Course Structure & Syllabus
M.Tech Energy Studies (Energy Technology)

w.e.f. Academic Session (2023-2024) onwards

Centre for Energy Studies
National Institute Of Technology
Hamirpur (H.P)-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

Eligibility Criteria

Candidates having BE/B.Tech/M.Sc/Equivalent from a recognized university in relevant discipline
Bachelor's Degree in Electrical/ EC/ Mechanical/ Chemical/Renewable Energy/ Energy/ Environmental science and Engineering/ Instrumentation Engineering/Mining/Petroleum/Production and Industrial Engineering/Agriculture/Biotechnology/ Civil or any other branch with a valid GATE score in any of the engineering disciplines are eligible for admission.
Candidates with M.Sc degree in Physics / Chemistry / Material Science/ Agricultural/ Microbiology/Electronics
Bachelor degree or equivalent degree in appropriate branch of Engineering / Technology of minimum four years duration.
Master degree in Sciences with 3yrs Bachelor degree in relevant subject will be equivalent to B.Tech in Engineering.
For admission in Master Programme the applicant must have CGPI of 6.5 on a 10-point scale (or equivalent) or 60% marks in case of Open/EWS/OBC-NCL candidates in qualifying degree. Whereas in case of SC/ST candidates, a CGPI of 6.0 on a 10-point scale (or equivalent) or 55% marks in qualifying degree shall be applicable.
The eligibility conditions given above shall be considered the absolute minimum.
Centre shall reserve the right to prescribe any requirements over and above these, subject to the approval of the SENATE.

ACADEMIC CURRICULUM
Course Structure
M.Tech Energy Studies (Energy Technology)
w.e.f. Academic Session 2023-2014 Onwards

Semester-I

S. No.	Course Code	Course Title	Teaching Schedule			Hour/ Week	Credit
			L	T	P		
1	EN- 601	Solar Photovoltaic Systems	4	0	0	4	4
2	EN- 602	Energy, Climate & Sustainability	4	0	0	4	4
3	EN- 603	Wind Energy Systems	4	0	0	4	4
4	EN- 701	Programme Elective-I	4	0	0	4	4
5	EN- 702	Programme Elective-II	4	0	0	4	4
6	EN- 604	Energy Laboratory-I	0	0	4	4	2
Total			20	0	4	24	22

Programme Elective-I & II: List of Programme Electives is given in the Annexure.

Semester-II

S. No.	Course Code	Course Title	Teaching Schedule			Hour/ Week	Credit
			L	T	P		
1	EN- 605	Solar Thermal Energy systems	4	0	0	4	4
2	EN- 606	Bioenergy systems and Biofuels	4	0	0	4	4
3	EN- 607	Energy Management and Audit	4	0	0	4	4
4	EN- 7MN	Programme Elective-III	4	0	0	4	4
5	EN-7MN	Programme Elective-IV	4	0	0	4	4
6	EN-608	Energy Laboratory-II	0	0	4	4	2
Total			20	0	4	24	22

Programme Elective-I & II: List of Programme Electives is given in the Annexure.

Semester-III

S. No.	Course Code	Course Title	Hours/Week	Credit
1.	EN-800	M.Tech Dissertation	---	20

Semester-IV

S. No.	Course Code	Course Title	Hours/Week	Credit
1.	EN-800	M.Tech Dissertation	---	20

Total Credit of the Program = 84

List of Programme Elective Courses
M.Tech Energy Studies (Energy Technology)

Programme Elective-I

S. No.	Subject Code	Course Title	Elective	Credits
1.	EN- 701	Energy Storage Technology	**Elective-I**	4
2.	EN- 702	Smart Grid Systems	**Elective-I**	4
3.	EN- 703	Waste to Energy	**Elective-I**	4
4.	EN- 704	Hydrogen Energy Technology	**Elective-I**	4
5.	EN- 705	Energy Economics and Policies	**Elective-I**	4

Programme Elective-II

S. No.	Subject Code	Course Title	Elective	Credits
1.	EN- 706	Biofuels conversion processes	**Elective-II**	4
2.	EN- 707	Alternative Fuels	**Elective-II**	4
3.	EN- 708	Circular Economy	**Elective-II**	4
4.	EN- 709	Materials for Energy & Applications	**Elective-II**	4
5.	EN- 710	Sustainable Buildings	**Elective-II**	4

Programme Elective-III

S. No.	Subject Code	Course Title	Elective	Credits
1.	EN- 711	Hydro Energy Systems	**Elective-III**	4
2.	EN- 712	Modelling and Optimization of Energy Systems	**Elective-III**	4
3.	EN- 713	Hybrid Electric Vehicle	**Elective-III**	4
4.	EN- 714	Renewable Energy Applications	**Elective-III**	4
5.	EN- 715	Environmental Impact Assessment	**Elective-III**	4

Programme Elective-IV

S. No.	Subject Code	Course Title	Elective	Credits
1.	EN- 716	Renewable Energy Markets	**Elective-IV**	4
2.	EN- 717	Life cycle assessment of RE systems	**Elective-IV**	4
3.	EN- 718	Decentralized Energy Systems	**Elective-IV**	4
4.	EN- 719	Sustainability and Sustainable Development Goals	**Elective-IV**	4
5.	EN- 720	Carbon Capture Technologies	**Elective-IV**	4

Course Name: **SOLAR PHOTOVOLTAIC SYSTEMS**
Course Code: **EN- 601**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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:

Introduction to Solar PV:

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 1st,2ndand 3rdgeneration of PV technologies: Fabrication, Manufacturing process, Working principle and performance of different photovoltaic cells/modules,

Balance of systems:

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.

Solar PV power plant:

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.

Standards &Testing:

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,

Different Applications:

Application, future trend of use, PV water pumping, Application to building 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

References

1. Solar Photovoltaics: Fundamentals, Technologies and Applications by Chetan Singh Solanki, Prentice Hall India, 3rd Edition. ISBN 9788120351110
2. Terawatt Solar Photovoltaics, Roadblocks and Opportunities Edited by M. Tao, Springer, 2014 edition. ISBN 978-1-4471-5643- 7
3. Handbook of Photovoltaic Science and Engineering, Edited by A. Luque and S. Hegedus, John Wiley & Sons, Ltd, 2012 edition. ISBN 978-0- 470-72169- 8

Course Name: **ENERGY, CLIMATE & SUSTAINABILITY**
Course Code: **EN- 602**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

Course Objectives

- To impart knowledge about the renewable energy and impacts on climate.
- To introduce the fundamental concepts relevant to energy sector and climate change.
- To enable the students to understand the relevance of sustainability in terms of 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 foot print, 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 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

References:

1. IPCC: *Climate Change 2014: Impacts, Adaptation and Vulnerability*, Cambridge University Press,https://doi.org/10.1017/CBO9781107415379
2. UNDP New York, 2000, *World Energy Assessment: Energy and the Challenge of Sustainability*, ISBN: 92-1-126126-
3. Peak and Joe Smith, *Climate Change: From science to sustainability*, Oxford University Press
4. NebojsaNakicenovic, ArnulfGrubler and Alan McDonald *Global energy perspectives*, Cambridge University Press, 1998Fowler, J.M., *Energy and the environment*, 2nd Edn., McGraw Hill, New York, 1984

Course Name: **WIND ENERGY SYSTEMS**
Course Code: **EN- 603**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

Course Objectives

- To learn basics of wind energy systems and resource assessment techniques.
- To learn aerodynamics ad 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, etc.

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.

References:

1. Freris L.L., Wind Energy Conversion Systems, ISBN 978-0139605277 Prentice Hall 1990.
2. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, 1994.
3. Johnson, G.L., Wind Energy Systems, Prentice Hall, ISBN 978-0139577543, 1985.
4. James F. Manwell, Jon G. McGowan, Anthony L. Rogers, Wind Energy Explained: Theory, Design and Application 2nd Edition, Wiley ISBN: 978-0470015001, 2010.
5. Paul Gipe, Wind Energy for the Rest of Us: A Comprehensive Guide to Wind Power and How to Use it, Chelsea Green Publishing Co; Com edition (12 December 2016) ISBN 978-0997451818.

Course Name: **SOLAR THERMAL ENERGY SYSTEMS**
Course Code: **EN- 605**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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.

References:

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

Course Name: **BIOENERGY SYSTEMS AND BIOFUELS**
Course Code: **EN- 606**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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

Introduction:

Biomass: 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 – 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 utilisation, 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.

References:

1. Capareda S, Introduction to biomass energy conversion, CRC Press. ISBN: 978-1-466-51333-4
2. Brown RC and Stevens C, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Wiley and Sons. ISBN: 978-0-470-72111-7
3. Vaughn C. Nelson, Kenneth L. Starcher, Introduction to Bioenergy (Energy and the Environment), CRC Press. ISBN: 978-1-498-71698-7
4. Yebo Li and Samir Kumar Khanal, Bioenergy: Principles and Applications, Wiley-Blackwell. ISBN: 978-1-118-56831-
5. Ted Weyland, Bioenergy: Sustainable Perspectives, Callisto Reference. ISBN: 978-1-632-39633-4 Video links:https://nptel.ac.in/noc/individual_course.php?id=noc18-bt15
   https://www.youtube.com/watch?v=fR0chD3Ob1M

Course Name: **ENERGY MANAGEMENT AND AUDIT**
Course Code: **EN- 607**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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.

References:

1. Guide to Energy management, by Barney L.Capehart, Wayne C.Turner, and William J.Kennedy, The 10airmont press, INC. Fourth edition
2. http://www.nptelvideos.in/2012/11/energy-resources-and-technology.html
3. Bhattacharyya, Subhes C. Energy economics: concepts, issues, markets and governance. Springer Science & Business Media, 2011, ISBN 978-0-85729-268-1.
4. Energy Demand – Analysis, Management and Conservation,Ashok V. Desai, Wiley Eastern Ltd., New Delhi.,1990, ISBN 9788122402025.
5. Handbook of Energy Audits by Albert Thumann. CRCpress 9th ed.
6. BEE guide books for energy auditor and energy manager exam https://beeindia.gov.in/content/energy-auditors

Course Name: **ENERGY LABORATORY-I**
Course Code: **EN- 604**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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 Sun shine 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.

Course Name: **ENERGY LABORATORY-II**
Course Code: **EN- 608**
Course Type: **Core Course**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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.

Course Name: **ENERGY STORAGE TECHNOLOGY**
Course Code: **EN- 701**
Course Type: **Elective-I**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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

I**ntroduction**: Energy storage technology, requirement for energy storage, Current status, electricity storage services and benefits, cost performance and maturity of storage technology, methods and tools for evaluation of storage, future prospect of storage.

Electrochemical Energy Storage: lead acid battery, Li ion battery, Ni metal hydride battery, Flow Battery, Capacitor etc. Comparison, Ragone plot and state-of-art application, their function and deployments. Technical characteristics, battery states and their estimation methods, battery-based hybrid storage system, battery aging. Performance characteristics, testing, safety, standards and system sizing for mobile and stationary application, operation with renewable systems. Introduction of battery management system, battery thermal management, requirement of battery storage integration. Case study/project.

Thermal energy Storage (TES) Methods - Sensible TES, Passive and active systems. Main means of accumulation, Importance of thermal stratification, Strategies to enhance the thermal stratification - Latent TES Selection of phase change materials depending on the application. Types of storage systems by change of phase, - Cold TES - Seasonal TES - Characteristics of heat storage materials. Design and operation of thermal storage systems - Performance characteristics, testing, safety, standards and system sizing, Energy conservation using TES - Energy and Energy Analyses of TES Systems - Energy savings by TES, Case study/project.

Mechanical Energy Storage Systems: flywheel energy storage (FES), pumped hydropower storage (PHS), and compressed-air energy storage (CAES). Comparison and application state-of-art including principle, function and deployments. Performance characteristics, testing, safety, standards and system sizing. Case study/project based on mechanical energy storage.

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

References:

1. Christopher D. Rahn and Chao-Yang Wang, Battery system engineering, Wiley, 2013, ISBN: 9781119979500
2. DOE/EPRI Electricity Storage Handbook, U.S. Department of Energy and the Electric Power Research Institute in collaboration with the National Rural Electric Cooperative Association.
3. Frank S Barnes, John G Levine, Large Energy Storage Systems Handbook. CRC press 2011, ISBN 9781420086003
4. Robert Huggins, Energy Storage, Springer Nature; 2nd ed. 2016 edition ISBN 3319212389
5. Ibrahim Dincer and Marc A. Rosen, Thermal energy storage systems and applications, ISBN:9780470747063, 2nd edition, 2011.
6. Luisa F. Cabeza, Advances in Thermal Energy Storage Systems: Methods and Applications, Woodhead Publishing, ISBN-13: 978-1782420880, 2014

Course Name: **SMART GRID SYSTEMS**
Course Code: **EN- 702**
Course Type: **Elective-I**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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, Definitions ,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), 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.

References:

1. Stuart Borlase , Smart Grid: Infrastructure, Technology and Solutions, CRC Press 2012, ISBN 9781439829059.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, Smart Grid: Technology and Applications, Wiley, 2012, Print ISBN:9780470974094 |Online ISBN:9781119968696.
3. Mini S. Thomas, John D McDonald, Power System SCADA and Smart Grids, CRC Press, 2015, ISBN-13: 978-1482226744.
4. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, Communication Networks for Smart Grids, Springer, 2014, ISBN 978-1-4471-6302-2.
5. Henrik Lund, "A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions" Academic Press, ISBN: 9780124104235.

Course Name: WASTE TO ENERGY
Course Code: EN- 703
Course Type: Elective-I

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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:

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.

References:

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

Course Name: **HYDROGEN ENERGY TECHNOLOGY**
Course Code: **EN- 704**
Course Type: **Elective-I**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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 the knowledge of various fuel cell technology.
- To understand and apply codes and standards related to hydrogen safety.

Course Content

Introduction to Hydrogen Energy: Global scenario, Uses for Hydrogen, Prospects, Prognosis and Future for Hydrogen energy, challenges. Production of Hydrogen: from Fossil fuels, synthetic fuels. Electrolysis of water, Using Solar energy:

Transportation, Distribution and Storage : Strategic Considerations, Distribution and Bulk Storage of Gaseous, Dewars for transport applications Gas Cylinders, Pipelines, Large-scale Storage, Metal Hydrides, Chemical and Related Storage, Simple Hydrogen-bearing Chemicals, Complex Chemical Hydrides, Nano-structured Materials, Hydrogen Storage in Road Vehicles, Industrial scale pressurized hydrogen storage

Hydrogen as a Fuel in Heat Engines: Stationary and powering vehicles in road transport and aviation industry, Hydrogen energy, Hydrogen as a fuel, Liquid and Gaseous Fuels. Physico-chemical characteristics. Efficiency calculations and fuel consumption, Internal combustion engines and aircraft. Hydrogen-fuelled Transportation

Metering, Instrumentation and Safety Issues: Hydrogen gas and Liquified hydrogen properties and associated hazards - Safety regulations - Codes and Standards - Physiological, physical and chemical hazards of hydrogen, Safety of hydrogen storage facilities - Effects of Hydrogen on Materials of Construction - Hydrogen Embrittlement - Loss of Thermal Stability. Hydrogen use in vehicles - Onboard vehicle hydrogen storage and safety - Hydrogen Fueling of Vehicles - Case studies

Fuel Cell Systems: basic principles and classification; proton exchange membrane fuel cell, fuel cell poisoning. Reversible and irreversible losses, efficiency of FC. Fuel Crossover/Internal Current Losses, Ohmic Losses, Mass Transport /Concentration Losses.System integration; Power management, Thermal management, Fuel cell system design, application of fuel cells to automotive sectors. Case study/project.

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

References:

1. Angelo Basile, Adolfo Iulianelli (Editors), Advances in hydrogen production, storage and distribution, ISBN 978-0-85709-768-2, 2014 Elsevier Ltd.
2. Broom, Darren P, Hydrogen Storage Materials: The Characterisation of Their Storage Properties, 2011, ISBN 978-0-85729-221-6, Springer
3. Arno A. Evers, 2010. The Hydrogen Society. HydrogeitVerlag. ISBN 978-3-937863-31-3.
4. Vladimir Molkov, Fundamentals of hydrogen safety engineering - I, Bookboon.com, ISBN 978-87-403-0226-4
5. Vladimir Molkov, Fundamentals of hydrogen safety engineering - II, Bookboon.com, ISBN 978-87-403-0279-0

Course Name: **ENERGY ECONOMICS AND POLICIES**
Course Code: **EN- 705**
Course Type: **Elective-I**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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:
Introduction, sector wise consumption of energy resources: Electricity, Fuel, Transportation, Energy Scenario of different sectors: Indian and International Level – 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 - Concept, 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, Electricity Act 2003 and amendments, 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 – 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.

References:

1. SC Bhattacharyya. Energy Economics, Concepts, Issues, Markets and Governance, Springer Science & Business Media, (2011) ISBN 978-0-85729-268-1.
2. RS Axelrod & SD VanDeveer (Eds.). The Global Environment: Institutions, Law, and Policy. CQ Press; Fifth edition (2019). ISBN 1544330146
3. TF Braun & MG Lisa. Understanding Energy and Energy Policy. Zed Books, (2014) ISBN 1780329342
4. Kandpal, Tara Chandra, and HariPrakashGarg. Financial evaluation of renewable energy technologies. MacMillam India Limited, 2003.
5. Nersesian, Roy L. *Energy economics: markets, history and policy*. Routledge, 2016, ISBN-13: 978-1138858374, ISBN-10: 1138858374.
6. Zweifel, Peter, Aaron Praktiknjo, and Georg Erdmann. *Energy economics: theory and applications*. Springer, 2017, ISBN 978-3-662-53022-1.

Course Name: **BIOFUELS CONVERSION PROCESSES**
Course Code: **EN- 706**
Course Type: **Elective-II**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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

Thermochemical Conversion of Biomass to Biofuels: Introduction; 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: The Feedstock And The Process And Their Constraints; 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

Chemical Conversion:
Chemical conversionof syngas to methanol and ethanol and some advanced fuels like bio butanol, 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 Waste water 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.

References:

1. Edited by Robert C. Brown © 2011 *Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals and Power*, First Edition . John Wiley & Sons, Ltd. Published 2011 by John Wiley & Sons, Ltd. ISBN: 978-0-470-72111-7
2. *Worldwatch Institute* London, Biofuels for Transport Global Potential and Implications for Sustainable Energy and Agriculture ISBN 9781138964693, Published 2016 by Routledge
3. Anthony San Pietro, *Biochemical and Photosynthetic aspects of Energy Production*, Academic Press, New York, 1980;
4. R.C. Maheswari, *Bio Energy for Rural Energisation*, Academic press, New York, 2000;
5. Bent Sorensen, *Renewable Energy* Concepts Publication, 1997
6. Thomas B. Johansson (et.al.) (Ed).*Renewable energy: sources for fuels and electricity*,Earthscan Publishers, London1993.
7. Dr.SemidaSilveira , *Bioenergy - Realizing The Potential* Elsevier, Jul-2005

Course Name: **ALTERNATIVE FUELS**
Course Code: **EN- 707**
Course Type: **Elective-II**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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

Introduction: I.C. Engine, and SI engines, Gasoline and diesel self-ignition characteristics of the fuel, Octane number, Cetanenumber, 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 Green house effect , global warming, Exhaust gas emission effect on environmental ,N2 , CO2, CO, NOx, SO2, O2 pollution, Global Carbon Budget, Carbon foot print and Carbon credit calculations. Emission norms as per Bharat Standard up to BS – IV and procedures for confirmation on production.

Alcohol: 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 Diesels: 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 Diesel blended with vegetable oil, and difference in performance of Engine. Biogas: 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: Hydrogen as a substitute fuel. Study Properties, Sources and methods of Production of Hydrogen, Storage and Transportation of hydrogen. Also, the economics of Application 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

Others: 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.

References:

1. Richard.L. Bechtold- Alternative Fuels Guide Book- SAE International Warrendale-1997.
2. Thipse.S.S., Alternative Fuels; Concepts, Technologies and Developments, Jaico Book Distributors, 2010
3. GajendraBabu, M. K. and Subhramanian, K. A., Alternative Transportation Fuels, CRC Press, 2013
4. MaheswarDayal- Energy today & Tomorrow-I&B Horishr India_1982.

Course Name: **CIRCULAR ECONOMY**
Course Code: **EN- 708**
Course Type: **Elective-II**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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:
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 and Critical assessment on current sustainable technologies. Material management, Circular economy towards zero waste: circular economy and waste sector, waste management in the context of circular economy

Business models:
Circular bioeconomy, Circular Business Models. The 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,

Policy :
Circular economy policy framework, universal circular economy policy goals, role of governments and networks and 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

References:

1. The Circular Economy A User's Guide by Walter R Stahel. CRC Press 2019.
2. The Circular Economy Handbook: Realizing The Circular Advantage by Peter Lacy,Jessica Long, WesleySpindler. 2020.
3. Waste to Wealth: The Circular Economy Advantage Peter Lacy, JakobRutqvist, 2015.
4. Towards Zero Waste: Circular Economy Boost, Waste to Resources María-Laura
5. Franco-García, Jorge Carlos Carpio-Aguilar, Hans Bressers. Springer InternationalPublishing 2019
6. Strategic Management and the Circular Economy Marcello Tonelli, NicoloCristoni,Routledge 2018.

Course Name: **MATERIALS FOR ENERGY & APPLICATIONS**
Course Code: **EN- 709**
Course Type: **Elective-II**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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: introduction of nanotechnology, 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 cell. 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

References:
1. Advanced Techniques for Materials Characterization: A. K. Tyagi, M. Roy, S. K. Kulshrestha, S. Banerjee (Materials Science Foundations-Trans Tech Publications).
2. Nanostructures and Nanomaterials Synthesis, Properties and Applications: G. Cao (Imperial College Press-2006).
3. Nanotechnology for the energy challenge: Javier Garcia-Martinez (WILEY- VCH)
4. Fuel cell technology handbook :Hoogers (CRC Press).

Course Name: **SUSTAINABLE BUILDINGS**
Course Code: **EN- 710**
Course Type: **Elective-II**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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, over view 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

Standards and Ratings:
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, 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.

References:

1. Kubba, S, LEED Practices, Certification, and Accreditation Hand book, 1st ed. Elsevier, 2010.
2. Minsitry of Power, Energy Conservation Building Code 2018, Revised Version, Bureau of Energy Efficiency, 2018,
3. Architectural Energy Corporation, Building Envelope Stringency Analysis, International Institute for Energy Conservation, 2004
4. Indian Building Congress, Practical Handbook on Energy Conservation in Buildings, 1 st ed. Nabhi Publication, 2008.
5. McQuiston, F.C., and Parker, J.D. Heating, Ventilating, and Air Conditioning, Analysis and Design, Fourth Ed. John Wiley & Sons, Inc,1994.
6. Clarke, J.A., Energy Simulation in Building Design, Adam Hilger Ltd. 1985.
7. TERI-Griha's Green Design practices (www.teriin.org/bcsd/griha/griha.html)

Course Name: **HYDRO ENERGY SYSTEMS**
Course Code: **EN- 711**
Course Type: **Elective-III**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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

Hydropower Basics:
Water Cycle in Nature, Classification of Hydropower Plants, Status of Hydropower Worldwide, Advantages and Disadvantages of Hydropower, Hydro potential and exploitation in India, small/mini/micro hydel Power Projects , Major hydroelectric Power Plants in India, Operational Terminology, Legal Requirements

Working Principles & Structural Parts:
Locating a Hydropower Plant, Basics of Fluid Mechanics for hydro power, single and multiple reservoir system, cascaded power plants Structural parts of Hydropower Station: Dam and Spillway, Surge Chambers, Stilling Basins, Penstock and Spiral Casing, Tailrace, Pressure Pipes, Caverns, auxiliary parts.

Hydroelectric Equipment:
Types of hydroelectric equipment:, characteristics and testing of ac generators; Sizing and specification of single and three phase generators ; Power factor and its correction methodologies, excitation systems; Electro-mechanical and digital governor, electronic load controller ; Types of relays, contactors and control schemes for hydro power stations,; Supervisory control and data acquisition (SCADA), integrated computer control system for hydro station; Switchyard equipments, power and instrument transformers, circuit breakers, bus-bar; Protection schemes for generator, transformer and bus-bar, design of circuit diagram for auxiliary and grounding systems

Hydro Turbines:
Classification and working principles of hydro turbines, different components of impulse and reaction turbines; Design concepts of hydro turbines, pump-as-turbine and other nonconventional hydro turbines; Characteristics of hydro turbines, geometric similarity, main characteristic and operating characteristic curves, hill curves; Governing of hydro turbines, mechanical and electro-mechanical governors, electronic load controller, mechanical drives,; Selection of hydro turbines based on specific speed and their optimal selection; Classification, components and selection of gates and valves; Model testing of hydro turbines, performance testing of turbines at site; Causes and impact of cavitation, silt erosion and their combined effect; Erection, commissioning, operation and maintenance of turbines

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.

References:

1. Brown, G., “Hydro-electric Engineering Practice”, Vol. I, II & III, CBS Publication
2. Nigam, P.S., “Hand book of Hydroelectric Engineering”, Nem Chand and Brothers
3. Clemen, D.M., “Hydro Plant Electrical Systems”, HCI Publication http://www.nptelvideos.in/2012/11/energy-resources-and-technology.html

Course Name: **MODELLING AND OPTIMIZATION OF ENERGY SYSTEMS**
Course Code: **EN- 712**
Course Type: **Elective-III**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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.

Optimization:

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 & DoE:

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:

Introduction to energy demand Forecasting : 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.

References:

1. J. Randolph and G. M. Masters, Energy for Sustainability: Technology, Planning, Policy, Island Press, 2018, ISBN-13: 978-1597261036.
2. M. Munasinghe and P. Meier, Energy Policy Analysis and Modeling, Cambridge University Press, 1993, ISBN:9780511983573.
3. Bhattacharyya, Subhes C. *Energy economics: concepts, issues, markets and governance*. Springer Science & Business Media, 2011, ISBN 978-0-85729-268-1.
4. Adrian Bejan,GeorgeTsatsaronis, Michael Moran, Thermal Design and Optimization, John Wiley, 1995, ISBN: 978-0-471-58467-4.
5. Y. Jaluria, Design and Optimization of Thermal Systems, 2e, CRC Press, 2008, ISBN 9781498778237.
6. W.F. Stoeker, Design of Thermal Systems, 3e, McGraw Hill, 2011, ISBN 10:125900239X / ISBN 13:9781259002397.
7. C. Balaji, Essentials of Thermal System Design and Optimization, ANE books, 2011, ISBN 13: 9781439891544.
8. Fabio De Bellis, "Energy Systems Simulation and Optimization", Lambert academic, ISBN-13: 978-3848420216.

Course Name: **HYBRID ELECTRIC VEHICLE**
Course Code: **EN- 713**
Course Type: **Elective-III**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

Course Objective:

- To learn the operation of different electric vehicle.
- 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 and 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, Business- 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.

References:

1. Emadi, A. (Ed.), Miller, J., Ehsani, M., "Vehicular Electric Power Systems" Boca Raton, CRC Press, 2003.
2. Husain, I. "Electric and Hybrid Vehicles" Boca Raton, CRC Press, 2010.
3. Larminie, James, and John Lowry, "Electric Vehicle Technology Explained" John Wiley and Sons, 2012.
4. Tariq Muneer and Irene IllescasGarcía, "The automobile, In Electric Vehicles: Prospects and Challenges", Elsevier, 2017.
5. Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 2013.

Course Name: ENVIRONMENTAL IMPACT ASSESSMENT (EIA)
Course Code: EN- 714
Course Type: Elective-III

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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

Introduction:
Concepts of Environmental Impact Assessment, Environmental Impacts; Environmental Impact Analysis; Environmental, Impact Assessment and Environmental Impact Statement; EIA- As An Integral Part of the Planning Process

Evolution of EIA:
EIA at project Regional and policy levels, Strategic EIA : EIA process 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 and 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.

Assessment of Impacts:
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- To liaise with and the importance of stakeholders in the EIA process.

References:

1. A Chadwick, Introduction to Environmental Impact Assessment, Taylor & Francis , 2007
2. Larry W. Canter, Environmental Impact Assessment, McGraw Hill Inc. Singapore , 1996
3. R.Therirvel, E. Wilson, S. Hompson, D. Heaney, D.Pritchard, Strategic Environmental Assessment, Earthscan, London , 1992
4. Paul, A Erickson, A Practical Guide to Environmental Impact Assessment, Academic Press , 1994

Course Name: RENEWABLE ENERGY APPLICATIONS
Course Code: EN- 715
Course Type: Open elective

Prerequisite: Nil

L	T	P	C
4	0	0	4

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.

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, waste water recovery from industrial waste through solar technologies, innovative 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 and 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, and 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 cost 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 plant 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.

Text and Reference Books:

1. Energy Thermodynamics by P.K. Nag, Tata McGraw-Hill.
2. Solar Energy- Principles of thermal collection and storage by SP Sukhatme, Tata McGraw-Hill, New Delhi.
3. Solar Engineering of Thermal Processes by JA Duffie and WA Beckman, John Wiley, NY.
4. Heat Transfer by I.ncropera, Tata McGraw- Hill.
5. A Text Book in Electrical Technology by Theraja B. L. and Theraja A. K., S. Chand and Co.
6. Generation, Distribution and Utilization of Electrical Energy by Wadhwa C. L.; New Age International
7. Basic Electrical Engineering by Kothari D. P. and Nagrath I., McGraw Hill, India
8. Fluid Flow by White F.M. Viscous, McGraw-Hill New York

Course Name: **RENEWABLE ENERGY MARKETS**
Course Code: **EN- 716**
Course Type: **Elective-IV**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

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, Activdemandside 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

References:

1. Darryl R. Biggar and Mohammad Reza Hesamzadeh, The Economics of Electricity Markets, John Wiley & Sons Ltd, 2014, ISBN:9781118775752.
2. S. Chowdhury, S.P. Chowdhury and P. Crossley, Microgrids and Active Distribution Networks, The Institution of Engineering and Technology, London, United Kingdom, 2009, ISBN: 9781849191029.
3. Koutitas, George, and Stan McClellan. The Smart Grid as an Application Development Platform, Artech House, 2017, ISBN: 9781630811099.
4. T. Morstyn, N. Farrell, S. J. Darby, and M.D. McCulloch, "Using peer-to-peer energy-trading platforms to incentivize consumers to form federated power plants," in Nature Energy, vol. 3, no. 2, pp. 94, Feb 2018.

Course Name: **LIFE CYCLE ASSESSMENT OF RE SYSTEMS**
Course Code: **EN- 717**
Course Type: **Elective-IV**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

Course Objectives:

- To learn 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

Introduction:
Importance of Life Cycle Assessment of Renewable Energy Sources, types of life cycle assessments, Procedure for Life Cycle Assessment, Methodology, life cycle design, development process, 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 and 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 i.e., wind, bio, solar etc., 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.

References:

1. Basosi, R., Cellura, M., Longo, S., Parisi, M.L , "Life Cycle Assessment of Energy Systems and Sustainable Energy Technologies", Springer
2. Kandpal, Tara Chandra, and HariPrakashGarg. Financial evaluation of renewable energy technologies. MacMillam India Limited,
3. Walter KÏopffer and Birgit Grahl"Life Cycle Assessment (LCA)" 2014 Wiley-VCH Verlag GmbH & Co. Germany, Print ISBN: 978-3-527-32986-1
4. Leda Gerber, "Designing Renewable Energy Systems: A Life Cycle Assessment Approach" Publisher: EPFL Press, Year: 2015, ISBN: 1498711278,9781498711272

Course Name: **DECENTRALIZED ENERGY SYSTEMS**
Course Code: **EN- 718**
Course Type: **Elective-IV**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

Course objectives:

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

Course Content

Introduction:

Need and 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: Definition, applications; smart grid communications, advanced metering infrastructure, demand response, energy consumption scheduling; renewable energy generation based Micro grid

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, other 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/appropriate/renewable 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

References:

1. Bollen M. H. and Hassan F. (2011); Integration of Distributed Generationin the Power System, Wiley-IEEE Press
2. Zerriffi H. (2011); Rural Electrification: Strategies for Distributed Generation,Springer
3. Jenkins N. Strbac G. and Ekanayake J. (2009); Distributed Generation,The Institution of Engineering and Technology
4. Keyhani A. (2011); Design of Smart Power Grid Renewable EnergySystems, Wiley–IEEE Press
5. Tester J. W. (et al.) (2012); Sustainable Energy: Choosing among Options,Second Edition, The MIT Press
6. Bhattacharyya S. (Ed.) (2013); Rural electrification through decentralisedOff-grid systems in Developing Countries, Springer
7. Zerriffi H. (2011); Rural Electrification: Strategies for Distributed Generation,Springer

Course Name: **SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT GOALS**
Course Code: **EN- 719**
Course Type: **Elective-IV**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

Course objectives:

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

Course Content

Introduction:

Origin, History of Sustainable Development Goals (SDGs), SDGs -aims, methodology and perspectives, 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

Climate Change:

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. SDGs and Society: Strengthening Institutions for Sustainability- Analysis of goals related to gender equality, affordable and clean energy, sustainable cities & communities, and 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, Realizing the SDGs: Implementation through Global –artnerships Analysis of SDG 17 which aims to implement the 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

References:

1. https://www.un.org/sustainabledevelopment/sustainable-development-goals

Course Name: **CARBON CAPTURE TECHNOLOGIES**
Course Code: **EN- 720**
Course Type: **Elective-IV**

Prerequisite: Nil	L	T	P	C
	4	0	0	4

Course objectives:

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

Course Content

Introduction:

The Carbon Cycle, Mitigating Growth of The Atmospheric Carbon Inventory, The Process of Technology Innovation, Carbon Capture, Carbon Storage, Power generation fundamentals: Physical and Chemical Fundamentals, Fossil-Fueled Power Plant, Combined Cycle Power Generation, Future Developments in Power-Generation Technology.

Carbon Capture from Power Generation:

Introduction, Pre-combustion Capture, Post-combustion Capture, Oxy- fuel Combustion Capture, Chemical Looping Capture Systems, Capture-Ready and Retrofit Power Plant, Approaches to Zero-Emission Power Generation. Carbon capture from industrial processes: Cement Production, Steel Production, Oil Refining, Natural Gas Processing. Absorption captures systems: Chemical and Physical Fundamentals, Absorption Applications in Post Combustion Capture, Absorption Technology RD & D Status.

Adsorption Capture Systems:

Physical and Chemical Fundamentals, Adsorption Process Applications, Adsorption Technology RD&D Status. References and Resources. Membrane separation systems: Physical and Chemical Fundamentals, Membrane Configuration and Preparation and Module Construction, Membrane Technology RD&D Status, Membrane Applications in Pre-combustion Capture, Membrane and Molecular Sieve Applications in Oxy-fuel Combustion, Membrane Applications in Post-combustion CO2 Separation, Membrane Applications in Natural Gas Processing

Cryogenic and distillation systems:

Physical Fundamentals, Distillation column configuration and operation, Cryogenic oxygen production for oxyfuel combustion, Ryan–Holmes process for $CO_2 – CH_4$ separation, RD&D in cryogenic and distillation technologies. Mineral carbonation: Physical and chemical fundamentals, Current state of technology development, Demonstration and deployment outlook. Geological storage: Introduction, Geological and engineering fundamentals, Enhanced oil recovery, Saline aquifer storage, Other geological storage options. Ocean storage: Introduction, Physical, chemical, and biological fundamentals, Direct CO2 injection, Chemical sequestration, Biological sequestration, Storage in terrestrial ecosystems, Other sequestration and use options

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.

References:

Carbon Capture and Storage Stephen A. Rackley Elsevier 2010