Master of Technology

in

Energy Studies (Energy Technology)

Course Structure & Syllabus

Centre for Energy Studies

National Institute of Technology Hamirpur

Hamirpur (HP) - 177005, India

CENTRE FOR ENERGY STUDIES

Vision:

To achieve excellence in research & technology and human resource development in the area of sustainable energy

Mission:

- To provide multidisciplinary education, research & development solutions with focus on clean energy sources.
- To identify energy, environmental concerns & policy issues to provide local and global solutions towards sustainability.
- To promote energy education, environmental awareness, entrepreneurship development, and National & International collaboration for technology transfer.
- To provide high-quality trained professionals for the Institutions/ Industry in the country and worldwide.

Program Outcomes (PO)

A student who has met the objectives of the program will possess:

PO1 An ability to carry out research and development work to solve different energy related problems

PO2 An ability to communicate, write and present a substantial technical report/document effectively

PO3 An ability to demonstrate energy science and allied systems, at master level

PO4 An ability to design commission and operate energy science & technology and allied systems

PO5 An ability to assess impact of renewable and non-renewable technologies on overall sustainable development.

ACADEMIC CURRICULUM
Course Structure
M.Tech Energy Studies (Energy Technology)
w.e.f. Academic Session 2024-2025 Onwards

Semester-I

S. No.	Course Code	Course Title	Teaching Schedule			Hour/ Week	Credit
			L	T	P		
1	EN- 611	Solar Photovoltaic Systems	4	0	0	4	4
2	EN- 612	Energy, Climate & Sustainability	4	0	0	4	4
3	EN- 613	Hydrogen Energy Technology	4	0	0	4	4
4	EN- 7MN	Programme Elective-I	4	0	0	4	4
5	EN- 7MN	Programme Elective-II	4	0	0	4	4
6	EN- 614	Energy Laboratory-I	0	0	4	4	2
Total			20	0	4	24	22

List of Programme Electives I & II is given in Annexure.

Semester-II

S. No.	Course Code	Course Title	Teaching Schedule			Hour/ Week	Credit
			L	T	P		
1	EN-621	Solar Thermal Energy systems	4	0	0	4	4
2	EN-622	Bioenergy systems and Biofuels	4	0	0	4	4
3	EN-623	Energy Management and Audit	4	0	0	4	4
4	EN-7MN	Programme Elective-III	4	0	0	4	4
5	EN-70N	Institute Elective	4	0	0	4	4
6	EN-624	Energy Laboratory-II	0	0	4	4	2
Total			20	0	4	24	22

List of Programme Elective III and Institute Electives is given in the Annexure.

Semester-III

S. No.	Course Code	Course Title	Hours/Week	Credit
1.	EN-798	M.Tech Dissertation	---	18

Semester-IV

S. No.	Course Code	Course Title	Hours/Week	Credit
1.	EN-799	M.Tech Dissertation	---	18

Total Credit of the Program = 80

Annexure

List of Programme Elective Courses

S. No.	Subject Code	Course Title
1.	EN- 711	Energy Storage Technology
2.	EN- 712	Smart Grid Systems
3.	EN- 713	Waste to Energy
4.	EN- 714	Wind Energy Systems
5.	EN- 715	Energy Economics and Policies
6.	EN- 716	Biofuels conversion processes
7.	EN- 717	Alternative Fuels
8.	EN- 718	Circular Economy
9.	EN- 719	Materials for Energy & Applications
10.	EN- 720	Sustainable Buildings
11.	EN- 721	Hydro Energy Systems
12.	EN- 722	Modelling and Optimization of Energy Systems
13.	EN- 723	Hybrid Electric Vehicle
14.	EN- 724	Renewable Energy Applications
15.	EN- 725	Environmental Impact Assessment
16.	EN- 726	Renewable Energy Markets
17.	EN- 727	Life cycle assessment of RE systems
18.	EN- 728	Decentralized Energy Systems
19.	EN- 729	Sustainability and Sustainable Development Goals
20.	EN- 730	Carbon Capture Technologies
21.	EN- 731	Power Quality

List of Institute Elective Courses

S. No.	Subject Code	Course Title
1.	EN- 701	Energy Policy, Economics and Audit
2.	EN- 702	Carbon Capture and Sustainability
3.	EN- 703	Emerging Renewable Energy Technologies

Course Name: **SOLAR PHOTOVOLTAIC SYSTEMS**
Course Code: **EN- 611**
Course Type: **Core Course**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives :

- To understand the concept of solar radiation.
- To import the knowledge about the concept of Photovoltaic system.
- To analyze solar power generation and estimate the losses in solar PV system.
- To design small and large solar Power Plants and prepare the reports.

Course Content

Solar spectrum details, Sun-path diagram and different angles, Types of solar radiation, Fundamentals of solar PV cells and systems: semiconductors as basis for solar cells materials and properties, P-N junction, I-V and QE curves of solar cells 1^{st},$2^{nd}$and 3^{rd}generation of PV technologies: Fabrication, Manufacturing process, Working principle and performance of different photovoltaic cells/modules, BOS for power plant: Supporting structures, mounting and installation, Battery storage, Power condition unit, Mechanical and electrical tracking systems, Selection of cables and balance of systems, Maintenance and schedule, Monitoring, Data Management. Estimating power and energy demand, Site selection, Land requirements, Choice of modules, Economic comparison, Off grid systems, Grid interface, Simulation with software, Sources of losses and prevention, Performance Analysis and Financial Analysis, Performance in Indian climatic conditions, Preparing DPR. Recent development in commercial solar cell technologies and systems, Standards and testing of PV modules, Characterization instruments and standards & certification, International Electro technical Commission (IEC) certification, Reliability tests, Module Degradation, Application, Future trend of use, PV water pumping, building application envelops, Organic-PV cells, traditional and innovative solar power applications, Concentrator solar cells, Low, medium and high concentration, reflector and lens based versions, Floating PV systems, Agro-voltaic, Recycling of solar PV modules, Methods of recycling.

Course Outcome:

Upon successful completion of the course, the students will be able to
CO1: Understand basics of solar PV and its manufacturing
CO2: Analyze solar power generation aspects
CO3: Evaluate different losses in solar PV systems and its components
CO4: Understand and apply solar PV module’s standards, reliability and degradation
CO5: Design small and large scale solar PV power plants with different applications

Textbooks and References:

1. C. S. Solanki, Solar Photovoltaics: Fundamentals, Technologies, and Applications, 2017.
2. J. P. Dunlop, & J. W. Twidell, Photovoltaic Systems, 2016.
3. M. Boxwell, Solar Electricity Handbook: A Simple, Practical Guide to Solar Energy - Designing and Installing Photovoltaic Solar Electric Systems, 2020.

Course Name: **ENERGY, CLIMATE & SUSTAINABILITY**
Course Code: **EN- 612**
Course Type: **Core Course**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To impart knowledge about renewable energy and its impacts on climate.
- To introduce the fundamental concepts relevant to energy sector and climate change.
- To enable the students to understand sustainability's relevance in energy consumption.

Course Content

Climate Change and Sustainability, Photosynthesis, Radiation and its parameters, Solar radiation, Spectrum and effects; Energy balance at the level of a leaf and ecosystem, Crop production, Canopy structure, radiation use efficiency, factors determining productivity, Sustainability, Ecosystem services, Millennium ecosystem assessment, Ecological footprint, Energy, Gaia hypothesis Climate Change and Sustainability, Natural Resources, Energy & Society at various space and time scale. Natural and anthropogenic climate change, Carbon capture and storage (CCS), Energy Sector and the Challenges, Energy Crisis, Energy security, The Needs of the Developing Countries, Energy sector and climate change, Climate risks as legal liabilities for the Energy sector, Incorporation of climate risks for energy firms and public disclosure, Challenges to low carbon society, Concept of a carbon-constrained world and its links to energy policies, Concept and Goals of Global Energy governance, Concept of Impact of Extreme weather on Energy Systems, International Legal and Policy Framework for Climate Change, Origin of concepts of sustainable development and sustainability, Kyoto Protocol, Clean development mechanism (CDM), Joint implementation, Emissions Trading System (ETS), Climate targets, CSR and sustainability, Role of UN, IPCC, UNFCC, COP, Paris Agreement on climate change, Climate change changing the focus of energy policy, International Environmental Policy Practices, UNFCCC, NAPCC, INDC

Course Outcomes:

On successful completion of this course, students will be able to
CO1: Understand the basics of climate change and its parameters
CO2: Evaluate the relationship between Energy and Climate change
CO3: Create sustainable understanding
CO4: Recognize low carbon sustainable technology
CO5: Understand and apply different framework for climate and sustainability

Textbooks and References:

1. R. A. Dunlap, Energy, Climate, and Sustainability: An Integrated Approach. Sustainable Publishers, 2020.
2. R. T. Wright, &, D. Boorse, Environmental Science: Toward a Sustainable Future, 2020.
3. W. J. Burroughs, Climate Change: A Multidisciplinary Approach. Cambridge University Press, 2019.

Course Name: **HYDROGEN ENERGY TECHNOLOGY**
Course Code: **EN- 613**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To learn hydrogen production and storage methodologies.
- To learn codes and standards related to hydrogen safety.
- To impart comprehensive and logical knowledge of hydrogen production, storage, utilization.
- To impart knowledge of various fuel cell technologies.
- To understand and apply codes and standards related to hydrogen safety.

Course Content

Properties of hydrogen, Importance of hydrogen in the context of energy transition, Overview of hydrogen energy systems Historical development and current status of hydrogen energy technology. Hydrogen Production Processes, Production from natural gas/ Hydrocarbon reforming, Steam reforming (steam methane reforming- SMR), Partial oxidation (POX), Autothermal reforming, Production from coal, Biomass gasification, Biomass pyrolysis, Biomass Combustion, Water Splitting Thermolysis, Water Splitting Photolysis, Water Splitting Electrolysis, Biophotolysis, Dark Fermentation, Photofermentation. Hydrogen Storage and Distribution, Compressed hydrogen storage, Liquid hydrogen storage, Hydrogen carriers: metal hydrides, chemical hydrogen storage, Pipeline transportation, Challenges and advancements in storage and distribution technologies. Hydrogen Utilization, Hydrogen fuel cells: principles and operation, Fuel cell vehicles (FCVs) and their advantages, Hydrogen refueling infrastructure, Hydrogen in refining, ammonia production, and petrochemical industries, Hydrogen as a reducing agent in metal production, Combined Heat and Power (CHP) systems, Industrial symbiosis and hydrogen integration, Hydrogen combustion turbines, Hydrogen-fueled internal combustion engines, Hydrogen as a feedstock for electricity generation, Integration with renewable energy sources, Hydrogen Safety, Safety barrier diagram, Risk analysis, Safety in handling and refueling stations, Safety in vehicular and stationary applications, Fire detection systems, Safety management, and Challenges, Environmental Impacts and Economics, Greenhouse gas emissions and air pollution considerations, Life cycle analysis of hydrogen production and utilization, Comparison with conventional fossil fuels and other alternative energy sources, Cost analysis of hydrogen production methods, Economic incentives and government policies supporting hydrogen energy, Market potential and investment opportunities in the hydrogen sector.

Course Outcome:
Upon successful completion of the course, the students will be able to
CO1: Understand hydrogen production methods
CO2: Understand and Apply the knowledge of storage methodologies
CO3: Understand and apply codes and standards related to hydrogen safety
CO4: Understand different challenges of hydrogen fuel application

Textbooks and Reference:

1. M. Ball and M. Wietschel, The Hydrogen Economy Opportunities and Challenges, Cambridge University Press, 2009
2. J. Bockris, Energy options: Real Economics and the Solar Hydrogen System,Halsted Press and London publisher, 1980.
3. J.Larminie & A. Dicks, Fuel cell systems explained (2nd ed.). John Wiley & Sons, 2015.
4. T.N. Veziroglu & F. Barbir (Eds.), Hydrogen energy: challenges and prospects. Springer Science & Business Media, 2007.
5. International Energy Agency (IEA), The Future of Hydrogen, 2021.

Course Name: **SOLAR THERMAL ENERGY SYSTEMS**
Course Code: **EN- 621**
Course Type: **Core Course**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To learn different aspects of solar radiation geometry Design various solar thermal applications and its performance analysis.
- To learn power generation aspects from solar thermal systems.
- To learn passive heating aspects from solar thermal systems.

Course Content

Solar Radiation, Basics of Solar Radiation, Instruments for measuring solar radiation, Solar radiation geometry, Empirical equations, Solar radiation on tilted surfaces, Flat Plate Collector, Liquid Flat plate Collector: Basic elements, performance analysis, absorptivity, heat transfer coefficients and correlations, collector efficiency and heat removal factors, effect of various parameters, types of other liquid flat-plate collectors, introduction to transient analysis, Evacuated tube collectors, applications on nanofluid, Concentrating Collectors, Type of concentrating collectors and their general characteristics, Geometry, Heat transfer correlations, Tracking requirements, Performance analysis, Effect of various parameters, Solar thermal power systems, Energy storage in solar process systems, Simulations in solar process design, Applications & Standards, Performance analysis of miscellaneous solar applications, Solar ventilation: stack effect, solar chimney for ventilation, absorber design, stack design, issues in opening design, Codes and Standards, Applications of solar flat plate water heater & Air heater for industrial process heat, Passive Heating & Cooling**,** Direct and indirect solar passive heating systems, Solarium, trombe-wall, Trans-wall, Passive cooling systems, Thermal mass, Courtyard effect, Wind tower design, Earth air tunnel system, Evaporative cooling, radiative cooling.

Course Outcomes:

Upon successful completion of course, the student will be able to
CO1: Understand solar geometry and assessment of solar resources.
CO2: Evaluate different of solar collector for different applications.
CO3: Apply passive heating and cooling aspects.
CO4: Understand different testing standards and its applications
CO5: Design and development of new generation solar thermal applications.

Textbooks and References:

1. S. P. Sukhatme &, J. K. Nayak, Solar Energy (4th ed.), McGraw-Hill Education Pvt. ISBN: 978-93-5260-711-2, 2018.
2. J. A. Duffie &, W. A. Beckman, Solar Engineering of Thermal Processes (4th ed.), Wiley, ISBN: 978-0-470-87366-3, 2013.
3. D. Y. Goswami, Principles of Solar Engineering (3rd ed.), CRC Press. ISBN: 978-1-4665-6379-7, 2015.

Course Name: **BIOENERGY SYSTEMS AND BIOFUELS**
Course Code: **EN- 622**
Course Type: **Core Course**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To learn about the renewable techniques of transportation and electricity generation.
- To learn the fundamental concepts relevant biomass resource and its processing.
- To enable the students to understand the factors that cause the resource depletion and degradation of resources.

Course Content

Biomass resources, types, production, classification and characterization, Techniques for biomass assessment, Energy plantation/crops, Food security and environmental impacts of biomass conversion to energy, Indoor Air pollution, Thermochemical Conversion, Direct combustion, Incineration, Pyrolysis, Biomass gasifiers,Types of gasifiers, Sizing selection and design of gasifiers, Biomass-fired boilers and types, Improved chullas, Co-firing and co-generation, Biomass integrated gasification/combined cycles systems, Biomass pyrolysis and their types, Manufacture of charcoal, Manufacture of pyrolytic oils and gases, Plastic waste management, Compatibility of Engines with biogas, Bioethanol and biodiesel, Biological Conversion, Anaerobic digestion, Process parameters of biomethanation and chemical kinetics, Biogas plant types, Biogas purification and utilization, Concept of Biorefinery, Algal biomass conversions: Algal fuels and byproducts, Chemical Conversion, Fermentation, Pre-treatment Processes for bioethanol production, Fischer-Tropsch, hydrolysis and hydrogenation, Biooil Extraction processes, Solvent extraction of hydrocarbons, Transesterification, Biodiesel and biohydrogen production, Solvent extraction of hydrocarbons, Solvolysis of wood, biocrude, catalytic distillation.

Course Outcomes:

On successful completion of this course,, students will be able to
CO1: Analyze and describe the nature and principles of bioenergy systems.
CO2: Design and distinguish the bioenergy systems and learn technical analysis.
CO3: Evaluate the environmental benefits and consequences of bioenergy production.
CO4: Understand different testing tools for environmental analysis.
CO5: Design and development of new generation biofuel applications.

Textbooks and References:

1. S. Capareda, Introduction to Biomass Energy Conversion, CRC Press, ISBN: 978-1-466-51333-4, 2018.
2. R. C. Brown & C. Stevens, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power. Wiley and Sons, ISBN: 978-0-470-72111-7, 2009.
3. V. C. Nelson & K. L. Starcher, Introduction to Bioenergy (Energy and the Environment), CRC Press, ISBN: 978-1-498-71698-7, 2018.
4. Y. Li &, S. K. Khanal, Bioenergy: Principles and Applications, Wiley-Blackwell, ISBN: 978-1-118-56831-5, 2016.
5. T. Weyland, Bioenergy: Sustainable Perspectives, Callisto Reference, ISBN: 978-1-632-39633-4, 2018.
6. R.A. Andersen, Algal Culturing Techniques, Elsevier, 2005.

Course Name: **ENERGY MANAGEMENT AND AUDIT**
Course Code: **EN- 623**
Course Type: **Core Course**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To familiarize students with concepts of energy management concepts and tools.
- To learn techniques of finding energy efficiency of various electrical and mechanical utilities.
- To teach then to perform energy audit of industrial units.

Course Content

General Aspects of Energy Management & Energy Audit: Energy Scenario, Basics of Energy and its various forms, Energy Conservation Act and related policies, Energy management and Audit, Material and Energy Balance, Energy Action Planning, Financial Management, Energy Monitoring and Targeting, Energy Efficiency in Thermal Utilities, Fuel and Combustion, Boiler, Steam system, Furnaces, Insulation and Refractories, Cogeneration, Waste Heat Recovery, Heat Exchangers, HVAC and refrigeration system, Compressed Air System, Energy Efficiency in Electrical Utilities, Electrical Systems, Electrical Motors and variable speed drives, Pump and pumping systems, Compressors, HVAC system, Fan and Blowers, Lighting systems, Power generating system, Energy Conservation in buildings, Energy Performance Assistance, Steel Industry; Cement Industry, Textile Industry, Pulp and paper Industry, Fertilizer Industry, Buildings and Commercial Establishments.

Course Outcome:

On successful completion of this course, students will be able to
CO1: Evaluate the techno-economic feasibility of the energy conservation technique adopted.
CO2: Analyze and identify the efficiency improvement process in any industry.
CO3: Apply the knowledge gained to conduct energy audit of an industry/organization.
CO4: Prepare energy audit reports.
CO5: Understanding different industries performance.

Textbooks and References:

1. T. C. Kandpal & H.P. Garg, Financial Evaluation of Renewable Energy Technologies, MacMillan India Limited, 2003.
2. Y. G. Yohanis, &, B. Norton, Sustainable Energy: Opportunities and Limitations, Oxford University Press, ISBN: 978-0-19-926178-9, 2006.
3. A. Thumann, A & W.R.Younger, Handbook of Energy Audits, CRC Press, ISBN: 978-1-4200-7581-1, 2010.
4. A. M. Paul, Energy Management and Conservation Handbook, CRC Press, ISBN: 978-0-367-36843-6, 2019.
5. BEE guidebooks for energy auditor and energy manager exam https://beeindia.gov.in/content/energy-auditors

Course Name: **ENERGY LABORATORY-I**
Course Code: **EN- 614**
Course Type: **Core Course**

Contact Hours/Week: **4P** Course Credits:**02**

Course Objectives

- To learn Practical applicable of Theoretical concept of Solar PV System.
- To analyse the solar Power generation with designing small and larger solar Power Plant.

Course content

1. To investigate the I-V and PV curves of Solar PV modules in series and parallel combination.
2. To investigate the I-V and PV curves of solar PV modes under varying solar radiations.
3. To study the characteristics of PV module under different tilt angles.
4. To study the characterises under STC condition using Sun simulator.
5. To investigate the effect of shading on module output.
6. To carry out performance analysis of three different PV technologies.
7. To work out power flow calculation of standalone PV System of DC load with battery.
8. To work out Power flow calculation of standalone PV system of AC load with battery.
9. To Study the PV wind hybrid Systems.
10. Measurement of Solar radiation (beam, dilutes and Global) radiation and Sunshine hour from Automatic weather station hourly data.
11. Analysis of wind and solar date from NASA data base.
12. Design standalone PV system using Simulation tool.
13. Analysis of load demand using Excel.
14. Design Hybrid System using Simulation tools.
15. 15. Design PV Power plant using Simulation tool.

Course Outcomes:

Upon successful completion of the course, the students will be able
CO1: To understand the performance analysis of PV System.
CO2: To understand the working principle of Solar Photovoltaic cell/ module.
CO3: To understand the designing of standalone or hybrid Power generation system.
CO4: To understand the concept of modelling input and methods of renewable Energy Systems.

*Note- The concerned course coordinator will prepare the actual list of experiments/problems at the start semester based on above generic list.

Course Name: **ENERGY LABORATORY-II**
Course Code: **EN- 624**
Course Type: **Core Course**

Contact Hours/Week: **4P** Course Credits:**02**

Course Objectives

- To learn Power generation as pact from solar Thermal and Bio energy system.
- To understand the various types of properties of Biomass.
- To learn the practical applicability of theoretical concept of Solar Thermal energy.

Course Content

1. Evaluation of Thermal performance of Solar water heater with flat plate collector in radiation natural mode of flow with fixed.
2. Evaluation of Thermal performance of flat plate solar water heater in force mode of flow with fixed radiation. 3. Evaluation of Thermal performance of flat plate collector in natural mode under varying radiation.
3. Calibration of Thermocouple/ RTD using PRT and dry calibration bath.
4. To calculate Solar Thermal efficiency of parabolic dish collector.
5. To estimate the thermal performance of box type solar cooker.
6. To study the vapour absorption system using ammonia and water.
7. To study the measurement of moisture content in Biomass.
8. To study the performance of Fuel cell for Power generation using Fuel cell kit.
9. To study the process of briquette formation from Biomass.
10. To study the measurement of calorific value of any Biomass.
11. To study the char formation process from Biomass.
12. Model development of Renewable sources in MATLAB or Simulink.
13. Design a wind Power System using Simulation tool.
14. Design biomass-based energy system using simulation tools.
15. Energy data analysis using statistical software tools.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Evaluate and analyses the performance of solar thermal systems.
CO2: To understand the working methodology of solar thermal and Bio energy System.
CO3: To carry out the performance analysis of Bio energy systems.
CO4: TO understand the use of practical solar Thermal and Bio Energy system in daily life application.

*Note-The concerned course coordinator will prepare the actual list of experiments/problems at the start semester based on above generic list.

Course Name: **ENERGY STORAGE TECHNOLOGY**
Course Code: **EN- 711**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course objectives:

- To study the details of various Energy storage systems along with applications.
- To identify the optimal solutions to a particular Energy storage application / utility.
- To learn energy storage integration and hybrid energy storage systems.

Course Content

Overview of energy storage, Importance in the context of renewable energy, Basic principles and concepts, Historical development and milestones, Electrochemical Energy Storage: Batteries: types, working principles, and applications, Fuel cells: principles and applications, Capacitors and supercapacitors, Comparison of electrochemical storage technologies, Mechanical Energy Storage: Pumped hydro storage, Compressed air energy storage (CAES), Flywheel energy storage, Gravity-based energy storage, Thermal Energy Storage: Sensible, latent, and thermochemical storage, Applications in buildings, industry, and power plants, Advantages and challenges of thermal energy storage, Advanced Energy Storage Technologies: Flow batteries, Lithium-sulfur and other advanced battery chemistries, Solid-state batteries, Innovations in energy storage research, Integration of Energy Storage Systems: Grid-scale energy storage, Microgrid applications, Hybrid renewable energy systems, Smart grids and energy management, Economic and Environmental Aspects: Cost analysis of energy storage, Life cycle assessments, Policy and regulatory considerations, Case studies on successful energy storage implementations.

Course Outcome:

Upon successful completion of the course, the students will be able to
CO1: Understand different aspects and parameters of electrical energy storage systems.
CO2: Evaluate utilization, sizing and operation of energy storage systems.
CO3: Apply the knowledge gained for energy storage integration and hybrid energy storage systems.
CO4: Understand different storage systems
CO5: Understanding different industrial applications

Textbooks and References:

1. R. Baxter, Energy Storage: A Nontechnical Guide. PennWell Books, ISBN-13: 978-1593703706, 2015.
2. R. Huggins & A. Ahmed, Energy Storage Systems, Springer, ISBN-13: 978-1493914481, 2015.
3. K.E. Kakosimos & G.P. Sakellaropoulos, Energy Storage: Fundamentals, Materials, and Applications, CRC Press. ISBN-13: 978-1498720578, 2016.
4. H.A. Kiehne, H. A. & P.J. Treadway, Battery Technology Handbook, CRC Press, ISBN-13: 978-0824709952, 2003.
5. P.T. Moseley, J. Schumacher & J. Kaiser, Introduction to Energy Storage: The Missing Link in the Energy Transition. Wiley. ISBN-13: 978-1119502149, 2020.
6. G.M. Shaver & G.G. Karady, Grid-Scale Energy Storage: Applications, Technologies, and Deployment Strategies. CRC Press, ISBN-13: 978-1138574473, 2019.

Course Name: **SMART GRID SYSTEMS**
Course Code: **EN- 712**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To learn Smart Grid technologies, different smart meters and advanced metering infrastructure.
- To learn the power quality management issues in Smart Grid.
- To learn the high performance computing for Smart Grid applications.

Course Content

The Smart Grids, Evolution of Electric Grid, Concept, Need for Smart Grid, Smart grid drivers, Functions, Opportunities, Challenges and benefits, Difference between conventional & Smart Grid, National and International Initiatives in Smart Grid, Conceptual model, Architectures, Interoperability, Communication technologies, Standards, National Smart Grid Mission (NSGM), Smart Transmission & Distribution Technologies, Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation , Transmission systems SCADA Systems, Energy management system (EMS), Phasor measurement units (PMU), Wide area measurement systems (WAMS), Distribution automation, Outage management systems, Automated meter reading (AMR), Fault location, Isolation and service restoration (FLISR), Outage Management Systems (OMS), Energy Storage, Renewable Integration, Monitoring and Measurement, Wide area monitoring system, Phasor measurement units, Smart meters, Smart Appliances, Advanced metering infrastructure (AMI), and other monitoring and measurement technologies, Information and Communication Technologies, Distribution line models, Communication infrastructures and protocols for smart grid operation, Standard for information exchange, State of art Interoperability, Information Security, Cyber Security Standards, Distributed Generation and Smart Consumption, Distributed energy resources (DERs), Smart appliances, Low voltage DC (LVDC) distribution in homes / buildings, Home energy management system (HEMS), Net Metering, Building to Grid B2G, Vehicle to Grid V2G, Solar to Grid, Microgrid, Economic Grid Operation, Basic Concepts Related to Electricity Systems, Economic Dispatch, Merit Order Dispatch, Incremental Cost Method, Unit Commitment, Demand Response (selection of generators & loads to operate), Energy constraints: hydro, fuel management and maintenance scheduling.

Course Outcome: Upon successful completion of the course, the students will be able
CO1: To understand and apply the concept and related infrastructure of a smart grid.
CO2: To evaluate basic operations and design.
CO3: To create the modern and innovative application fields of distributed generating units and relative merits.
CO4: To understand different smart grid challenges.
CO5: To understand different energy constraints.

Textbooks and References:

1. J. Momoh & L.Yao, Smart Grid: Fundamentals of Design and Analysis, CRC Press, ISBN-13: 978-1439856236, 2012.
2. S.Borlase & D.Mercer, Smart Grids: Infrastructure, Technology, and Solutions, CRC Press. ISBN-13: 978-1466503312, 2012.
3. J.Ekanayake, N. Jenkins & K. Liyanage, Smart Grid: Technology and Applications, Wiley. ISBN-13: 978-0470666535, 2012.
4. J.C. Stephens, Smart Grid (R)Evolution: Electric Power Struggles. Cambridge University Press. ISBN-13: 978-1107085593, 2015.
5. T. Ackermann, N. Hadjsaid & D. Ernst, Smart Grids: Opportunities, Developments, and Trends, Springer, ISBN-13: 978-3642358406, 2013.

Course Name: WASTE TO ENERGY
Course Code: EN- 713
Course Type: Programme Elective

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To understand the concept of Waste to Energy.
- To learn to apply and analyse different technologies for Waste to Energy.
- To design a waste to energy plant by selecting appropriate technology.

Course Content

Introduction to waste management, Definitions, characteristics, types, sources, properties, on site handling, collection and transfer of agro, forest, domestic, industrial and solid waste. Industrial waste (hazardous and non-hazardous), Biorefineries, Integrated Waste Management, Plastic waste, Refuse derived fuel-fluff, Briquettes, Pellets. Cultivation of algal biomass from wastewater and energy production from algae. Resource and Energy Recovery, Logistic methods in waste management, Segregation methods and efficiency, Source segregation and Duties of waste generator, Introduction of concept of partnership in Swachh Bharat, Waste to Energy Conversion Technologies, Biochemical Conversion, Energy production from organic waste through anaerobic digestion, Fermentation and transesterification, Designing of Plants, Anaerobic digestion bioreactors and plant designs, Case studies, Thermo-Chemical Conversion, Combustion, Incineration, Pyrolysis, Gasification, Plasma Arc Technology and other newer technologies, Designing of Plants, New relevant technologies, Operation and maintenance, Case studies of waste to energy plants at international level, Success and Failures of Indian Waste to Energy plants, Health and environmental impacts from different waste to energy conversion technologies, Measures to mitigate environmental effects, Rules-Regulations-Policies & Opportunity, Government regulations on waste and Laws in India, The Environmental Protection Act, The Plastic Waste Rules, 2011, Bio-Medical Waste Rules, 1998, Solid Waste Management Rules 2016. Stake holder engagement, Waste to Energy Entrepreneurship opportunities and Innovations.

Course Outcome:

Upon successful completion of the course, the students will be able

CO1: To understand of the concept of Waste to Energy.

CO2: To apply and analyse different technologies for energy generation from waste.

CO3: To design a waste to energy plant based upon regulations.

CO4: To analyse technical and management principles of waste to energy plant.

CO5: To understand health and environmental impacts from different waste to energy conversion technologies.

Textbooks and References:

1. G. Tchobanoglous, H. Theisen & S.A.Vigil, Integrated Solid Waste Management: Engineering Principles and Management Issues (2nd ed.). McGraw-Hill, 2014.
2. R.C. Brown, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, John Wiley & Sons, 2019.
3. S. Capareda, Introduction to Biomass Energy Conversions. CRC Press, 2013.
4. K.J. Ptasinski, Efficiency of Biomass Energy: An Exergy Approach to Biofuels, Power, and Biorefineries, John Wiley & Sons, 2016.
5. P.A. Vesilind & W.A. Worrell, Solid Waste Engineering (2nd ed.), Cengage India, 2016.

Course Name: **WIND ENERGY SYSTEMS**
Course Code: **EN- 714**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To learn basics of wind energy systems and resource assessment techniques.
- To learn aerodynamics and components of wind turbine, power generation and environmental assessments.
- To design, operation, control, and integration of wind power plants.

Course Content

Wind Energy Basics & Wind Resources, Wind Energy Basics, Types of wind energy converters, Advantages and disadvantages, Introduction of modern wind energy and its origins, Wind characteristics, Atmospheric boundary layer, Local effects on wind, Site selection, Roughness length, Wind shear, Wind speed variability, Wind variations, Weibull, Rayleigh distribution,Wind resources estimation, Wind measurement and Instrumentation, Aerodynamics & Components of Wind Turbine, Momentum theory, Betz limit, Wake rotation, Blade elemental theory, Blade shape, Effect of drag and blade number on performance. Airfoils and general concepts of aerodynamics, Rotor Blades, Gearboxes, Synchronous or Asynchronous Generators, Towers, Miscellaneous components, Design, Testing & Standards, Wind farm design, Testing and standards, Design procedure, Topologies, Wind turbine/farm simulation, Wind turbine testing and standards, Technical specifications, Wind turbine design loads, Power curve prediction, Wind turbine component testing, Life cycle assessment, Safety aspects, Case studies, Operation and Control, Wind Energy Converters, Pitch control, Stall Control, Yaw Control, Grid connectivity, Requirement and related issue, Reactive power control, Wind turbine environmental aspects and impacts, Issue of Noise and Its Control, Visual impacts, Electromagnetic interference, Applications, Small and hybrid wind turbines, Introduction of micro/small and hybrid wind turbines, Siting small turbines in complex terrain, Offshore wind turbines, Operation and challenge of offshore wind farms, On shore and off shore developments & policies.

Course Outcomes:

Upon successful completion of course, the students will be able to
CO1: Understand the basics of wind Energy conversion systems.
CO2: Understand and apply the principle of aerodynamics.
CO3: Understand different testing standards and its applications.
CO4: Design, operation, control, and integration of wind turbine.
CO5: Analyze on shore and off shore wind applications and future prospects.

Textbooks and References:

1. J. F. Manwell, J. G. McGowan, &, A. L. Rogers, Wind Energy Explained: Theory, Design and Application 2nd Edition Wiley, ISBN: 978-0470015001, 2010.
2. T. Burton, D. Sharpe, N. Jenkins, & E. Bossanyi, Wind Energy Handbook, John Wiley & Sons, 2011.
3. J. F. Manwell, J. G. McGowan &, A. L. Rogers, Wind Energy Explained: Theory, Design and Application, John Wiley & Sons, 2009.
4. C. L. Archer &, M. Z. Jacobson, Introduction to Wind Energy, Cambridge University Press, 2009.
5. B. N. Eldridge, Wind Energy Basics: A Guide to Small and Micro Wind Systems, New Society Publishers, 2014.
6. P. Jamieson, Innovation in Wind Turbine Design, John Wiley & Sons, 2012.

Course Name: **ENERGY ECONOMICS AND POLICIES**
Course Code: **EN- 715**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To enable students undertake feasibility emulation students of Energy Technology.
- To import the knowledge about techniques used in Energy Policy of government.
- To apply appropriate economic theory and analyze investment decisions in energy resources.

Course Content

Energy sectors & scenario, Sector wise consumption of energy resources, Electricity, Fuel, Transportation, Energy Scenario of different sectors such as Coal, Oil, Natural Gas, RE, Hydro, Nuclear, Global market outlook, Import and export position, Resources, Reserves, All India Energy Scenario, Energy Conservation Act 2001 and amendments, Energy Security Issues and Economics, Trade-Off between Energy Security and Climate Change, Energy Economics, Time Value of Money Concept, Simple Payback Period, IRR, NPV, Life Cycle Costing, LCA, LCOE, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation, Energy Chain, Energy Regulations in Indian Power Sector, Structure of Indian Power Sector, Indian Electricity Grid Code, National Electricity Policy, Deviation Settlement mechanism, Retail Competition, Tariff Regulations, Annual Revenue Requirements, Tariff Structure, Role of State/Central Regulatory Commissions, Involved costs, Energy purchase, Losses, Surcharges, O&M, Interests, Depreciation, Return on Equity, Total Revenue Requirement, Tariff Policy, Understanding tariff order, Policies for Renewable Energy, Renewable Energy Policy, Incentives and subsidies, Foreign Investment, Role of MNES, IREDA, Bio Energy Policy, Solar Policy, Waste Management Practices and policies, Renewable purchase obligations, Feed in Tariffs, Renewable Energy Certificates, National policy on Hydropower, India EV Policy, Other schemes such as Saubhagya, UJALA, UDAY, RFMS, Smart Cities, etc.

Course Outcome:

Upon successful completion of the course, the students will be able to
CO1: Appreciate and understand the various energy related eats and policies of governments.
CO2: Calculate payback period, cost of energy generated, life cycle costing etc.
CO3: Calculate the tariffs on energy charged regulatory bodies.
CO4: Understand different policies and challenges.
CO5: Understanding different government schemes.

Textbooks and References:

1. M. Kleinpeter, Energy Planning and Policy, John Wiley & sons, 1995.
2. R. Codoni, H. Park and K.V. Ramani, Integrated Energy Planning: A Manual, Vols. I, II & III. Asian and Pacific Development Centre, Kuala Lumpur, 1985.
3. J. Parikh, Energy Models for 2000 and Beyond, Tata McGraw Hill Publishing Company Limited, 1997.
4. M.S.Kumar, Energy Pricing Policies in Developing Countries: Theory and Empirical Evidence, International Labor Organization, 1987.
5. M. Munasinghe and P. Meir, Energy Policy Analysis and Modeling, Cambridge University Press, 1993.
6. A.V.Desai, Energy Planning, Wiley Eastern Ltd., 1990.
7. H.Campbell and R.Broron, Benefit-Cost Analysis, Cambridge University Press, 2003.
8. C.S.Park, Contemporary Engineering Economics, Prentice Hall Inc., 2002.

Course Name: **BIOFUELS CONVERSION PROCESSES**
Course Code: **EN- 716**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To Analyse and describe the nature and processes of biofuels.
- To develop, designs and distinguish the biofuel processes and learn environmental impacts.
- To evaluate the advances in biofuel substrate treatment and production.

Course Content

Bio-Mass Resources Biomass Resources and Classification, Physio -Chemical Characteristics, International And National Potential And Status of Bio-Fuels, Biomass to Biofuels, Thermochemical Conversion, Feedstocks for Biofuels, Composition of Lignocellulosic Biomass, Lignocellulosic Biomass Pretreatment Techniques, Biotechnological Conversion, Typical Issues for Life-Cycle Analysis, Production of Bioethanol from Lignocellulosic Feedstocks: First generation fuel, Ethanol production, Feedstocks and Process, Second-Generation Ethanol production, Feasibility of lignocellulosic ethanol Production, Production of bioethanol from Agroindustrial residues as feedstocks, Pretreatment Technologies for Lignocellulose-to-Bioethanol Conversion, Toxic compounds generated during pretreatment, Pretreatment processes, Biological pretreatments, Production of Biodiesel from Vegetable Oils Biotechnological methods to produce biodiesel, Enzymatic transesterification, Economic evaluation of enzymatic biodiesel production, Biodiesel production in supercritical fluids, Advanced fuel processing: Chemical conversion, Syngas to methanol and ethanol and some advanced fuels like biobutanol, bio propanol, Pyrolysis oil, Fast pyrolysis technologies, Composition and issues of bio- oil, Bio-oil up gradation technologies, Energy from Algae: Algae Cultivation, Photo-bioreactors, Harvesting, Sewage and Wastewater growth conditions, Algae biomass, Hydrogen production, Byproducts of Biofuel generation.

Course Outcome: On successful completion of this course,, students will be able to
CO1: Analyze and describe the conversion of biomass and waste organic matter.
CO2: Develop and designs the bio-ethanol, biodiesel and biogas plant.
CO3: Evaluate the environmental benefits and consequences of biofuel production.
CO4: Understand economic feasibility of the biofuel production process.
CO5: Understand the challenges of biofuel production.

Textbooks and References:

1. S. Capareda, Introduction to Biomass Energy Conversion, CRC Press, ISBN: 978-1-466-51333-4, 2018.
2. R. C. Brown & C. Stevens, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power. Wiley and Sons, ISBN: 978-0-470-72111-7, 2009.
3. V. C. Nelson & K. L. Starcher, Introduction to Bioenergy (Energy and the Environment), CRC Press, ISBN: 978-1-498-71698-7, 2018.
4. Y. Li &, S. K. Khanal, Bioenergy: Principles and Applications, Wiley-Blackwell, ISBN: 978-1-118-56831-5, 2016.
5. T. Weyland, Bioenergy: Sustainable Perspectives, Callisto Reference, ISBN: 978-1-632-39633-4, 2018.
6. R.A. Andersen, Algal Culturing Techniques, Elsevier, 2005.

Course Name: **ALTERNATIVE FUELS**
Course Code: **EN- 717**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To address the underlying concepts and methods behind alternate fuel and energy system.
- To know the properties, performance and emission characteristics of different alternative fuels.
- To present a problem oriented in depth knowledge of Alternate fuel and energy system.

Course Content

I.C. Engine, and SI engines, Gasoline and diesel self-ignition characteristics of the fuel, Octane number, Cetane number, Properties of different types of fuel (Rating of fuel, Ignition quality, volatility, Air / Fuel ratio, Calorific Value), Fuel efficiency, Fuel requirement, Engine efficiency and Engine life, Concepts of Greenhouse effect, Global warming, Exhaust gas emission effect on environmental pollution, Global Carbon Budget, Carbon footprint and Carbon credit calculations, Emission norms as per Bharat Standard up to BS – IV and procedures for confirmation on production, Methanol and Ethanol Sources and production, Properties of methanol & ethanol as engine fuels, Use of alcohols in S.I. and C.I. engines, Performance of blending methanol with gasoline, Emulsification of alcohol and diesel, Dual fuel systems, Improvement / Change in emission characteristics with respect to % blending of Alcohol, Bio Diesel base materials used for production of Bio Diesel (Karanji oil, Neemoil, Sunflower oil, Soyabeenoil, Musturd oil, Palm oil, Jatropha seeds), Process of separation of Bio Diesel, Properties of Diesel blended with vegetable oil, and difference in the performance of Engine, Biogas system, Process during gas formation, Factors affecting biogas formation. Usage of Biogas in SI engine & CI engine, LPG & CNG, Properties of LPG & CNG as engine fuels, Fuel metering systems, Combustion characteristics, Effect on performance, Emission, Cost and Safety, Hydrogen as a substitute fuel, Study Properties, Sources and methods of Production of Hydrogen, Storage and Transportation of hydrogen, Economics and advantages of hydrogen (Liquid hydrogen) as fuel for IC engine/ hydrogen car, Layout of a hydrogen car, Fuel Cells, Concept of fuel cells based on usage of Hydrogen and Methanol, Power rating, and performance, Heat dissipation, Layout of fuel cell vehicle, Solar Power, Solar cells for energy collection, Storage batteries, Layout of solar powered automobiles, Advantages and limitations, Electric & Hybrid Vehicles, Layout of an electric vehicles, Advantages & limitations, Systems components, Electronic controlled systems, High energy and power density batteries, Types of hybrid vehicles, Various Vegetable oils for Engines, Esterification, Performance and emission characteristics, Synthetic Alternative Fuels, Di-Methyl Ether (DME), P-Series, Eco Friendly Plastic fuels (EPF).

Course Outcome: On successful completion of this course, students will be able to
CO1: Analyze and describe the nature of transportation and stationary engine and fuels.
CO2: Develop and designs the available fuel technology.
CO3: Evaluate the environmental benefits and consequences of electric and hybrid vehicles.
CO4: Understand different environment friendly fuels as alternatives.

Textbooks and References:
1. L. Richard, Bechtold, Alternative Fuels Guide Book, SAE International Warrendale, 1997.
2. S.S Thipse, Alternative Fuels; Concepts, Technologies and Developments, Jaico Book Distributors, 2010
3. M.K.G. Babu and K.A. Subhramanian, Alternative Transportation Fuels, CRC Press, 2013
4. M. Dayal, Energy today & Tomorrow, I&B Horishr India,1982.

Course Name: **CIRCULAR ECONOMY**
Course Code: **EN- 718**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objective:

- Understand the concept of a circular economy based on its socio-technical, managerial and environmental characteristics.
- Learn principles of circularity and their application to sustainable development.
- Learn complexity aspects of circular economy for sustainable development.

Course Content

Introduction to circular economy, Purpose of circular economy, Circular sustainability, Advantages, Challenges for circular economy, future opportunities, Opportunities for circular transformations of products and services, Effective circular transformations, Systems based approaches, Sustainable Development and Circular Economy, Concept of sustainable development, Sustainable processes technologies, Critical assessment on current sustainable technologies, Material management, Circular economy towards zero waste, Circular economy in waste sector, Waste management in the context of circular economy, Business models, Circular bioeconomy, Circular business models, Role of Business in the circular economy, Circular business models to create economic and social value, Drivers for entrepreneurship in a Circular Economy, Business model innovation, Circular business model planning tool, Circular Design, Innovation and Assessment, Material science innovations, Nanotech developments, Assessing the environmental sustainability of circular systems, Tools and methods, Assessing the resource efficiency of circular systems, Circular economy policy framework, Universal circular economy policy goals, Role of governments, How policies and sharing best practices can enable the circular economy, Different policy studies based upon circular economy, Extended producer responsibility, Policies for extended product lifetimes.

Course Outcomes: Upon successful completion of the course, the students will be able
CO1: To understand the concept of a circular economy based on its socio-technical, and environmental characteristics
CO2: To Apply the principles of circularity and their application to sustainable development
CO3: To Apply complexity aspects of circular economy for sustainable development
CO4: To analyse and understand different circular business models

Textbooks and References:

1. W.R. Stahel, W. R, The Circular Economy: A User's Guide. CRC Press, 2019.
2. J.A. Smith, Circular Economy in the Energy Sector: Sustainable Practices for a Greener Future, Sustainable Publishing Co, 2020.
3. M. Tonelli & N. Cristoni, Strategic Management and the Circular Economy, Routledge, 2018.
4. L.H. Lovins & Cohen, B. (2017). Circular Economy Handbook for Business and Supply Chains: Repair, Remake, Redesign, Rethink. Greenleaf Publishing.

Course Name: **MATERIALS FOR ENERGY & APPLICATIONS**
Course Code: **EN- 719**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course objectives:

- To learn different materials used in energy applications.
- To learn material synthesis and production process.
- To learn materials characterization and further development.

Course Content

Overview of Energy and Power Materials Energy Storage, Electrochemical batteries, Electrochemical capacitors, Energy conversion fuel cells, Microturbines, Inorganic photovoltaics, Inorganic thermoelectric, Electric propulsion components, Magnetic superconducting coils, Battery technology, Lithium-ion batteries for EV, Redox flow batteries, Compatibility and performance of battery components, Gas separation and storage-porous materials, Membranes for storage, Sustainable carbon-based fuels, Semiconductors &Solar Energy Materials, Photonic devices, Photo detectors, LEDs, Semiconductor device, Fundamentals of different solar cells, Device structures, Output power, Metal semiconductor heterojunctions, Efficiency, Fill factor and Optimization for Maximum power, Surface structures for maximum light absorption, Operating temperature vs conversion efficiency, Solar cell properties and design, Materials for solar cells, Organic solar cells, Organic inorganic hybrid solar cells, Advanced concepts in photovoltaic research, Nanotechnology applications, Quantum dots, Nanomaterials Science and Engineering, Nanocomposite electrolytes for batteries, Nanomaterials for energetic materials, Overview of nanostructures, Properties of nanomaterials, Different dimensional nanostructures, Structural, Optical, Electrical, Dielectric and Magnetic properties of nanomaterials, Semiconductor and metal nanocrystals, Carbon nanotubes, Nanocomposites, Nanocrystalline thin films, Applications of nanotechnology in energy, space, optics, medicine and electronics, Environmental, health and safety issues, Nanotechnology for Energy Applications: Synthesis and characterization of nanomaterials, Nanomaterials and nano systems for energy applications, Energy storage and energy harvesting technologies, Micro-fuel cell technologies, Fuel cells, Polymer membranes for fuel cells, PEM fuel cells, Acid/ alkaline fuel cells, Design of fuel cells, Hydrogen storage in carbon nanotubes, Use of nanoscale catalysts to save energy, Nanomaterials based rechargeable batteries, Advanced Techniques for materials characterization: Techniques for atomic structure and surface morphology determination, Working principle and data analysis for X-ray Diffraction (XRD), Transmission electron microscopy (TEM), Low energy electron diffraction (LEED), Scanning tunneling microscopy (STM) and Atomic force microscopy (AFM).

Course Outcomes: Upon successful completion of the course, the students will be able
CO1: To get insight of different materials used in energy applications.
CO2: To learn and apply material synthesis and production process
CO3: To learn materials characterization and further development
CO4: To analyse different nanomaterials and technology behind this

Textbooks and References:

1. D.R. Gaskell & M.J. M. Krane, An introduction to transport phenomena in materials engineering, CRC Press, 2024.
2. G.Ramalingam, A.K. Priya, L. Gnanasekaran, S. Rajendran, & T.K. Hoang, T. K, Biomass and waste derived silica, activated carbon and ammonia-based materials for energy-related applications–A review. Fuel, 355, 129490, 2024.
3. A. Kitanovski, Energy applications of magnetocaloric materials. Advanced Energy Materials, 10(10), 1903741, 2020.

Course Name: **SUSTAINABLE BUILDINGS**
Course Code: **EN- 720**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- Gain knowledge of contemporary issues pertaining to energy efficiency in buildings
- Learn design of energy efficient buildings
- Learn standards, codes and ratings in the design of energy efficient buildings

Course Content

Introduction to Energy Efficiency in Buildings, Energy Efficiency, Overview of energy efficiency in buildings and its benefits, Approach to energy efficiency in Buildings, Basics of energy systems in buildings interface of systems and envelope, Overview on energy consuming end uses, Energy consumption patterns of different end-use for varying building typologies, Energy consumption benchmarks in buildings, Concept of passive building design, Heating, Ventilation, and Air Conditioning (HVAC), HVAC basics, Types of HVAC systems, Psychometric analysis, Thermal comfort basics, Heating and cooling load of buildings, Elements of heating and cooling load, Load reduction approaches, Comfort zone, Indoor Environment quality, Improvement of IAQ, Standards, codes and rating of buildings (international and national perspective) related to energy efficiency in commercial buildings, Calculation and documentation for compliance and rating, Envelope, HVAC, lighting, and controls for code compliance, Sustainable Energy Applications in Buildings, Building integrated photovoltaics and its types, Building-mounted/augmented wind turbines, Net zero buildings, Green buildings, Daylight management in buildings, National mission for sustainable habitat.

Course Outcome:

Upon successful completion of the course, the students will be able
CO1: To develop knowledge of contemporary issues pertaining to energy efficiency in buildings.
CO2: To apply the knowledge of engineering in design of energy efficient buildings.
CO3: To apply standards, codes and ratings in the design of energy efficient buildings.
CO4: Understand different Heating, Ventilation, and Air Conditioning system.
CO5: Understanding energy loss in building design.

Textbooks and References:

1. C.J. Kibert, Sustainable Construction: Green Building Design and Delivery, John Wiley & Sons, ISBN: 978-1119055174, 2016.
2. J. Broome & K. McCloud, The Green Self-Build Book: How to Design and Build Your Own Eco-Home, Frances Lincoln, ISBN: 978-0711226182, 2007.
3. N.C. Sinha, Sustainable Architecture and Building Design, CRC Press, ISBN: 978-0367135567, 2020.
4. F.D.K. Ching & I.M. Shapiro, Green Building Illustrated. Wiley. ISBN: 978-1118562376, 2018.

Course Name: **HYDRO ENERGY SYSTEMS**
Course Code: **EN- 721**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives :

- To learn operation and design of specific types of turbines and installation for a specific location.
- To understand the principle of hydraulic turbine and applications.
- To learn environmental impacts of hydropower with mitigation strategies.

Course Content

Historical development and significance of hydropower, Current global and national status of hydropower, Fundamental principles of hydropower, Differentiating between potential and kinetic energy in water, Hydropower Plants, Classification and working principles of Hydropower Plants, Characteristics, advantages, and limitations, Environmental considerations and sustainable practices, Reservoir Hydropower Plants, Reservoir management and challenges, Pumped Storage Hydropower (PSH), Principles of operation and energy storage, Applications, benefits, and limitations of PSH, Hydropower Components: Hydraulic Turbines, Types of turbines: Pelton, Francis, Kaplan Efficiency and suitability for different hydropower conditions, Generators and Powerhouses, Generator types used in hydropower systems, Powerhouse design and layout considerations, Control and Automation in Hydropower, Automation technologies for optimal hydropower operation, Control systems for load balancing and stability, Planning and Monitoring: Hydropower Project Planning, Site selection criteria and feasibility studies, Permitting and regulatory considerations, Environmental Impact Assessment (EIA), Principles and methodologies for assessing environmental impacts, Mitigation strategies for minimizing ecological disruption, Social and Community Aspects, Assessing and addressing social implications of hydropower projects, Community engagement and sustainable development practices, Hydropower Plant Maintenance, Strategies for improving efficiency and output, Analyzing successful and challenging hydropower projects.

Course Outcome:
Upon successful completion of the course, the students will be able
CO1: To understand the principles of operation and design of specific types of turbines and installation of the necessary accessories for a specific location.
CO2: To apply the concepts of hydro power systems.
CO3: To evaluate the environmental impacts of hydropower and suggest mitigation strategies.
CO4: To understand different hydroelectric equipment.

Textbooks and References:

1. B. Pandey & A. Shukla, Hydroelectric Energy: Renewable Energy and the Environment, CRC Press, SBN: 978-0367332949, 2021.
2. H.J. Delay, Introduction to Hydropower. ASCE Press, ISBN: 978-0784413118, 2013.
3. A. Smajgl, & N. Mirumachi, Hydropower Development in the Mekong Region: Political, Socio-economic, and Environmental Perspectives. Springer, ISBN: 978-3319731710, 2018.
4. M. Ragheb & P.A. Elghobashi, Hydroelectric Energy: Challenges and Opportunities. CRC Press. ISBN: 978-1138326828, 2019.
5. R. Randa, Small Hydropower Systems, CRC Press, ISBN: 978-1138055382, 2018.

Course Name: **MODELLING AND OPTIMIZATION OF ENERGY SYSTEMS**
Course Code: **EN- 722**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To learn efficient computational procedures for solving and optiztion problems.
- To use programming languages for executing important optimization methods.
- To optimize the performance of different energy systems

Course Content

Modelling and Simulation Principles, Modelling overview levels of analysis, Steps in model development, Examples of models, Hardy Cross method, Multivariable Newton-Raphson simulation method, Simulation of renewable energy systems/Case studies, Simulation using differential equations, Mathematical modelling of thermodynamic properties, Steady state simulation of large systems, Simulation of dynamic systems, Objectives/constraints, Problem formulation, Unconstrained problems, Necessary&Sufficient conditions, Constrained Optimization lagrange multipliers, Constrained variations, Kuhn-Tucker conditions, Case studies of optimization in energy systems problems, Dealing with uncertainty probabilistic techniques, Linear programming, Dynamic programming, Non-traditional optimization techniques, Introduction system design Curve fitting, Search methods, Univariate / Multivariate, Characteristics of measurement systems, Time response of measurement systems, System response, First and second order systems and analysis, Error estimates and uncertainty analysis, Method of least squares, Propagation of uncertainty, Statistical analysis of experimental data normal error distributions (confidence interval and level of significance, chauvenet's criterion), Chi-square test of goodness of fit, Method of least squares (regression analysis, correlation coefficient), Multivariable regression, Error estimates using gaussian distribution, Static and dynamic characteristics, Dimensional analysis and similitude, Design of experiments, Forecasting energy demand, Simple and advanced Techniques, Econometric Approach to Energy Demand Forecasting, End-Use Method of Forecasting, Input–Output Model, Scenario based approach, ANN, Hybrid Approach.

Course Outcome: Upon successful completion of the course, the students will be able to
CO1: To design energy systems for engineering applications and model their performance
CO2: To analyze energy systems under various design and off-design operating conditions.
CO3: To optimize the performance of different energy systems.
CO4: To understand different forecasting and apply them into real conditions.
CO5: To learn design of experiments and statistical data analysis.

Textbooks and References:

1. J. Randolph and G. M. Masters, Energy for Sustainability: Technology, Planning, Policy, Island Press, ISBN-13: 978-1597261036, 2018.
2. Bhattacharyya, Subhes C. *Energy economics: concepts, issues, markets and governance*. Springer Science & Business Media, ISBN 978-0-85729-268-1, 2011.
3. Y. Jaluria, Design and Optimization of Thermal Systems, 2nd edition, CRC Press, ISBN 9781498778237, 2008.
4. W.F. Stoeker, Design of Thermal Systems, 3rd edition, McGraw Hill, ISBN 10:125900239X / ISBN 13:9781259002397, 2011.

Course Name: **HYBRID ELECTRIC VEHICLE**
Course Code: **EN- 723**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objective:

- To learn the operation of different electric vehicles.
- To learn different aspects of design-control and monitoring of EV.
- To gain knowledge in the field of vehicle business and policy.

Course Content

Introduction to E/H Vehicles, Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving, Energy consumption concept of hybrid electric drive trains, Architecture of hybrid electric drive trains, Electric propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switched reluctance motor, Introduction to Energy Storage, Requirements in Hybrid and Electric Vehicles: Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices, Sizing the drive system, Design of Hybrid electric vehicle and Plug-in Electric Vehicle, Energy management strategies, Automotive networking and communication, EV charging standards, V2G, G2V, V2B, V2H., Control Unit, Function of CU, Development Process, Software, Hardware, Data Management, GUI/HMI, Electric Vehicles charging station, Type of Charging station, Selection and Sizing, Components of charging station, Single line diagram, Battery Management System (BMS)/Energy Management System (EMS), Battery charging and discharging calculation, Cell Selection and sizing, Battery lay outing design, Battery Pack Configuration, Construction, Battery selection criteria, Need of BMS, Rule based control and optimization-based control, Software-based high level, Supervisory control, Mode of power, Behavior of motor, Advance Features, Business & Policy, E-mobility business, Electrification challenges, E-mobility business, Electrification challenges, Connected mobility and autonomous mobility, Case study, E-mobility Indian roadmap perspective, EVs in infrastructure system, Integration of EVs in smart grid, Social dimensions of EVs, Overview of national policies.

Course Outcomes:
Upon successful completion of the course, the students will be able
CO1: To know the electric vehicle function and design.
CO2: To evaluate different aspects of design-control.
CO3: To evaluate the challenges of electric vehicle business and policy.
CO4: To analyze and design integration.

Textbooks and References:

1. I. Husain, Electric and Hybrid Vehicles, Boca Raton, CRC Press, 2010.
2. L. James, and J. Lowry, Electric Vehicle Technology Explained, John Wiley and Sons, 2012.
3. T. Muneer and I. Garcia, The automobile, In Electric Vehicles: Prospects and Challenges, Elsevier, 2017.
4. S.W. Sheldon, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Springer, 2013.

Course Name: ENVIRONMENTAL IMPACT ASSESSMENT (EIA)
Course Code: EN- 724
Course Type: Programme Elective

Contact Hours/Week: **4L** Course Credits:**04**

Course Objective:
- To Identify the need to assess and evaluate the impact on environment.
- To understand major principles of environmental impact assessment.
- To understand the different steps within environmental impact assessment.

Course Content

Concepts of Environmental Impact Assessment, Environmental Impacts, Environmental Impact Analysis, Integral Part of the Planning Process, Evolution of EIA, EIA at project regional and policy levels, Strategic EIA, Screening and scoping criteria, Rapid and comprehensive EIA, Specialized areas like environmental health impact assessment, Environmental risk analysis, Economic valuation methods, Cost-benefit analysis, Expert system and GIS applications Uncertainties, Environmental Law, Legislative and environmental clearance procedures in India and other countries, Siting criteria CRZ Public participation, Resettlement and rehabilitation, Practical applications of EIA, EIA methodologies, Baseline data collection Prediction, Assessment of impacts on physical, biological and socio-economic environment, Environmental management plan, Post project monitoring, EIA report and EIS Review process, Case studies on project, Regional and sectoral EIA, Prediction and Methods of Assessment of Impacts on Various Aspects of Environment, Application of various models for the Prediction of impact on Air Environment, Water Environment, Noise Environment and Land Public participation in environmental decision-making process, EIA notification September 2006 and amendments, Categorization of projects, Procedure for getting environmental clearance

Course Outcomes:
Upon successful completion of the course, the students will be able
CO1- To understand the assessing risks posing threats to the environment.
CO2- To access different case studies/examples of EIA in practice.
CO3**- T**o liaise with and the importance of stakeholders in the EIA process.

Textbooks and References:

1. A Chadwick, Introduction to Environmental Impact Assessment, Taylor & Francis , 2007
2. W. Larry, Canter, Environmental Impact Assessment, McGraw Hill, 1996
3. T.B. Fischer & A. González, Introduction to handbook on strategic environmental assessment, Edward Elgar Publishing, 2021.
4. S.A. Morrison, J. Arts, A. Bond, J. Pope, & F.Retief, Reflecting on, and revising, international best practice principles for EIA follow-up, Environmental Impact Assessment Review, 89, 106596, 2021.

Course Name: RENEWABLE ENERGY APPLICATIONS
Course Code: EN- 725
Course Type: Programme Elective

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives :

- To understand the overview of different clean and sustainable energy sources.
- To understand the basic principles and conversion technologies.
- To understand the application of different clean and sustainable energy sources.
- To understand the application of different bio energy resources.

Course Content

Solar Energy, Low cost and efficient Photovoltaic based thermal storage systems for refrigeration in cold storages, Milk chillers and air conditioners, Solar cooking system(chulha) with storage, Wastewater recovery from industrial waste through solar technologies, Innovative in solar thermal technologies for cooling/process heating for Industrial applications, Environmental impact on development of large scale solar power plants or solar parks, Automatic shadow detection via digital image process for solar rooftops, Solar rooftop power plant with plug and play system, High capacity solar pumps, Irrigation systems for hilly regions, Universal Solar Pump Controller (USPC), Sustainable cleaning of PV modules, Innovative Agro PV based solar plants, Re-cycling of PV modules at end of life and processes for segregation/reuse of different components of PV module, Hybrid inverters suitable for Indian Grid, perovskite /organic/multijunction solar cell, Wind Energy: Cost reduction and indigenization of wind turbine components and sub systems, Development of materials, Techniques and technologies for offshore wind energy deployment, Modelling and simulation including high-performance computing (HPC) to improve generation forecasting, Performance analysis, LiDAR installations and Horizontal/Vertical Axis turbine, Off-shore wind installation to power Indian islands as well as drinking water by desalination, Bio Energy: Multi-feed, Pre-treatment and competitive process for biogas production, Temperature control systems for enhancing biogas production, Low-cost technology for biogas purification and bottling and its business modal, Development of multi feed biomass gasifiers for heating and power generation, Innovative technologies for drying of digested slurry of biogas plant, Innovative technologies for co-digestion of waste (biomass/sewage sludge), Production of bio-hydrogen, Small Hydro: Modular turbines with reduced weight and higher conversion efficiency at lower cost, Development of small innovative hydro plants for various applications.

Course Outcome:

Upon successful completion of the course, the students will be able to

CO1: Understand basics of solar PV and its applications

CO2: Understand the basics of Solar thermal Systems

CO3: Design and development of Bio energy, Solar thermal and PV systems

CO4: To evaluate and design small/large Renewable energy based power plants.

Textbooks and References:

1. G. Boyle, Renewable Energy: Power for a Sustainable Future. Oxford University Press, ISBN: 978-0199545339, 2012.
2. C.W. Donovan & R.A. Simmons, Renewable Energy Finance: Powering the Future. World Scientific Publishing, ISBN: 978-1783266999, 2015.
3. V.C. Nelson, Introduction to Renewable Energy, CRC Press, ISBN: 978-1439820409, 2011.
4. B. Sørensen, Renewable Energy: Physics, Engineering, Environmental Impacts, Economics & Planning. Academic Press, ISBN: 978-0123750259, 2010.
5. J.F. Manwell, J.G. McGowan & A.L. Rogers, Wind Energy Explained: Theory, Design and Application. Wiley. ISBN: 978-0470015001, 2002.
6. S.A. Kalogirou, Solar Energy Engineering: Processes and Systems, Academic Press, ISBN: 978-0123745019, 2009.

Course Name: RENEWABLE ENERGY MARKETS
Course Code: EN- 726
Course Type: Programme Elective

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To understand the requirements of renewable Energy into power systems.
- To understand power electronic comports nieces any for Energy production.
- To study the distributed generation systems.

Course Content

System Impacts Of RE Integration On Power Systems, Primary economic effects of RE, Role of forecasts in power economics, Other potentially important effects at local level and aggregated level, Weather fronts and wind/PV(RE) rmps, Challenges And Issues With Re Integration In Markets : Why to integrate RE in Electricity market structure?, Organization of the pool-based electric energy market, Impact of RE in different time frames (Short Term, Long Term), Planning issues with RE, Flexibility, Flexibility resources, Incentivizing flexibility, Intraday and balancing markets, Concepts of Capacity and Flexibility markets, Ancillary Service Markets: Issues with the present market design, Ancillary services recognized in various markets, Ancillary service procurement, Ancillary service auction sequential and simultaneous approach, Automatic generation control, AGC pricing, present practices, Balancing Markets: Need of balancing markets, Impact of RE, Multiple levels of balancing, Day ahead, Intraday and Real Time energy markets, Balancing market auctions, Two price imbalance settlement, Act demand side participation, Impact of Network Constraints, Procurement of Balancing Services, Procurement of Frequency Based Balancing Services, Volume of Frequency Control Balancing Services Required, Allocating the Costs of Balancing Services, System Impacts Of RE Integration On Power Systems : Primary economic effects of RE, Role of forecasts in power economics, Other potentially important effects at local level and aggregated level, Weather fronts and wind/PV(RE)ramps, Flexibility From Distribution System : Evolving vision for the future energy trading, Smart Grid and smart utility, Transition from DNO to DSO and consumers to prosumers, Active distribution system management, Role of Microgrids in future electricity grids, Concepts of Local Energy Transactions, Local Energy Trading: Concepts of VPP, Microgrids and Local electricity market, Energy collective or community markets, Distributed optimization, coordination of distributed energy resources, Role of Aggregator, Peer-to-peer energy market, Re- designing network charges.

Course Outcomes: Upon successful completion of the course, the students will be able

CO1: To recognize the different forms of energy markets to support renewable integration.
CO2: To Compare and analyze how different market designs and regulatory regimes affect the competitive environment, investment behavior and agent profits in energy markets.
CO3:To evaluate the benefits of integrating RE in Electricity market structure
CO4:Understand local energy trading system
CO5:To analyze future electricity grid concepts

Textbooks and References:

1. D.R. Biggar & M.R. Hesamzadeh, The Economics of Electricity Markets. John Wiley & Sons Ltd. ISBN: 9781118775752, 2014.
2. S. Chowdhury, S.P. Chowdhury & P. Crossley, Microgrids and Active Distribution Networks, The Institution of Engineering and Technology, London, United Kingdom, ISBN: 9781849191029, 2009.
3. G. Koutitas & S. McClellan, The Smart Grid as an Application Development Platform. Artech House. ISBN: 9781630811099, 2017.
4. T. Morstyn, N. Farrell, S.J. Darby & M.D. McCulloch, Using peer-to-peer energy-trading platforms to incentivize consumers to form federated power plants, Nature Energy, 3(2), 94, 2018.

Course Name: **LIFE CYCLE ASSESSMENT OF RE SYSTEMS**
Course Code: **EN- 727**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To learn the financial feasibility of any energy project.
- To evaluate the environmental properties of different energy and production systems.
- To learn LCA of renewable energy systems.

Course Content

Importance of Life Cycle Assessment of Renewable Energy Sources, types of life cycle assessments, Procedure for Life Cycle Assessment, Life cycle design, Design strategies, and solution, Evaluation indicators of financial performance, Comparison of different methods, Cost-benefit analysis of projects, Approaches to uncertainty, Life Cycle Costing Economics, Cycle Cost Models, Cost Estimation Methods, Life Cycle Energy Analysis, Concept of embodied energy, Energy analysis methodologies, Process chain analysis, Input-output method, Hybrid inventory analysis, Cumulative energy demand, Energy yield ratio, Energy payback, Specific emission of materials, Life- Cycle Assessment of various renewable energy sources, Case studies, Life Cycle Environmental Analysis, Renewable energy systems and reduction in CO_2 emission, Greenhouse gas calculations, Concept of carbon footprint of materials and systems, Carbon Offsetting and emissions trading, Cumulative emission for renewable energy systems, Environmental indicators RE systems. Concept of decarbonization pathways, Standards & Codes, Alternative approaches for sustainability assessment, LCA software tools and databases, Need and requirement of LCA software, General structure and function, Evaluating LCA software, Reports and result analysis, Future developments, ISO 14040 and ISO 14044 on Life cycle assessment, ISO 14067 on the Carbon footprint of products, ISO 14020, ISO 14021, ISO 14024, ISO 14025, and ISO 14026 on Environmental labels, LCA based labeling and certifications programs.

Course Outcome:
Upon successful completion of the course, the students will be able to
CO1: Evaluate the financial feasibility of any energy project.
CO2: Evaluate the environmental properties of different energy and production systems.
CO3: Conduct LCA of renewable energy systems.
CO4: Understand different tools of LCA.

Textbooks and References:

1. W. Klöpffer & B. Grahl, Life Cycle Assessment (LCA), Wiley-VCH Verlag GmbH & Co, Germany Print, ISBN: 978-3-527-32986-1, 2014.
2. L. Gerber, Designing Renewable Energy Systems: A Life Cycle Assessment Approach” Publisher: EPFL Press, ISBN: 1498711278,9781498711272, 2015.
3. A. Dervishaj & K. Gudmundsson, From LCA to circular design: A comparative study of digital tools for the built environment. Resources, Conservation and Recycling, 200, 107291, 2024.

Course Name: **DECENTRALIZED ENERGY SYSTEMS**
Course Code: **EN- 728**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course objectives:

- To learn rural energy development activities.
- To learn financial estimations of different energy projects for development.

Course Content

Need advantage of decentralized energy systems, Decentralized generation technologies, Costs and choice of technology, Demand, and benefits, Overview of forecasting and program development, Economic and financial analysis of decentralized electrification projects, Decentralized versus Centralized generation, Traditional power systems, Load curves and analysis, Integrated Rural Energy Planning (IREP), Rural electrification, Linkages with rural livelihoods, Rural industries and social development, Efficient/appropriate renewable energy technologies for rural areas, Study on energy potential in study locations, Smart Grid applications, Smart grid communications, Advanced metering infrastructure, Demand response, Energy consumption scheduling, Renewable energy generation based Microgrid, Scope and Challenges, Scope and challenges in implementing off-grid solutions, Policy and regulatory framework for decentralized electricity in India, Integrated Energy Policy, Power for All, Electricity Act, RGGVY, Village Energy Security Program (VESP). Status of grid-connected and off-grid distributed generation (national and International), Case studies on various national and international distributed energy generation systems, Hybrid System and its Use in Decentralized Energy Systems, Hybrid system architectures, Advantages and disadvantages, System components, Control strategies and the use of storage, Demand-side technologies evaluation, Optimal design of hybrid energy systems, Energy economics of integrated energy systems, Sample problems and case studies, Simulation tools Use of efficient enewable energy technologies for rural areas, Technologies/products for cooking, Water heating, Drying, Irrigation pumping, Small/micro-enterprises, lighting etc.

Course Outcomes: Upon successful completion of the course, the students will be able
CO1: To analyse different scopes for rural energy development activities.
CO2: To perform financial estimations of different energy projects.
CO3: To get insight of different national rural energy programs.
CO4: To develop integrated planning model

Textbooks and References:

1. M.H. Bollen & F. Hassan, Integration of Distributed Generation in the Power System, Wiley-IEEE Press, 2011.
2. H. Zerriffi, Rural Electrification: Strategies for Distributed Generation, Springer, 2011.
3. N. Jenkins, G. Strbac & J. Ekanayake, Distributed Generation, The Institution of Engineering and Technology, 2009.
4. A. Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley–IEEE Press, 2011.
5. S. Bhattacharyya, Rural Electrification through Decentralised Off-grid Systems in Developing Countries, Springer, 2013.
6. H. Zerriffi, Rural Electrification: Strategies for Distributed Generation. Springer, 2011.

Course Name: **SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT GOALS**
Course Code: **EN- 729**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course objectives:

- To provide comprehensive understanding on Sustainability.
- To learn the fundamental knowledge about Sustainable Development Goals and sustainability.

Course Content

Origin, History of Sustainable Development Goals (SDGs), Relation to the Millennium Development Goals, Sustainable Development Goals as drivers of sustainable, Health and social initiatives, Assessment of health and environmental beneficence of new ideas to achieve SDGs based on scientific tools, SDGs and Environment: Assessment of community vulnerability and resiliency development to the effects of climate change, Process of identifying and understanding community needs to engage people into participating in achieving the aims of SDGs, Process of using health and environmental benefits of sustainable or social value propositions to strengthen the business cases to help funding activities with innovation and social investors, SDGs and Society: Ensuring resilience and primary needs in society, Analysis of goals related to poverty, Hunger, health & well-being and education, Strengthening Institutions for Sustainability, Analysis of goals related to gender equality, Affordable and clean energy, Sustainable cities, communities, peace, justice & strong institutions, SDGs and the Economy: Shaping a Sustainable Economy, Analysis of goals related to work & economic growth, industry, Innovation & infrastructure, Inequalities, responsible production & consumption, SDGs and the biosphere, Development within planetary boundaries, Analysis of goals related to clean water, climate, life below water and life on land, Implementation through Global partnerships, SDGs through partnerships, finance, technology and the development of coherence between policies, Process of creating social, health or sustainability startups based on SDGs, Community needs and climate change preparedness activities.

Course Outcomes: Upon successful completion of the course, the students will be able
CO1- To understand the development and idea of the UN Sustainable Development Goals
CO2- To identifying and understanding community needs to engage people into participating in achieving the aims of SDGs
CO3- To understand the role of Higher Educational Institutions for realizing the Sustainable Development Goals

Textbooks and References:

1. S. Hazra & A. Bhukta, Sustainable Development Goals, Springer International Publishing, 2020.
2. S.O. Idowu, R. Schmidpeter & L. Zu, The future of the UN sustainable development goals, Springer International Publishing, 2020.
3. H. Confraria, T. Ciarli & E. Noyons, Countries' research priorities in relation to the sustainable development goals. Research Policy, 53(3), 104950, 2024.

Course Name: **CARBON CAPTURE TECHNOLOGIES**
Course Code: **EN- 730**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course objectives:

- To develop and understand different carbon storage methods: storage in coal seams, depleted gas reservoirs and saline formations.

Course Content

Overview of greenhouse gas emissions, Importance of carbon capture in mitigating climate change, Historical context and development of carbon capture technologies, Policy and regulatory landscape, Carbon Capture Technologies, Post-Combustion Capture, Pre-Combustion Capture, Oxy-Fuel Combustion, Direct Air Capture, Reforestation, solid and farming practice, Natural absorption, Biological carbon capture, CO2 Separation Technologies: Absorption, Adsorption, Chemical Looping Combustion, Membrane Separation, Hydrate based separation, Cryogenic distillation, Carbon Storage Techniques, Geological Storage, Ocean Storage, Saline aquifers, Mineralization, Terrestrial Carbon Storage, Depleted oil and gas reservoirs, Risk assessment and safety considerations in storage, Carbon Capture and Utilization (CCU): Production of synthetic fuels such as methane, methanol, or even synthetic aviation fuels, Generation of chemicals and materials like plastics and construction materials, Formation of stable carbonates for use in construction materials, Use of CO2 in the food and beverage industry for carbonation, Social and Environmental Impacts of Carbon Capture:. Community Engagement and Public Perception, Social Equity Considerations, Environmental Benefits, Potential Risks, Policy and Regulatory Frameworks for Carbon Capture, National and International Policies, Carbon Trading, Carbon Pricing Mechanisms and Incentives, Economic considerations in carbon capture and sequestration (CCS): Cost of Carbon Capture, Transportation Costs, Storage Costs, Cost of Monitoring and Verification, Economic Incentives and Policies, Carbon Credit Trading, Project Financing, Operational Efficiency and Scale, Cost-Effectiveness of Carbon Capture Utilization.

Course Outcomes: Upon successful completion of the course, the students will be able

CO1-To understand the impacts of climate change and the measures that can be taken to reduce emissions.
CO2- To understand the carbon capture and carbon storage technologies.
CO3- To understand methods of carbon capture from power generation and industrial processes.

Textbooks and References:

1. A.Stephen, Carbon Capture and Storage, Rackley Elsevier 2010
2. R. Abedini, Carbon Capture, Utilization and Storage: A Comprehensive Introduction, Wiley, ISBN-13: 978-1119267151, 2018
3. Y. Wu & J.J. Carroll, Carbon Capture and Storage: Technologies, Policies, Economics, and Implementation Strategies. Wiley. ISBN-13: 978-0470711669, 2010.

Course Name: **Power Quality**
Course Code: **EN- 731**
Course Type: **Programme Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives:

- To understand the various power quality phenomenon, their origin and monitoring and mitigation methods.
- To understand the effects of various power quality phenomenon in various equipment.

Course Content

Electric power quality phenomena IEC and IEEE definitions, power quality disturbances, voltage fluctuations, transients, unbalance, waveform distortion, and power frequency variations, Voltage variations, voltage sags, short interruptions, flicker-longer duration variations, sources, range, and impact on sensitive circuits, standards, solutions, mitigations, equipment, and techniques, Transients, origin and classifications, capacitor switching transient, lightning, load switching impact on users, protection, mitigation. harmonics, sources, definitions & standards, impacts calculation and simulation, harmonic power flow, mitigation and control techniques, filtering, passive and active, Power quality conditioners, shunt and series compensators, DSTATCOM, dynamic voltage restorer, unified power quality conditioners , Case studies.

Course Outcome: On successful completion of this course, students will understand

CO1: Power quality and the compensation techniques.
CO2: Recognize recent developments in design aspects of renewable power conversion systems.
CO3: Understand the production of Voltage Sags

Textbooks and References:

1. G. T. Heydt, Electric Power Quality, Stars in a Circle Publications, Indiana, 2nd edition 1996.
2. M. H. J. Bollen, Understanding Power Quality Problems, Voltage Sags and Interruptions, IEEE Press, New York, 2000.
3. J. Arrillaga, Watson, N. R., S. Chen, Power System Quality Assessment, Wiley, New York, 2000.
4. R. C. Duagan, M. F. Mcgranaghan and H. W. Beaty, Electric Power System Quality, McGraw-Hill, 2001.
5. N. G. Hingorani and L. Gyugyi, Understanding FACTS, IEEE Press, Delhi, 2001.

Course Name: **ENERGY POLICY, ECONOMICS AND AUDIT**
Course Code: **EN- 701**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To import the knowledge about techniques used in Energy Policy of the Government.
- To apply appropriate economic theory and analyze investment decisions in energy resources.
- To familiarize students with concepts of energy management concepts and tools.
- To learn techniques of finding energy efficiency of various electrical and mechanical utilities.
- To teach them to perform energy audits of industrial units.

Course Content

Energy Scenario, Introduction to Energy and its forms, Units of energy, Energy sources (renewable and non-renewable), Energy consumption trends globally and regionally, Sustainability and Environmental Impact, Global Energy Challenges and Solutions, Policies, Introduction to Energy Policy and Regulatory Framework, Interplay of national and international policies in the energy sector, Policy Formulation Parameters, Renewable Energy Policy, Energy Conservation Act and related policies, Incentives and Subsidies, Foreign Investment in the Energy Sector, Role of MNRE, IREDA, Bio Energy Policy, Solar Policy, Waste Management Practices and Policies, National Green Hydrogen Mission, India EV Policy, Renewable Energy Certificates (RECs), Policies Regarding Smart Cities, Energy Economics, Discount rate, Time Value of Money Concept, Simple Payback Period, IRR, NPV, LCA, Cost of Saved Energy, Cost of Energy generated, CO_2 emissions, Energy management & audit, Energy consumption pattern, Role of Energy manager and Auditor, Material and Energy Balance, Energy Action Planning, Financial Management, Energy Monitoring and Targeting, Energy Efficiency in Thermal Utilities, Energy Efficiency in Electrical Utilities, Energy Performance Assistance in industrial, buildings and commercial establishments.

Course Outcome:

Upon successful completion of the course, the students will be able to
CO1: Appreciate and understand the various energy related policies of governments.
CO2: Calculate payback period, cost of energy generated, life cycle costing etc.
CO3: Evaluate the techno-economic feasibility of the energy conservation technique adopted.
CO4: Apply the knowledge gained to conduct energy audit of an industry/organization.
CO5: Prepare energy audit reports.

Textbooks and References:

1. R. S. Axelrod, & S. D. VanDeveer, The Global Environment: Institutions, Law, and Policy (5th ed.), CQ Press, ISBN: 1544330146, 2019.
2. T. F. Braun & M. G. Lisa, Understanding Energy and Energy Policy, Zed Books, ISBN: 1780329342, 2014.
3. T. C. Kandpal & H. P. Garg, Financial Evaluation of Renewable Energy Technologies, MacMillan India Limited, 2003.
4. R. L. Nersesian, Energy Economics: Markets, History, and Policy, Routledge, ISBN-13: 978-1138858374, ISBN-10: 1138858374, 2016.
5. BEE guidebooks for energy auditor and energy manager exam https://beeindia.gov.in/content/energy-auditors

Course Name: **CARBON CAPTURE AND SUSTAINABILITY**
Course Code: **EN- 702**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To provide comprehensive understanding on Sustainability.
- To learn the fundamental knowledge about Sustainable Development Goals and sustainability.
- To develop and understand different carbon storage methods.

Course Content

Historical development and evolution of carbon capture technologies, Sources of carbon emission, Significance of carbon capture in the context of sustainability, Ethical considerations and the role of carbon capture in climate action, Carbon Capture Technologies: Post-Combustion Capture, Pre-Combustion Capture, Oxy-Fuel Combustion, Direct Air Capture, Reforestation, solid and farming practice, Natural absorption, Biological carbon capture, CO_2 Separation Technologies: Absorption, Adsorption, Chemical Looping Combustion, Membrane Separation, Hydrate based separation, Cryogenic distillation, Carbon Storage Techniques: Geological Storage, Ocean Storage, Saline aquifers, Mineralization, Terrestrial Carbon Storage, Depleted oil and gas reservoirs, Risk assessment and safety considerations in storage, Carbon Capture and Utilization (CCU): Production of synthetic fuels such as methane, methanol, or even synthetic aviation fuels, Generation of chemicals and materials like plastics and construction materials, Formation of stable carbonates for use in construction materials, Use of CO_2 in the food and beverage industry for carbonation, Social and Environmental Impacts of Carbon Capture:. Community Engagement and Public Perception, Social Equity Considerations, Environmental Benefits, Potential Risks, Policy and Regulatory Frameworks for Carbon Capture, National and International Policies, Carbon Trading, Carbon Pricing Mechanisms and Incentives.

Course Outcomes:

On successful completion of this course, students will be able to
CO1: To understand the impacts of climate change and the measures that can be taken to reduce emissions.
CO2: To understand the carbon capture and carbon storage technologies.
CO3: To identify and understand community needs to engage people into participating in achieving the aims of SDGs.
CO4: Apply Ethical and Sustainable Practices

Textbooks and References:

1. H. J.Herzog, Carbon Capture: A Technology Assessment, Routledge. ISBN-13: 978-1138666566, 2016.
2. Y. Wu & J.J. Carroll, Carbon Capture and Storage: Technologies, Policies, Economics, and Implementation Strategies. Wiley. ISBN-13: 978-0470711669, 2010.
3. T, Hunter & K. L Bubna, Carbon Capture and Storage: Emerging Legal and Regulatory Issues. Routledge. ISBN-13: 978-0415675937, 2012.
4. H. J. Herzog, Introduction to Carbon Capture and Sequestration. Imperial College Press. ISBN-13: 978-1848167364, 2010.
5. Carbon Capture and Storage Stephen A. Rackley Elsevier 2010
6. R. Abedini, Carbon Capture, Utilization and Storage: A Comprehensive Introduction, Wiley, ISBN-13: 978-1119267151, 2018

Course Name: **EMERGING RENEWABLE ENERGY TECHNOLOGIES**
Course Code: **EN- 703**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- Highlight ongoing research and development efforts in the field of renewable energy.
- Evaluate the environmental benefits and challenges associated with emerging technologies.
- Explore future trends and developments in renewable energy technologies.

Course Content

Introduction to Solar Photovoltaics and Solar Thermal, Perovskite Solar Cells, Tandem Solar Cells, Bifacial Solar Panels, Flexible and Transparent Solar Panels, Solar Paint, Floating Solar Farms, Solar Desalination, Concentrated Solar Power (CSP) Systems, Next-Generation Solar Collectors, Next-Generation Solar Collectors, Small-Scale and Distributed Solar Thermal, Hybrid Systems, Energy Storage: Advanced Battery Technologies, Solid-State Batteries and their Potential, Flow Batteries: Concepts and Applications, Hydrogen Energy Storage: Technologies and Challenges, Ocean Energy and Geothermal Innovations: Tidal and Wave Energy: Harnessing Ocean Power, Ocean Thermal Energy Conversion (OTEC), Enhanced Geothermal Systems (EGS), Closed-Loop Geothermal Systems, Smart Grid Technology: Grid Integration of Renewable Energy, Demand Response Systems, Smart Grid Communication Technologies, Cybersecurity in Smart Grids, Hybrid Renewable Systems: Integrating Multiple Renewable Sources, Microgrid Design and Implementation, Case Studies of Successful Hybrid Systems, Bioenergy Advances: Advanced Biofuels and Feedstocks, Anaerobic Digestion for Energy Production, Biomass Gasification Technologies, Carbon Capture and Utilization in Bioenergy, Wind Power Advances: Floating Wind Turbines, Vertical Axis Wind Turbines (VAWT), Wind Farm Planning and Optimization, Wind Power and Wildlife Conservation, Hydrogen Energy: Hydrogen Production Technologies, Hydrogen Storage and Transportation, Fuel Cells and Hydrogen Utilization, Hydrogen in Industry and Power Generation, Hydrogen in Transportation, Global Hydrogen Economy and Policies, Research and Innovation in Hydrogen Energy, Electric Vehicle: Introduction to Electric Vehicles, Electric Vehicle Components, Charging Infrastructure, Energy Management and Efficiency, Electric Vehicle Integration in Transportation, Advanced Electric Vehicle Technologies.

Course Outcome:

Upon successful completion of the course, the students will be able to

CO1: Well-rounded skill set and knowledge base that prepares them to contribute to the advancement and application of emerging renewable energy technologies in real-world scenarios.

CO2: Analyze Energy Storage Systems

CO3: Evaluate and implement energy efficiency technologies in various contexts.

CO4: Develop and design hybrid renewable energy systems.

Textbooks and References:

1. A. Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley–IEEE Press, 2011.
2. D.P. Kothari, K.C.Singal, R.Ranjan, Renewable Energy Sources And Emerging Technologies, PHI Learning Pvt. Ltd., 2009.
3. P.S. Fox-Penner, Smart Power: Climate Change, the smart Grid, and the Future of Electric Utilities, 2010.
4. IEA (International Energy Agency) - "Renewables 2021 Global Status Report"