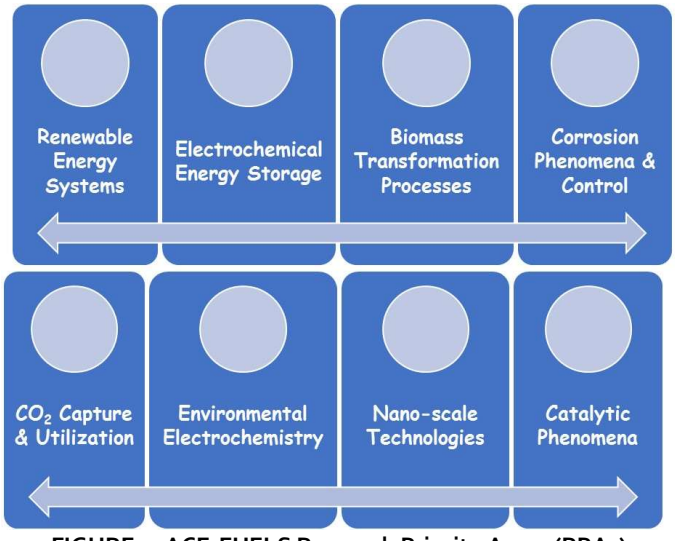

FIGURE 1: ACE-FUELS Research Priority Areas (RPAs)

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. PhD PROGRAMME DESCRIPTION/STRUCTURE

3.1 Philosophy of the Programme

In line with the overall philosophy of the Federal University of Technology Owerri (FUTO), Nigeria, the PhD programmes of the Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) at FUTO are designed to develop high-skilled professionals in Future Energies, Electrochemical Technology, Nanotechnology and Corrosion Technology, to be able to develop novel technologies and new materials for efficient exploitation of the region's abundant energy resources and in this way address the regional development challenge of poor availability and access to energy.

3.0 Aim/Objectives of the Programme

The primary goal in creating ACE-FUELS Centre is to actively contribute towards the development and deployment of renewable and clean energy technologies in Nigeria and indeed Sub-Saharan Africa, and in this way address the regional development challenge of poor availability and access to energy. Thus, ACE-FUELS programmes are designed to –

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

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

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

3.3 Programme Description

The ACE-FUELS PhD programmes are designed as 36-month full-time courses. Students in the programme spend a 30-month period of learning and research on campus and 1- 6 months internship period with a relevant industry partner within the second year of study.

Each PhD programme of study is made up of three (3) essential modules of instruction – (1) Module of Specialization, (2) Research Development Module, (3) Project Module. The modules include lectures, tutorials, seminars, hands-on sessions as well as guest lectures by foreign academic partners and industry subject-matter experts. The minimum credit units for the ACE-FUELS PhD programme is 70 units.

3.4 Programme Structure

Each of the ACE-FUELS PhD programmes is structured into three (3) modules, totaling 70 credit units. Each credit unit corresponds to 15 hours of instruction.

MODULE 1:

Name	Credit Units	Duration
Module of Specialization	18	24 weeks

The Module of Specialization provides solid and advanced education in the different areas of specialization and research interest. The Module is made up of three (3) advanced courses in the area of specialization (9 Credit Units), and any three (3) courses from a list of fundamental 800 Level elective courses (6 Credit Units).

MODULE 2:

Name	Credit Units	Duration
Research Development Module	15	48 weeks

The Research Development Module is designed to provide a solid foundation and insights in research conceptualization, design and translation, in novel and relevant research methodologies, research

communication, research policies, research ethics and conduct etc. Students will be guided to **author review articles** (up to 2) based on their coursework and research focus, for publication.

MODULE 3:

Name	Credit Units	Duration
Project Module	40	60 weeks

In the Project Module, each student, under guidance from a team of supervisors including one principal supervisor, two co-supervisors and an industry-based supervisor (where necessary), shall develop, conduct, write and defend an original R&D project addressing specified problems in the area of interest. The team of supervisors shall be assigned at the start of the programme and will work closely with the students all through the study period.

The PhD Project Module includes nine (9) seminar sessions.

PhD Seminar Schedule	
Year 1	Literature Review
	Research Proposal
	Candidacy
Year 2	Progress Report 1
	Progress Report 2
	Progress Report 3
Year 3	Progress Report 4
	Final Report/Internal Examination
	External Examination

3.5 Candidacy Examination

On successful completion of Modules 1 and 2, the student proceeds to PhD candidacy status. The candidacy examination is an oral examination to ascertain a student's general and specific knowledge of the proposed research focus area, including the student's potential to initiate and complete original high-level research as typically required for PhD level research. All PhD students must undertake and pass the Candidacy examination before the end of the second (2^{nd}) year of study.

3.6 Internship Programme

Students who are successful in Modules 1 and 2 and have undertaken the research proposal seminar may proceed for the compulsory 1-6 months Internship with an industry partner any time within the second (2^{nd}) year of study. The internship has no assigned credit units, but is a compulsory component of the programme, which provides an industry perspective in the research project. During the internship, the student is expected to apply theoretical and practical knowledge acquired in the programme in the industrial setting. On conclusion of the internship, the student should be able to translate a sectoral challenge into a pertinent research question

3.7 Expectations from Students

(i) ***Review Articles:*** Each student is expected to publish two (2) review articles in relevant Tier 1 peer-reviewed journals indexed by Scopus/Thompson Reuters.

(ii) ***Research Publications:*** Each student is expected to author and publish at least three (3) articles related to their research work, in relevant Tier 1 peer-reviewed journals indexed by Scopus/Thompson Reuters.

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

(iv) ***Grants***: Each student is expected to draft and submit at least one research grant proposal to an international funding agency or corporation.

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

3.8 PhD Program Monitoring

The academic progress of students occurs primarily at the program level so that student, supervisor, and program-wide problems are discovered and addressed early. Any notable variances in student completion rates provides indications of localized challenges and concerns that can be addressed quietly and effectively with students, tutors and supervisors. The next stage of monitoring at the postgraduate school level assesses performance of different programs in order to enable effective diagnosis and interventions on a university-wide scale, to better position the overall postgraduate program.

3.9 PhD Program Impact

We have developed a two-pronged approach for measuring the impact of our PhD program:

i. Productivity of the program and program participants (faculty and students) as measurable from the program completion rate, on-time graduation, number and reputation of academic and industry partners, number and quality of journal publications, patents, ability to attract funding, international faculty, international students etc.

ii. Alumni tracer studies to provide and assess the relevance of our PhD curriculum to the professional development of our graduates and to identify what work-based professional development programmes are needed to continually improve on-the-job performance. Feedback from such tracer studies shall guide curriculum review and improvement. This initiative shall promote establishment of strong bonds with our graduates, who are the subjects of the program training impact study, which the tracer studies represent. The initiative shall benefit from established close relationships with industrial and sectoral stakeholders, who employ the graduates.

3.10 Teaching/Learning Methods

A broad range of teaching and learning methods will be employed, including lectures, workshops and seminars, independent supported learning and group assignments.

TEACHING/LEARNING METHOD	HOURS
Lectures/instruction	50
Seminars and workshops	50
Wider reading or practice	30
Preparation for scheduled sessions	20
Follow-up work	20
Revision	30
Completion of assessment task	30
Total study time	**225**

3.11 Assessment Methods

Each student will be required to submit a written research proposal and an initial written literature review, leading up to publication of a review article. Assessment criteria is as follows:

Assignment	SCORE
Oral Research Proposal	20%
Written Research Proposal (6 – 10 pages)	30%
Written Literature Review (3000 – 5000 words)	50%

At the start of the Research Development Module, each student, after due consultation with the Team of Supervisors, must submit a brief outline of the proposed research project.

4. RESEARCH AND CAREER OPPORTUNITIES

4.1 PhD 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 bio-fuel, bio-ethanol 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 very 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. PhD degree in Future Energies prepares students for careers in the academia, industrial R&D, government and regulatory laboratories. In fact, if you are looking for a stable job that pays well, a career in Future Energies is what you need.

4.2 PhD ELECTROCHEMICAL TECHNOLOGY

Research Areas

Research projects on electrochemical technologies at the Centre are focused on electrochemical energy conversion and storage systems *(Solar cells, Fuel cells, Batteries, Supercapacitors), including* 3-D printed solar cells and 3-D printed graphene-based energy storage devices. These devices are indispensable enabling technologies for storage and transmission of electricity from renewable energy, with market demand in the multibillion US Dollar range. We are also interested in development of new carbon-based materials for electrochemical devices, from abundant local carbonaceous materials and agricultural wastes. Research shall also explore Nigerian rich biodiversity to develop locally produced nanomaterials for applications in electrochemical storage devices, bioethanol in proton exchange membrane and solid oxide fuel cells. We are interested in developing new conversion technologies to enable more innovative exploitation of the starch-rich process water from cassava processing plants, including design and fabrication of a prototype "indirect fuel cell" device. Environmental electrochemistry research focus is on design and fabrication of electrochemical sensors of different dimensions, including 3-D printed electrochemical sensors for environmental monitoring, as well as electrochemical detection for the monitoring of corrosion inhibitors.

We are focusing on electrochemical treatment of wastewater via electrolysis, advanced oxidation processes and heterogeneous photocatalysis using different semiconductor electrodes. We are as well interested in the electrokinetic remediation of contaminated soils and sediments, metal recovery and electrochemical effluent gas treatment.

Career Opportunities

Graduate students with training in electrochemical science and technology find ready career opportunities with international relevance in such industrial sectors as utilities, transportation, aerospace, automobile, aviation, chemical, petrochemical, oil and gas, metallurgical, pulp and paper, pharmaceutical, natural resources, environmental protection, new products development, etc., as Industry R&D scientist, industrial management, founder of startup company, industrial consultant, government specialist. PhD degree in nanotechnology prepares students for careers in the academia, industrial R&D, government and regulatory laboratories.

4.3 PhD NANOTECHNOLOGY

Research Areas

Nanotechnology research is focused on development of novel low-cost materials for photovoltaic and photoelectrochemical cells and explore opportunities to link up local developmental needs using locally produced nanomaterials. This includes production, modification and functionalization of nanofillers from agro-industry waste, preparation of polymer/clay nanocomposites and nanocomposite thin films for photovoltaic surfaces as well as for surface modification and anticorrosion protection. We are also interested in development of nano-structured ceramics membranes for carbon capture applications from various gas streams for clean energy production.

Career Opportunities

Nanotechnology is an interdisciplinary field of study, requiring expertise within physics, chemistry, biotechnology, mathematics, and materials science. Graduate students with such interdisciplinary education and qualifications are thus invaluable with respect to solving the many challenging materials problems present on the nanoscale. Career opportunities exist globally in such industrial sectors as chemical/allied, agriculture, food, pharmaceutical, cosmetics, natural resources, environmental etc., as Industry R&D scientist, nano scientist, industrial management, founder of startup companies, industrial consultant, government specialist. PhD degree in nanotechnology prepares students for careers in the academia, industrial R&D, government and regulatory laboratories.

4.4 PhD CORROSION TECHNOLOGY

Research Areas

Corrosion research at ACE-FUELS is focused on corrosion control of iron and steel and other structural materials deployed in service in different aggressive environments as found in oil and gas operations, including development of novel inexpensive and non-toxic corrosion inhibitors from local biomass resources and other sources, functional anticorrosion coatings like superhydrophobic coatings and self-healing coatings. Such investigations have profound relevance for the oil and gas industry in Nigeria, which loses up to $765 Million USD yearly to corrosion, with profound environmental degradation due to products spillage. We are also interested in corrosion phenomena in renewable energy systems, like corrosion protection in hydroethanolic media and in biodiesel, as well as the corrosion behaviour of solar panels and other energy materials, in order to develop more corrosion resistant and long-lasting PV panels and and structures, hence

increase the durability and reliability of PV systems. Efficient corrosion monitoring and control is especially important for solar energy systems, which are expected to last for decades.

Career Opportunities

Employability is about more than just securing a job placement. We believe in helping our students gain the necessary experience for a successful career in the future, along with the skills to identify opportunities and make the most of them. This postgraduate programme in Corrosion Technology provides access to a fulfilling career in diverse industries like oil and gas, energy, construction, utilities, shipping, aviation, chemical, petrochemical etc. as Industry R&D scientist, corrosion engineer, industrial management, founder of Startup Company, industrial consultant, government specialist. PhD degree in Corrosion Technology prepares students for careers in the academia, industrial R&D, government and standards laboratories.

5. ADMISSION REQUIREMENTS/SELECTION PROCESS

5.1 Admission Requirements

(a) The minimum admission requirement for the PhD programmes is a master's degree in a relevant Science or Engineering discipline, performed at a high standard with substantial research component; or an equivalent qualification that demonstrates research experience and excellence.
(b) Ability to work optimally and independently in an international multidisciplinary environment.
(c) Strong interest in research, development and innovation in science and technology.
(d) Excellent oral and written communication skills.

There are no restrictions based on age, gender, religion, nationality, ethnicity, disability or political orientation of the candidates.

5.2 Selection Process

The selection process has two stages:

1. Selection based on the required application documents and fulfillment of the general application requirements.
2. Computer-based aptitude tests
3. Interview (face to face or by Zoom/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 70 points will be considered for admission into the programme.

5.3 Deadlines

Nomination and selection of PhD 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.

5.4 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

6.1 PhD FUTURE ENERGIES

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.

A. MODULE OF SPECIALIZATION

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

1. SOLAR ENERGY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 901	The science of solar energy	2	1	0	3
2	FEM 903	Photovoltaic solar energy conversion II	2	1	0	3
3	FEM 905	Design and modelling methods in solar energy systems	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

FEM 901: THE SCIENCE OF SOLAR ENERGY (3 UNITS)

Review of Solid-State Physics: Band theory of solids. Band structure of semiconductors. Defects in semiconductors. Review of Quantum Mechanics: Quantum states, energy levels and wave functions. Potential wells, potential barriers and quantum structures. Interaction of radiation with matter: Solar spectral irradiance. Absorptivity. Reflectivity. Transmissivity. Emissivity. Review of Atomic and Molecular spectroscopy: The electromagnetic spectrum. Orbitals and quantum numbers. Absorption and emission spectra. Spectroscopic techniques: (UV-Vis spectroscopy, infrared spectroscopy, X-ray diffraction, Raman spectroscopy, nuclear magnetic resonance, photoluminescence spectroscopy etc.). Review of Thermodynamics and Heat transfer: Laws of Thermodynamics. Thermodynamic functions.

FEM 903: PHOTOVOLTAIC SOLAR ENERGY CONVERSION II (3 UNITS)

Review of Physics of semiconductor materials and devices: Types of semiconductor materials. Density of states. Generation & Recombination process. Doping and doping density. Semiconductor junctions (p-n junction, homo- and hetero-junctions, metal-semiconductor junctions, Schottky junction). PV principle and charge separation process in organic and inorganic solar cells. Solar cell materials and their growth techniques: Organic and inorganic bulk and thin film semiconductor materials and antireflective coatings. Materials growth/synthesis techniques (Vapour phase and liquid phase techniques). Solar cell materials characterization techniques: Structural characterization techniques (XRD, Raman spectroscopy, FTIR etc). Optical characterization techniques (UV-Vis absorption, transmittance & reflectance. Refractive index, absorption coefficient, dielectric constant). Defect characterization techniques (Photoluminescence spectroscopy, thermoluminescence, admittance spectroscopy etc). Morphological characterization techniques (SEM, TEM, AFM, SPM etc). Compositional characterization techniques (EDX spectroscopy, Rutherford backscattering spectroscopy, Auger electron spectroscopy, secondary ion mass spectroscopy, XPS, etc). Electrical characterization techniques (Hall Effect, Four-point probe, Current-Voltage measurement, capacitance-voltage measurement etc). Solar cell fabrication steps (Organic, inorganic & hybrid solar cells): Materials synthesis, junction formation and metal contact fabrication. PV arrays. Inverters, converters and charge controllers. PV system monitoring (indoor and outdoor). Applications (building integration, water pumping, industrial application, street lighting, stand-alone and grid-tied power generation etc). Solar cell assessment: Dark I-V characterization (to determine barrier height, diode ideality factor, shunt and series resistances and diode rectification factor). Illuminated I-V characterization (to determine open-circuit voltage, short-circuit current, fill factor, maximum power and conversion efficiency). Internal and External quantum efficiency measurements. Capacitance-voltage measurement.

FEM 905: DESIGN AND MODELLING METHODS IN SOLAR ENERGY SYSTEMS (3 UNITS)

Design of Active Systems (f-Chart and Utilizability methods), Design of Passive and Hybrid Heating Systems, Design of Cooling Systems, Design of Photovoltaic Systems, Modelling and Simulation of Solar Energy Systems (use of TRNSYS Simulation software), and application of Artificial Intelligence (ANN, Fussy Logic etc).

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.

2. BIOENERGY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 911	Bioenergy and biomass processing chemistry	2	1	0	3
2	FEM 913	Biomass transformation processes	2	1	0	3
3	FEM 915	Bioenergy systems and process integration	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

FEM 911: BIOENERGY AND BIOMASS PROCESSING CHEMISTRY

An overview of the fundamentals of energy- Renewable and alternative clean energy; Energy efficient products and structures; Bio-based green and sustainable products; Energy efficient intelligent vehicles; Energy balance and life cycle analysis on bioenergy production system; Biomass as feedstock for bioenergy production and its basic properties; Basic chemistry of carbohydrates, polysaccharidddes and lignin. Bio-chemical conversions for biofuel and bioenergy production; Thermochemical conversions for biofuel and bioenergy production; Bioenergy use. Biomass and energy balances- Units and dimensions; Basic terminologies, Fundamentals of Material Balances; Material Balances for Single Units Without Reactions, Material Balances for Reactive Processes; Combustion Reactions, Material Balances for Systems with Recycle, Bypass, and Purge, Energy Balance Terminologies; Introduction to Energy Balances, Mechanical Energy Balances; Objectives and Procedures for Energy Balances, Energy Balances on Nonreactive Processes without Phase Change, Energy Balances on Nonreactive Processes with Phase Change, Mixing and Solutions; Fundamentals for Energy Balances on Reactive Processes, Energy Balances on Reactive Processes, Material and Energy Balances for Unsteady State Processes.Calculating flow rates,substrate and product flow rates. Measuring production efficiencies, Sources of biomass, types of biomass, biomass generation, biomass optimization, product purification.

FEM 913: BIOMASS TRANSFORMATION PROCESSES

Biomass types and characteristics for energy application .Technologies of biomass treatment, lignocellulosic residues pre-treatment and hydrolysis by physical, chemical or enzymatic means; technologies for obtaining hydrolysate and extracting sugarcane juice, extracting vegetable oils and microalgae oils; development of new biofuel catalysis and biocatalysis systems (fermentation of pentoses, immobilized enzyme, catalysis under supercritical conditions, etc.); design and optimization of reactors and bioreactors for the production

of bioethanol, biodiesel and other biofuels (biobutanol, etc.); development of processes and equipment for biofuel purification; development of systems and processes control loops for the production of biofuels; heat integration and energy recovery in the production of biofuels; formulation and development of integrated systems for production of first, second and third generation biofuel; development of technologies to save water and non-renewable inputs used in the production of biofuels.

FEM 915: BIOENERGY SYSTEMS AND PROCESS INTEGRATION

Introduction to plant technology - Biofuel/biogas plants- digester types and processes -: planning and designing of stirring and mixing technology for digesters, mixing pits and storage , Transport biofuels, biomass in power plants; physical and chemical properties of biomass and biofuels; biomass and biofuel combustion technologies as suspension firing, grate firing and fluidized bed firing, flame propagation in engines, mixing controlled combustion in engines, chemical recovery boiler, co-firing of biomass. Biomass assessment methods and analyses. Reaction and biochemical reactions engineering for gas and liquid fuels. Material and Energy Balances on the Pyrolysis, Gasification, Gas cleaning processes. Alternative solutions for treatment of biomass and Supercritical Water Gasification. Quality assessment of biomass and estimation of the suitability of biomass for the purpose of power generation, substrate parameter and their impact on plant performance.

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.

3. CLEAN HYDROCARBON ENERGY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 921	Carbon capture and storage	2	1	0	3
2	FEM 923	Carbon sequestration	2	1	0	3
3	FEM 925	Membrane technology for biofuels and solar energy	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

FEM 921: CARBON CAPTURE AND STORAGE (3 UNITS)

Carbon dioxide sources, Global carbon cycle, Carbon budget, Carbon emissions and their sources, Effects of carbon emissions on climate change. Carbon, Energy and the Atmosphere: Energy and electricity; The atmosphere; Climate models and the carbon cycle. Carbon capture: Introduction to carbon capture concepts and technologies: Absorption – Design of an absorption process, Selection of absorbent, optimizing an absorption process. Adsorption: Design of an adsorption process, Selection of adsorbent, Novel materials for adsorption. Enhanced oil recovery (miscible and immiscible CO_2 flooding). Different methods of CO_2

transport & storage. CO_2 properties under transport & storage 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 & storage. Reservoir properties and storage. Development of CO_2 storage sites. Selection of storage sites.

FEM 923: CARBON SEQUESTRATION (3 UNITS)

Potential Sequestration Technologies: Chemical and physical absorption; Chemical and physical adsorption; Low-temperature distillation; Gas-Separation Membranes; Mineralization and vegetation. Geological Sequestration: Introduction to geological sequestration, Geologic carbon sequestration - continuum scale, Geologic carbon sequestration – pore-scale phenomena, Biological sequestration. Sequestration in oil and gas formation; Sequestration in Brine formation Sequestration in coal formation. Ocean Sequestration: Direct injection of CO_2, Natural ocean sequestration, Other approaches to ocean sequestration, Ocean sequestration concerns. Terrestrial Sequestration: Terrestrial Ecosystems, Global Estimates of Terrestrial Carbon Stock, The Biomes and Potential Sequestration by Biomes. Geoengineering.

FEM 925: MEMBRANE TECHNOLOGY FOR BIOFUELS AND SOLAR ENERGY (3 UNITS)

Membranes: Design of membrane process, Selection of membrane materials, Membrane research. Membranes for CO_2 capture. 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. Applications of high-performance membranes in biofuel separation. Market potential and technical barriers for membranes for Biofuels. Bio-alcohol production. Biocatalyst immobilization. Membrane bioreactors. Membrane integrated with solar and wind energy and for water related application. Membrane technologies for solar-hydrogen production, Solar water electrolysis - Thermochemical water-splitting cycles - Solar membrane steam reforming. Membrane technologies for solar-desalination plants. Photovoltaic systems for membrane desalination; Solar thermal systems for membrane desalination.

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.

4. GEOTHERMAL ENERGY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 931	Geothermal geology & exploration	2	1	0	3
2	FEM 933	Petrophysics & well logging in geothermal wells	2	1	0	3
3	FEM 935	Geothermics & hydrogeology	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

FEM 931: GEOTHERMAL GEOLOGY & EXPLORATION (3 UNITS)
Geothermal Geology: Understanding high temperature geologic formation; rock deformation, hydraulic fracturing/natural fractures; geothermal gradients etc. Description of a comprehensive range of Geothermal Play Types in terms of generic conceptual models of geological and tectonic settings in which geothermal systems might naturally develop or be engineered around the world. Terminology and definitions for a classification framework for Geothermal Potential (resource/reserve). Surface Geothermal Exploration: Fundamental concepts of geothermal resources exploration; remote sensing, geochemical methods. Geothermal resources exploration: geophysical methods (seismic, magnetics, magneto-tellurics, TEM, geo-electrics gravity), acquisition of existing surface/sub-surface data.

FEM 933: PETROPHYSICS & WELL LOGGING IN GEOTHERMAL WELLS (3 UNITS)
Petrophysics: Relevance and development of Petrophysics, rock-forming minerals, influencing factors for petrophysical properties. Properties of pores, e.g. like porosity, volume and content of the pores, saturation, tortuosity, inner surface etc. Density of rocks, determination in the laboratory & on-site, borehole. Relationships to porosity, saturation, proctor density. Magnetic properties: para-, dia-, ferro-, antiferro-, ferrimagnetism. Magnetic properties of minerals and rocks, remnant magnetization, dependency of temperature and pressure. Well Logging: Well logging history and goals. Fundamentals & types of geophysical well logging methods. Technical log data acquisition & equipment. Well log data interpretation. Radioactive, acoustic, radiometric & electrical well logging methods.

FEM 935: GEOTHERMICS & HYDROGEOLOGY (3 UNITS)
Principles of Geothermics: Physical basis of heat transfer: fundamental terms of heat conduction, heat conduction equations, and thermal properties of rocks. Thermal state of the earth's interior: methods of temperature determination (of uppermost crust, at great depths). Geothermal Data Acquisition: Temperature profiles from fluid injection and production wells. Processing of temperature data from borehole (wellbore) measurements. Radioactive, acoustic, radiometric & electrical well logging methods. Hydrogeology for Geothermal Energy Production: Introduction to hydrogeology and water cycle. Hydrological rock properties, water flow in porous and fractures aquifers, Darcy's law and groundwater flow equation, groundwater modeling with MODFLOW. Introduction to hydrochemistry, water composition: major, minor and trace elements, Sampling techniques, application of tracer, water pollutants. Hydro-chemical characterization of groundwater levels. Thermodynamic fundamentals for hydro-geochemical modeling, training on the use of PHREEQC and PHAST software.

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.

5. HYDROGEN ENERGY SPECIALIZATION

Module Contents
The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 941	Hydrogen energy systems	2	1	0	3
2	FEM 943	Hydrogen integration in energy systems	2	1	0	3
3	FEM 945	Hydrogen energy applications	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

FEM 941: HYDROGEN ENERGY SYSTEMS

Fundamentals of Hydrogen, including Chemical and Thermal and Thermodynamic Properties of Hydrogen. Contemporary applications of hydrogen. Hydrogen Production Technologies: Hydrogen from Fossil Fuels (natural gas, coal) and Biomass. Sustainable Hydrogen Production Technologies: Electrolysis, photocatalytic and direct solar technologies. Hydrogen Storage technologies: Physical-based and materials-based storage technologies. Geological storage. Hydrogen transport and distribution. Hydrogen conversion technologies: Combustion, catalytic combustion, Fuel cell technologies.

FEM 943: HYDROGEN INTEGRATION IN ENERGY SYSTEMS

Concept of Energy Systems Integration: Uncertainties, obstacles, benefits. Simulation models for hydrogen production, storage, and utilization within energy systems. Efficiency, sustainability, and economic viability of hydrogen integration. How hydrogen empowers the energy transition. Strategies for enhancing the role of hydrogen in energy systems. Hydrogen Codes and Standards.

FEM 945: HYDROGEN ENERGY APPLICATIONS

The Hydrogen Economy. Hydrogen value chain. Drivers of infrastructure investments. Infrastructure for the hydrogen economy. Developments and challenges. Adapting existing oil and gas infrastructure. Hydrogen for mobile applications. Hydrogen storage technologies and materials for mobility sector. Hydrogen refuelling stations and facilities. Safety considerations. Hydrogen for stationary power applications: Storage and conversion systems. Safety considerations. The future of hydrogen: Hydrogen production and storage challenges, obstacles and competition. R&D goals and strategies.

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.

B. RESEARCH DEVELOPMENT MODULE

S/N	CODE	COURSE TITLE				UNITS
1	REM 912	Research Design & Innovative Methods				15
TOTAL						**15**

REM 912: RESEARCH DESIGN & INNOVATIVE METHODS (15 Units)

This module, which is designed to support students engaging in postgraduate research projects, covers the whole research process from research conceptualization to dissemination of research findings. The module

is aimed at imparting the requisite skills and knowledge, necessary for the student to undertake high-level research, including proposal drafting, review of relevant literature, research paradigms and ethical considerations, choice of appropriate methodologies, project planning, data analysis and discussion, oral and written dissemination, authoring thesis and research publications.

Module Content

Fundamental concepts of scientific research. Procedures involved in designing a research project (devising a research question - providing a rationale). Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings and the critical analysis of existing research. Data collection strategies (reliability & validity of tools). Using ICT and research productivity tools (statistical, referencing, research design etc). Analyzing data - implications of potential findings for practice. Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Ethical considerations and the role of ethics committees. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on Research translation and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and Entrepreneurship.

Learning Outcomes

On completion of the module the student should be able to:

1. Show improved oral and written presentation and top rate research dissemination skills.
2. Formulate research questions and where appropriate set relevant hypotheses.
3. Demonstrate practical understanding of different research methodologies and their suitability to answer specific research questions.
4. Critically appraise and evaluate published research that relates to relevant subject areas, for effective information retrieval.
5. Devise and critically review data collection, analysis and discussion approaches used in both qualitative and quantitative methods.
6. Demonstrate a critical understanding and awareness of the role and procedures involved in gaining ethical approval related to collaboration with industry, with regards to data collection and use.

6.2 PhD ELECTROCHEMICAL TECHNOLOGY

Electrochemical technology represents another important multidisciplinary area linking up the chemical, physical, biological and materials sciences and plays a vital role in several modern technological processes in diverse fields including manufacturing, new materials development, corrosion protection, environmental remediation, energy storage and conversion. Electrochemical technologies are indeed becoming increasingly important with increasing global focus on clean and sustainable energy and the associated need for clean energy storage options. This postgraduate programme focuses on two broad areas of specialization: (i) Electrochemical Energy and (ii) Environmental Electrochemistry and equips students with cutting-edge knowledge and skills in research, development, innovations. The Electrochemical Technology programme, like other ACE-FUELS programmes, takes an immersive approach to learning both the principles and practices of electrochemical technology with much of the material based around examples and practical exercises. Students completing this course will have a firm, broad-based grasp of the current practices and directions in this exciting area and will have the knowledge and skills to apply develop new applications that better benefit humanity.

PROGRAMME OUTCOMES

At the end of this postgraduate programme the graduates should:

1. Develop and demonstrate broad-based expertise in electrochemical technology, including its applications in diverse contexts.

2. Demonstrate competence in responsible conduct of research, as well as ability to critically analyze data as well as design and manage research projects independently.
3. Develop effective oral and written skills.
4. Demonstrate ability to identify and respond to key innovation dilemmas by recognizing and exploiting relevant sources of information for innovation.
5. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
6. Be effectively prepared for professional employment and entrepreneurship.

A. MODULE OF SPECIALIZATION

There are two (2) areas of specialization in the PhD Future Energies programme

1. ENVIRONMENTAL ELECTROCHEMISTRY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	ETM 907	Advanced Electrochemistry	2	1	0	3
2	ETM 913	Electrochemical Sensing and Environmental Monitoring	2	1	0	3
3	ETM 915	Electrochemical Remediation of Pollutants	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

ETM 907: ADVANCED ELECTROCHEMISTRY

Electrochemical Thermodynamics: Nernst equation, Gibbs free energy, equilibrium potentials. Electrode Kinetics: Butler-Volmer equation, Tafel kinetics, exchange current density, overpotential. Mass Transport: Diffusion, migration, convection, concentration profiles, limiting current. Electrolyte properties and ionic conductivity. Characterization Techniques in Electrochemical Energy Technologies: Spectroscopic techniques (XRD, XPS, Raman, UV-Vis, FTIR) ; Microscopy techniques (SEM, TEM, AFM); Electrochemical techniques (CV, LSV, EIS, GITT); In situ and operando characterization methods. Environmental Policy, Safety, and Ethics in Electrochemical Applications; Regulatory Frameworks for Electrochemical Technologies. Electrolyte Chemistry and Electrodes: Electrolyte properties (conductivity, viscosity, electrochemical window), electrolyte-electrode interactions, interfacial phenomena, solid-state electrolytes. Electrode Processes: Electrocatalysis, corrosion, passivation, electrodeposition. Advanced Topics: Microelectrodes, scanning electrochemical microscopy, spectroelectrochemistry. Fundamentals of Electrochemical Sensing: Principles of amperometry, potentiometry, and conductometry; Sensor response and selectivity.

ETM 913: ELECTROCHEMICAL SENSING AND ENVIRONMENTAL MONITORING

Introduction to Electrochemistry in Environmental Systems; Electrochemical principles and environmental applications; Redox chemistry in natural and engineered environments Electrochemical Interfaces in the Environment; Electrochemical double layer and surface reactions; Charge transfer and adsorption phenomena; Applications of Electrochemistry in Environmental Systems (Water and wastewater treatment; Air purification and carbon capture; Soil remediation). Design and Fabrication of Electrochemical Sensors; Electrode materials and modification techniques, Signal amplification and data acquisition. Detection of

Environmental Pollutants (Heavy metals (Pb, Hg, Cd) and toxic anions (NO_3^-, ClO_4^-); Pesticides, pharmaceuticals, and organic pollutants). Biosensors and Nanomaterial-Based Sensors (Enzyme and DNA-based electrochemical sensors, Graphene, carbon nanotubes, and MOFs in sensing). Field Deployable and Real-Time Sensors. Wireless and IoT-enabled electrochemical sensors. Case studies in environmental monitoring.

ETM 915: ELECTROCHEMICAL REMEDIATION OF POLLUTANTS

Electrochemical Degradation of Organic Pollutants; Advanced oxidation processes (AOPs) Electrocatalytic degradation of pesticides and pharmaceuticals; Photocatalysis and nanocatalysis; Perovskites and transition metal-based catalysts; Sabatier principle and catalyst selectivity. Heavy Metal Removal via Electrochemical Methods; Electrocoagulation and electrochemical precipitation; Electrodialysis and ion exchange membranes. Electroreduction of Atmospheric Pollutants (NO_x, SO_x, and CO_2 reduction pathways); Electrochemical air purification technologies. Electrochemical CO_2 Reduction to Fuels (Mechanisms of CO, CH_4, and methanol formation; Role of single-atom catalysts in CO_2 conversion). Integration with Biological and Photocatalytic Systems; Microbial-assisted electrochemical remediation; Photoelectrochemical and Microbial Electrochemical Water Purification; Microbial fuel cells for wastewater treatment. Case Studies in Electrochemical Remediation (Industrial wastewater treatment, Oil spill remediation using electrochemical approaches)

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.

2. ELECTROCHEMICAL ENERGY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	ETM 907	Advanced Electrochemistry	2	1	0	3
2	ETM 913	Electrochemical Sensing and Environmental Monitoring	2	1	0	3
3	ETM 915	Electrochemical Remediation of Pollutants	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

ETM 907: ADVANCED ELECTROCHEMISTRY

Electrochemical Thermodynamics: Nernst equation, Gibbs free energy, equilibrium potentials. Electrode Kinetics: Butler-Volmer equation, Tafel kinetics, exchange current density, overpotential. Mass Transport: Diffusion, migration, convection, concentration profiles, limiting current. Electrolyte properties and ionic conductivity. Characterization Techniques in Electrochemical Energy Technologies: Spectroscopic techniques (XRD, XPS, Raman, UV-Vis, FTIR); Microscopy techniques (SEM, TEM, AFM); Electrochemical

techniques (CV, LSV, EIS, GITT); In situ and operando characterization methods. Environmental Policy, Safety, and Ethics in Electrochemical Applications; Regulatory Frameworks for Electrochemical Technologies. Electrolyte Chemistry and Electrodes: Electrolyte properties (conductivity, viscosity, electrochemical window), electrolyte-electrode interactions, interfacial phenomena, solid-state electrolytes. Electrode Processes: Electrocatalysis, corrosion, passivation, electrodeposition. Advanced Topics: Microelectrodes, scanning electrochemical microscopy, spectroelectrochemistry. Fundamentals of Electrochemical Sensing: Principles of amperometry, potentiometry, and conductometry; Sensor response and selectivity

ETM 923: ADVANCED BATTERY TECHNOLOGIES

Battery performance metrics (C-rate, capacity retention, cycle life); Voltage profiles, charge-discharge curves, and efficiency; Energy density vs. power density trade-offs. Principles of lithium-ion, sodium-ion, and beyond-Li batteries: Multivalent Battery Technologies; Alternative chemistries: (Mg-ion, Zn-ion, Al-ion batteries); Cathode, anode, and electrolyte design; Intercalation vs. conversion mechanisms. Solid-state batteries and next-generation anodes/cathodes; Polymer, ceramic, and sulfide electrolytes; Interface challenges in solid-state systems; Dendrite suppression strategies; High-voltage cathodes and all-solid-state battery designs. Redox Flow Batteries and Large-Scale Storage; Vanadium and non-vanadium redox flow batteries; Electrolyte design and membrane optimization; Grid-scale energy storage applications; Techno-economic analysis of flow batteries. Environmental impact and circular economy in battery technologies: Battery degradation mechanisms and lifetime prediction; Battery recycling, sustainability and second-life applications.

ETM 925: ADVANCED ELECTROCATALYSIS

Electrocatalysts for Oxygen reduction reaction (ORR) and hydrogen evolution reaction (HER). Non-precious metal catalysts for fuel cells, Nanostructured catalysts for efficiency improvement. Electrocatalysis for CO_2 conversion. Computational design of electrocatalysts: Density functional theory (DFT) for electrocatalysis, Molecular dynamics simulations for electrolyte stability, AI-driven discovery of new electrode materials, Machine learning for battery lifetime prediction, High-throughput screening of electrocatalysts. Supercapacitors and Hybrid Energy Storage Devices: Electrochemical double-layer capacitors (EDLCs), pseudocapacitors, hybrid supercapacitors. Hybrid Energy Storage Devices (Combination of batteries, supercapacitors, flywheels, fuel cells) to leverage the strengths of each and enhance overall performance, efficiency, and reliability.

B. RESEARCH DEVELOPMENT MODULE

S/N	CODE	COURSE TITLE				UNITS
1	REM 912	Research Design & Innovative Methods				15
TOTAL						**15**

REM 912: RESEARCH DESIGN & INNOVATIVE METHODS (15 Units)

This module, which is designed to support students engaging in postgraduate research projects, covers the whole research process from research conceptualization to dissemination of research findings. The module is aimed at imparting the requisite skills and knowledge, necessary for the student to undertake high-level research, including proposal drafting, review of relevant literature, research paradigms and ethical considerations, choice of appropriate methodologies, project planning, data analysis and discussion, oral and written dissemination, authoring thesis and research publications.

Module Content

Fundamental concepts of scientific research. Procedures involved in designing a research project (devising a research question - providing a rationale). Concepts underlying peer-reviewed research. Referencing:

Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings and the critical analysis of existing research. Data collection strategies (reliability & validity of tools). Using ICT and research productivity tools (statistical, referencing, research design etc). Analyzing data - implications of potential findings for practice. Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Ethical considerations and the role of ethics committees. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on Research translation and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and Entrepreneurship.

Learning Outcomes

On completion of the module the student should be able to:

1. Show improved oral and written presentation and top rate research dissemination skills.
2. Formulate research questions and where appropriate set relevant hypotheses.
3. Demonstrate practical understanding of different research methodologies and their suitability to answer specific research questions.
4. Critically appraise and evaluate published research that relates to relevant subject areas, for effective information retrieval.
5. Devise and critically review data collection, analysis and discussion approaches used in both qualitative and quantitative methods.
6. Demonstrate a critical understanding and awareness of the role and procedures involved in gaining ethical approval related to collaboration with industry, with regards to data collection and use.

6.3 PhD NANOTECHNOLOGY

The study of nanomaterials, nanoscience and nanotechnology exists at the overlap between physics, chemistry and biology and incorporates the cross-disciplinary principles and theories to design and development of new products on the nanoscale. This postgraduate programme has three possible areas of specialization: (i) Nanophysics Specialization, (ii) Nanochemistry Specialization, (iii) Nanobiotechnology Specialization and equips students with cutting-edge knowledge and skills in research, development, innovation and application of nanotechnology in diverse fields. The course takes an immersive approach to learning both the principles and practices of nanotechnology with much of the material based around examples and practical exercises. Students completing this course will have a firm, broad-based grasp of the current practices and directions in this exciting area and will have the knowledge and skills to design new products and processes on the nano-scale.

PROGRAMME OUTCOMES

At the end of this postgraduate programme in Nanotechnology, the graduates should:

1. Develop and demonstrate broad-based expertise in nanotechnology, including identification, design, fabrication, characterization and utilization of nanomaterials in diverse fields.
2. Demonstrate competence in responsible conduct of research, as well as ability to critically analyze data as well as design and manage research projects independently.
3. Develop effective oral and written skills.
4. Demonstrate ability to identify and respond to key innovation dilemmas by recognizing and exploiting relevant sources of information for innovation.
5. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
6. Develop strategies and practices to manage the concerns and risks associated with widespread utilization of nanomaterials.

A. MODULE OF SPECIALIZATION

There are Three (3) areas of specialization in the PhD Future Energies programme

1. NANOPHYSICS SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	NTM 901	Nanocomposite materials	3	0	0	3
2	NTM 903	Molecular Self-assembly and nanostructures	3	0	0	3
3	NTM 911	Nanophysics	3	0	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

NTM 901: NANOCOMPOSITE MATERIALS (3 Units)

Critical issues in synthesis, fabrication, processing, and characterization of nanocomposites. Challenges in manufacturing low cost real-life components for industrial applications; commercial success stories, future directions. Principles guiding structure-property relationships of nanocomposites. Incorporation of different nanophases into polymeric matrixes for functional materials fabrication. Surface energy control, dispersion methods, techniques for nanocomposite materials characterization. Influence of dispersed (organic or mineral) elements on; the chemical nature and morphologies of nanocomposite materials. Various fields of application of nanocomposite materials.

NTM 903: MOLECULAR SELF-ASSEMBLY AND NANOSTRUCTURES

Top-down vs. bottom-up nanofabrication approaches; Lithography techniques. Hybrid organic-inorganic nanoparticles; Introduction to self-assembled monolayers. Micro-nano patterning. Aromatics on metal SAMs. Amino acids on metal SAMs. Mixed SAMs. Self-Assembling Biomaterials (Lipid Bilayer Formation. Protein Folding Basics, Self-Assembly in Bacterial Biofilms, Viruses: Masters of Self-Assembly). Growth dynamics and energetics of SAMs in different environments (UHV, liquid environments). Phase transitions. Characterization Techniques in Nanotechnology: Microscopy techniques: SEM, TEM, AFM, STM; Spectroscopy techniques: XRD, XPS, Raman, UV-Vis, FTIR; Dynamic Light Scattering (DLS) and Zeta Potential Analysis; Thermal analysis (TGA, DSC); Electrochemical characterization (Cyclic Voltammetry, EIS). Computational Modelling of Nanoscale Systems: Basics of molecular dynamics (MD) simulations. Force fields for nanomaterials. Simulation of nanoparticle-protein interactions. Modelling self-assembly processes. Applications in materials discovery. AI and Machine Learning for Nanomaterial Discovery: AI-driven nanomaterial design. Data-driven discovery of nanomaterials. Predictive modelling for nanocatalysis. Computational screening of functional nanomaterials. Deep learning applications in materials science. Ecotoxicology and Risk Assessment of Nanomaterials, including Ethics, Safety and Regulatory Aspects: Risk assessment and toxicity studies. Environmental and health impact of nanomaterials. Regulatory frameworks and ISO standards. Ethical considerations in nanomedicine and human trials. Nanobiotechnology and societal implications.

NTM 911: NANOPHYSICS

Advanced Quantum Mechanics for Nanoscale Systems: Schrödinger equation and wavefunction behavior in low dimensions; Quantum wells, wires, and dots. Tunneling effects and electron transport at the nanoscale;

Many-body interactions and exchange-correlation effects; Quantum coherence, decoherence, and entanglement; Quantum dot lasers and LEDs; Single-photon sources for quantum cryptography. Solid-State and Condensed Matter Physics: Electronic band structures and Bloch's theorem; Phonons and lattice dynamics in nanostructures; Semiconductor physics and heterostructures; Defects, doping, and charge transport in nanomaterials; Spintronics and magnetic nanostructures. Nanoscale Electrodynamics and Plasmonics: Maxwell's equations at the nanoscale; Surface plasmon resonance and near-field effects; Light-matter interaction at subwavelength scales; Optical properties of quantum dots and 2D materials; Metamaterials and negative index materials. Topological and Quantum Materials: Topological insulators and Dirac/Weyl semimetals; 2D materials (graphene, transition metal dichalcogenides); Superconductivity in low-dimensional systems; Quantum Hall effect and Berry phase physics; Exotic phases of matter in nanostructures. Nanostructured Semiconductors for Energy Applications: Quantum efficiency in nanostructured solar cells; Carrier dynamics in perovskite and organic photovoltaics; Nanostructured thermoelectric materials; Plasmonic enhancement in energy conversion devices; Hot electron dynamics in nanophotonic systems; Superconducting qubits and quantum circuits; Vortex dynamics in superconductors.

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.

2. NANOCHEMISTRY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	NTM 901	Nanocomposite materials	3	0	0	3
2	NTM 903	Molecular Self-assembly and nanostructures	3	0	0	3
3	NTM 921	Nanochemistry	3	0	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

NTM 901: NANOCOMPOSITE MATERIALS (3 Units)

Critical issues in synthesis, fabrication, processing, and characterization of nanocomposites. Challenges in manufacturing low-cost real-life components for industrial applications; commercial success stories, future directions. Principles guiding structure-property relationships of nanocomposites. Incorporation of different nanophases into polymeric matrixes for functional materials fabrication. Surface energy control, dispersion methods, techniques for nanocomposite materials characterization. Influence of dispersed (organic or mineral) elements on; the chemical nature and morphologies of nanocomposite materials. Various fields of application of nanocomposite materials.

NTM 903: MOLECULAR SELF-ASSEMBLY AND NANOSTRUCTURES

Top-down vs. bottom-up nanofabrication approaches; Lithography techniques. Hybrid organic-inorganic nanoparticles; Introduction to self-assembled monolayers. Micro-nano patterning. Aromatics on metal SAMs. Amino acids on metal SAMs. Mixed SAMs. Self-Assembling Biomaterials (Lipid Bilayer Formation. Protein Folding Basics, Self-Assembly in Bacterial Biofilms, Viruses: Masters of Self-Assembly). Growth dynamics and energetics of SAMs in different environments (UHV, liquid environments). Phase transitions. Characterization Techniques in Nanotechnology: Microscopy techniques: SEM, TEM, AFM, STM; Spectroscopy techniques: XRD, XPS, Raman, UV-Vis, FTIR; Dynamic Light Scattering (DLS) and Zeta Potential Analysis; Thermal analysis (TGA, DSC); Electrochemical characterization (Cyclic Voltammetry, EIS). Computational Modelling of Nanoscale Systems: Basics of molecular dynamics (MD) simulations. Force fields for nanomaterials. Simulation of nanoparticle-protein interactions. Modelling self-assembly processes. Applications in materials discovery. AI and Machine Learning for Nanomaterial Discovery: AI-driven nanomaterial design. Data-driven discovery of nanomaterials. Predictive modelling for nanocatalysis. Computational screening of functional nanomaterials. Deep learning applications in materials science. Ecotoxicology and Risk Assessment of Nanomaterials, including Ethics, Safety and Regulatory Aspects: Risk assessment and toxicity studies. Environmental and health impact of nanomaterials. Regulatory frameworks and ISO standards. Ethical considerations in nanomedicine and human trials. Nanobiotechnology and societal implications.

NTM 921: NANOCHEMISTRY

Advanced Physical and Chemical Properties of Nanomaterials: Introduction to nanomaterials: Classification and properties. Quantum size effects and surface energy considerations. Electronic, optical, and magnetic properties of nanomaterials. Thermodynamics and phase stability at the nanoscale. Defects, doping, and heterostructures in nanomaterials. Synthesis and Functionalization of Nanomaterials: Top-down vs. bottom-up approaches. Chemical vapor deposition (CVD), atomic layer deposition (ALD), and molecular beam epitaxy (MBE). Sol-gel processing, hydrothermal synthesis, and co-precipitation. Functionalization techniques (ligand exchange, surface coatings). Green synthesis of nanomaterials. Surface Chemistry and Catalysis at the Nanoscale: Surface energy and reactivity of nanomaterials. Adsorption, desorption, and catalytic mechanisms. Nanocatalysts in heterogeneous catalysis. Electrocatalysis for energy conversion. Self-assembled monolayers and interface engineering. Green Synthesis of Nanomaterials: Principles of green chemistry and sustainability. Plant, microbial, and enzyme-mediated synthesis. Biodegradable nanomaterials. Sustainable catalysts and bio-inspired nanomaterials. Industrial applications of green nanotechnology. Nanomaterials for Energy Harvesting and Storage: Nanostructured electrode materials. Lithium-ion and sodium-ion batteries. TiO_2 and ZnO nanomaterials for photocatalysis. Solar-driven water splitting and CO_2 reduction. Nanocatalysts for fuel cells and hydrogen storage.

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.

3. NANOBIOTECHNOLOGY SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	NTM 901	Nanocomposite materials	3	0	0	3
2	NTM 903	Molecular Self-assembly and nanostructures	3	0	0	3
3	NTM 921	Nanobiotechnology	3	0	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

NTM 901: NANOCOMPOSITE MATERIALS (3 Units)

Critical issues in synthesis, fabrication, processing, and characterization of nanocomposites. Challenges in manufacturing low-cost real-life components for industrial applications; commercial success stories, future directions. Principles guiding structure-property relationships of nanocomposites. Incorporation of different nanophases into polymeric matrixes for functional materials fabrication. Surface energy control, dispersion methods, techniques for nanocomposite materials characterization. Influence of dispersed (organic or mineral) elements on; the chemical nature and morphologies of nanocomposite materials. Various fields of application of nanocomposite materials.

NTM 903: MOLECULAR SELF-ASSEMBLY AND NANOSTRUCTURES

Top-down vs. bottom-up nanofabrication approaches; Lithography techniques. Hybrid organic-inorganic nanoparticles; Introduction to self-assembled monolayers. Micro-nano patterning. Aromatics on metal SAMs. Amino acids on metal SAMs. Mixed SAMs. Self-Assembling Biomaterials (Lipid Bilayer Formation. Protein Folding Basics, Self-Assembly in Bacterial Biofilms, Viruses: Masters of Self-Assembly). Growth dynamics and energetics of SAMs in different environments (UHV, liquid environments). Phase transitions. Characterization Techniques in Nanotechnology: Microscopy techniques: SEM, TEM, AFM, STM; Spectroscopy techniques: XRD, XPS, Raman, UV-Vis, FTIR; Dynamic Light Scattering (DLS) and Zeta Potential Analysis; Thermal analysis (TGA, DSC); Electrochemical characterization (Cyclic Voltammetry, EIS). Computational Modelling of Nanoscale Systems: Basics of molecular dynamics (MD) simulations. Force fields for nanomaterials. Simulation of nanoparticle-protein interactions. Modelling self-assembly processes. Applications in materials discovery. AI and Machine Learning for Nanomaterial Discovery: AI-driven nanomaterial design. Data-driven discovery of nanomaterials. Predictive modelling for nanocatalysis. Computational screening of functional nanomaterials. Deep learning applications in materials science. Ecotoxicology and Risk Assessment of Nanomaterials, including Ethics, Safety and Regulatory Aspects: Risk assessment and toxicity studies. Environmental and health impact of nanomaterials. Regulatory frameworks and ISO standards. Ethical considerations in nanomedicine and human trials. Nanobiotechnology and societal implications.

NTM 931: NANOBIOTECHNOLOGY

Advanced Nanomaterials for Biological Applications: Fundamentals of nanobiotechnology. Classification of nanomaterials (organic, inorganic, hybrid). Biocompatibility and biofunctionalization. Surface chemistry and ligand interactions. Self-assembly of biomolecular nanostructures. Molecular and Cellular Interactions with Nanomaterials: Cellular uptake mechanisms (endocytosis, passive diffusion). Nanoparticle-cell membrane interactions. Intracellular trafficking and biodistribution. Immune system response to nanomaterials. Genotoxicity and cytotoxicity assays. Biofunctionalization of Nanoparticles: Surface modification for targeted delivery. Conjugation strategies (covalent and non-covalent). Protein corona formation and its impact on bioactivity. Peptide and DNA-based nanoparticle functionalization. Stability and degradation of biofunctionalized nanomaterials. Nanomedicine & Targeted Drug Delivery: Nanocarriers for drug delivery (liposomes, dendrimers, polymeric nanoparticles). Passive vs. active targeting mechanisms. Controlled and stimuli-responsive drug release. Blood-brain barrier penetration using nanotechnology. Clinical translation

of nanomedicine; Challenges and solutions, Tissue Engineering and Nanobioimaging: Nanostructured biomaterials for scaffolding. Stem cell-nanomaterial interactions. 3D bioprinting with nanomaterials. Fluorescence properties of quantum dots. Biofunctionalization for targeted imaging.

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.

B. RESEARCH DEVELOPMENT MODULE

S/N	CODE	COURSE TITLE				UNITS
1	REM 912	Research Design & Innovative methods				15
TOTAL						**15**

REM 912: RESEARCH METHODS & INNOVATION (15 Units)
This module, which is designed to support students engaging in postgraduate research projects, covers the whole research process from research conceptualization to dissemination of research findings. The module is aimed at imparting the requisite skills and knowledge, necessary for the student to undertake high-level research, including proposal drafting, review of relevant literature, research paradigms and ethical considerations, choice of appropriate methodologies, project planning, data analysis and discussion, oral and written dissemination, authoring thesis and research publications.

Module Content
Fundamental concepts of scientific research. Procedures involved in designing a research project (devising a research question - providing a rationale). Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings and the critical analysis of existing research. Data collection strategies (reliability & validity of tools). Using ICT and research productivity tools (statistical, referencing, research design etc). Analyzing data - implications of potential findings for practice. Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Ethical considerations and the role of ethics committees. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on Research translation and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and Entrepreneurship.

Learning Outcomes
On completion of the module the student should be able to:

1. Show improved oral and written presentation and top rate research dissemination skills.
2. Formulate research questions and where appropriate set relevant hypotheses.
3. Demonstrate practical understanding of different research methodologies and their suitability to answer specific research questions.

4. Critically appraise and evaluate published research that relates to relevant subject areas, for effective information retrieval.
5. Devise and critically review data collection, analysis and discussion approaches used in both qualitative and quantitative methods.
6. Demonstrate a critical understanding and awareness of the role and procedures involved in gaining ethical approval related to collaboration with industry, with regards to data collection and use.

6.4 PhD CORROSION TECHNOLOGY

Corrosion is a phenomenon of great importance because of its disastrous effects on the economy, safety, energy consumption and environment. The oil and gas industry in Nigeria for instance loses up to $765 Million USD yearly to corrosion, with profound environmental degradation due to products spillage. This postgraduate programme in Corrosion Technology provides unique and comprehensive training on the theory and practice of corrosion and corrosion control interventions in varied environments. By means of an innovative blended-learning approach involving classroom teaching and practical hands-on sessions, the students will receive fundamental training on corrosion appreciation and monitoring as well as diagnosing corrosion problems and choosing appropriate corrosion control technologies to solve diverse corrosion-associated problems. The ACE-FUELS Corrosion Technology programme provides an exceptional opportunity for bright students from Nigeria and Sub-Saharan Africa to develop and diversify their skill set and ultimately enhance their employability across a broad spectrum of national, regional and multinational companies.

PROGRAMME OUTCOMES

At the end of the programme in Corrosion Technology, the graduates should:

1. Develop and demonstrate broad-based expertise in the theory and practice of corrosion monitoring, assessment and control as well as deployment of corrosion protection interventions in diverse fields.
2. Demonstrate competence in responsible conduct of research, as well as ability to critically analyze data as well as design and manage research projects independently.
3. Develop effective oral and written skills.
4. Demonstrate ability to identify and respond to key innovation dilemmas by recognizing and exploiting relevant sources of information for innovation.
5. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
6. Develop strategies and practices to manage corrosion and its associated consequences and risks.

A. MODULE OF SPECIALIZATION

Module Contents

The module is comprised of specially designed selected topics in four (4) core areas, plus any three (3) elective courses, giving a total of 18 Credit Units.

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	CTM 901	Selected Topics I	2	1	0	3
2	CTM 903	Selected Topics II	2	1	0	3
3	CTM 905	Corrosion Behaviour of Selected Metals	2	1	0	3
4	REM 801	Research Methods & Innovation	2	1	0	3
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
7	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**18**			

CTM 901: SELECTED TOPICS I (3 UNITS)
- Basic Corrosion Concepts
- Atmospheric Corrosion
- High Temperature Corrosion
- Corrosion in Deep Sea Environments
- Pitting/Crevice Corrosion

CTM 903: SELECTED TOPICS II (3 UNITS)
- Protective Oxide Films
- Organic Anticorrosion Coatings
- Smart/Self-healing Coatings
- Superhydrophobic Coatings
- Microbial Influenced Corrosion Inhibition

CTM 905: CORROSION BEHAVIOUR OF SELECTED METALS (3 UNITS)
- Mild Steel
- Aluminium Alloys
- Magnesium Alloys
- Stainless Steels
- Galvanic Couples

B. RESEARCH DEVELOPMENT MODULE

S/N	CODE	COURSE TITLE				UNITS
1	REM 912	Research Design & Innovative Methods				15
TOTAL						15

REM 912: RESEARCH DESIGN & INNOVATIVE METHODS (15 Units)

This module, which is designed to support students engaging in postgraduate research projects, covers the whole research process from research conceptualization to dissemination of research findings. The module is aimed at imparting the requisite skills and knowledge, necessary for the student to undertake high-level research, including proposal drafting, review of relevant literature, research paradigms and ethical considerations, choice of appropriate methodologies, project planning, data analysis and discussion, oral and written dissemination, authoring thesis and research publications.

Module Content

Fundamental concepts of scientific research. Procedures involved in designing a research project (devising a research question - providing a rationale). Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings and the critical analysis of existing research. Data collection strategies (reliability & validity of tools). Using ICT and research productivity tools (statistical, referencing, research design etc). Analyzing data - implications of potential findings for practice. Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Ethical considerations and the role of ethics committees. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on Research translation and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and Entrepreneurship.

Learning Outcomes

On completion of the module the student should be able to:

1. Show improved oral and written presentation and top rate research dissemination skills.
2. Formulate research questions and where appropriate set relevant hypotheses.
3. Demonstrate practical understanding of different research methodologies and their suitability to answer specific research questions.
4. Critically appraise and evaluate published research that relates to relevant subject areas, for effective information retrieval.
5. Devise and critically review data collection, analysis and discussion approaches used in both qualitative and quantitative methods.
6. Demonstrate a critical understanding and awareness of the role and procedures involved in gaining ethical approval related to collaboration with industry, with regards to data collection and use.

6.5 GENERAL ELECTIVE COURSES

While ACE-FUELS offers a rich selection of 14 elective courses for its MSc programmes, the availability of these courses varies each session. Students are therefore strongly advised to consult the official course schedule for each session and register only for those elective courses that are specifically advertised as being offered during that particular period.

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	CHM 864	Statistical Thermodynamics	2	0	0	2
7	CHM 868	Applied Spectroscopy and Electrochemistry	2	0	0	2
8	FEM 842	Smart Grid Technology Overview	2	0	0	2
9	FEM 844	Fuels and Combustion	2	0	0	2
10	MGT 846	Renewable Energy Finance and Management	2	0	0	2
11	FEM 858	Mini-grids: Planning and Design	2	0	0	2
12	FEM 852	Appliances for off-grid communities	2	0	0	2
13	MGT 852	Corporate Sustainability	2	0	0	2
14	EVM 852	Climate Change Adaptation	2	0	0	2
15	MGT 801	Project Management Basics	2	0	0	2
16	MGT 803	Change Management	2	0	0	2
17	MGT 805	Entrepreneurship	2	0	0	2
18	EVM 801	Climate Change	2	0	0	2

CHM 624: 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.

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 specific field 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 considering implications on fuel use in industry.

MGT 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.

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 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 858: 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.

MGT 852: CORPORATE SUSTAINABILITY

This course aims to provide students with a holistic approach to conducting business, while achieving long-term environmental, social and economic sustainability. Topics include: Pillars of Corporate Sustainability. Corporate Sustainability vs Corporate Social Responsibility. Benefits of Corporate Sustainability. Strategies to support Corporate Sustainability. Overcoming the challenges of Corporate Sustainability.

EVM 852: CLIMATE CHANGE ADAPTATION

This course highlights actions that help reduce vulnerability to the current or expected impacts of climate change like weather extremes and hazards, sea-level rise, biodiversity loss, or food and water insecurity at both national and international levels. Topics include: Impacts of climate change. Linkage between climate change and disaster. Adaptation to climate change. Challenges related to climate change adaptation. African cases of climate adaptation. Global Goal on Adaptation (GGA). National Adaptation Plans (NAPs). Innovative grassroots climate adaptation solutions around the world.

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.

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.

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.

7.0 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
Asiegbu, Baldwin C.	Professor
Ebiringa, Ofoeregbulam	Professor
Enenebeaku, Conrad K.	Professor
Eya, Dominic D.	Professor
Madu, Chinyere A.	Professor
Nkwocha, Edmund E.	Professor
Nweke C. O.	Professor
Ogbulie, Toochukwu E.	Professor
Ogoke, Iheanyi J.	Professor
Ogueke, Nnamdi V.	Professor
Oguzie, Emeka E	Professor
Okereke, Chikwendu N.	Professor
Onyekuru, Samuel O.	Professor
Opara, Alexander I.	Professor
Azeez, Taofik O.	Reader
Duru Ijeoma	Reader
Ejem, E. A.	Reader
Ibeneme, Ikechukwu S.	Reader
Ike, Innocent S.	Reader
Iwuji, Samuel C.	Reader
Nze, I. C.	Reader
Ohia, Nnaemeka P.	Reader
Okeoma, Kelechi	Reader
Ujowundu, Cosmas O.	Reader
Uzoije, Atulegwu P.	Professor
Aharanwa, Bibiana C.	Senior Lecturer
Akalezi, Christogonus	Senior Lecturer
Anyiam, Chioma K.	Senior Lecturer
Arukalam, Innocent O.	Senior Lecturer
Chukwu, Scholastica	Senior Lecturer
Echeme, Ibeawuchi I.	Senior Lecturer
Echendu, Obi K.	Senior Lecturer
Iheme, Callistus I.	Senior Lecturer

Name	Rank
Ihugba, Okezie A.	Senior Lecturer
Nwadike, Chijioke E.	Senior Lecturer
Nwanonenyi, Simeon C.	Senior Lecturer
Nwogu, Ngozi C.	Senior Lecturer
Obiukwu, Osita O.	Senior Lecturer
Oguzie, Kanayo L.	Senior Lecturer
Onyeachu, Ikenna B.	Senior Lecturer
Orga, Anselem C.	Senior Lecturer
Oze, Rita	Senior Lecturer
Ugwu, Kelechi E.	Senior Lecturer
Ayogu, Ignatius I.	Senior Lecturer
Chidiebere, Arinze M.	Senior Lecturer
Amadi, Emmanuel	Senior Lecturer
Chijioke, Chinonye F.	Lecturer 1
Uba Osigwe, Kelechi	Sectoral Partner
Ozumba, Chinyere	Sectoral Partner
Nwankwo Emeka	Sectoral Partner