CURRICULUM

M. TECH. in Renewable Energy

(August 2023 admissions onwards)

Faculty Board

Teaching Scheme of Joint Program

ISO 9001:2008

Sardar Swaran Singh
National Institute Of Bio- Energy
Kapurthala

Dr. B R Ambedkar
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Jalandhar

VISION

To be a leader in promoting the renewable energy resources and tackle the complex Energy and Environmental challenges through cutting-edge research, innovative technologies, and collaborative partnerships for the welfare of the society.

MISSION

- To provide quality higher engineering education and training programs for integrating and providing skilled personnel to academia and industry in the areas of energy and environment.
- To widen the treaty with world class R&D organizations, premiere educational institutes, and industries for excellence in teaching, research, and consultancy services.
- To facilitate the development of sustainable and cost-effective innovations and create interactive infrastructure in the multidisciplinary domains of renewable energy and environment.
- Peruse and nurture education & research on energy and environment for sustainable growth; and development of the society with global academic and industrial partnership and networking.

QUALITY POLICY

- To develop analytical skills among students for problem solving in the fields of energy and environment.
- To provide academic excellence through developing state of the art laboratories.
- To develop efficient technologies for energy production in eco- friendly manner.
- To inculcate moral and ethical values amongst students
- To contribute towards sustainable development of community and technology interventions.

Programme Educational Objectives

PEO1: To impart knowledge in Energy and Environment sector with emphasis on resource assessment, energy harnessing processes for various applications.

PEO2: To provide an academic ambiance that nurtures students for effective collaborators/ innovators to address social, technical, and engineering challenges being faced in energy and environment sectors.

PEO3: To provide skilled personnel for innovative and independent research work in Academia/ Industry for development and maintenance of renewable energy systems and processes.

PEO4: To inculcate professional ethics, teamwork skills, integrity, environmental and social responsibility, and life-long learning.

Program Outcomes - M.Tech (Renewable Energy)

PO1: An ability to carry out independent, collaborative and multidisciplinary research/ development work to solve practical problems

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

PO3: Students should be able to demonstrate a degree of mastery over the renewable energy and allied areas. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PO4: Ability to think critically and use sustainable technologies to solve the energy & environment complex problems

PO5: An ability to work in an ethical manner for the benefit of society and encourage lifelong learning

Programme Specific Outcomes

PSO1: To what extent are you able to develop and implement innovative ideas and product development for the benefit of society and industry through your renewable energy systems knowledge of solar, wind, hydro?

PSO2: To what extent are you able to solve challenges and creating opportunities using hardware and software tools and sustaining a passion for real-world applications using optimal resources as an entrepreneur/researcher?

Anxxeure 1

Structure of Curriculum for M.Tech Programme in Renewable Energy

Duration	Two years (4 semesters)
Number of Courses	13 (Theory); 2 (Practical)
Dissertation work	02 semesters
Total Credits	80
Core Courses (Theory)	10
Department Electives	3

Credit Distribution for M. Tech in Renewable Energy					
Category	**Sem - I**	**Sem - II**	**Sem - III**	**Sem - IV**	**Total No. of Credits to be earned**
Core Courses	**18**	**12**	**-**	**-**	**30**
Electives	**3**	**6**	**-**	**-**	**9**
Lab Courses	**0**	**4**	**-**	**-**	**4**
Seminar	**-**	**-**	**3**	**-**	**3**
Dissertation	**-**	**-**	**16**	**18**	**34**
Total	**21**	**22**	**19**	**18**	**80**

Course Structure and Syllabus for M.Tech (Renewable Energy)

FIRST SEMESTER				
S.No.	**Course Code**	**Course Title**	**L-T-P**	**Credit**
1.	**RE-501**	Introduction to Renewable Energy systems	3-0-0	3
2.	**RE-503**	Fundamentals of Energy and Environment	3-0-0	3
3.	**RE-505**	Solar Photovoltaic Devices and Systems	3-0-0	3
4.	**RE-507**	Bio-Energy and Biofuels	3-0-0	3
5.	**RE-509**	Wind and Small Hydro Energy Systems	3-0-0	3
6.	**RE-511**	Process Modeling & Simulation in Renewable Energy Systems	3-0-0	3
7.	**xx-xxx**	Elective I	3-0-0	3
		Total		**21**

SECOND SEMESTER				
S.No.	**Course Code**	**Course Title**	**L-T-P**	**Credit**
1.	**RE-502**	Solar Thermal Technologies and Applications	3-0-0	3
2.	**RE-504**	Energy Conservation, Management & Audit	3-0-0	3
3.	**RE-506**	Economics and Financing of Renewable Energy Systems	3-0-0	3
4.	**RE-508**	Waste to Energy Conversion Processes	3-0-0	3
5.	**xx-xxx**	Elective II	3-0-0	3
6.	**xx-xxx**	Elective III	3-0-0	3
7.	**RE-510**	Renewable Energy Lab	0-0-3	2
8.	**RE-530**	Computational Techniques & Data Analysis lab	0-0-3	2
		Total		**22**

THIRD SEMESTER				
S.No.	**Course Code**	**Course Title**	**L-T-P**	**Credit**
1.	**RE-600**	M Tech Dissertation (Phase I)	0-0--	16
2.	**RE-601**	Seminar	0-0-6	3
		Total		**19**

FOURTH SEMESTER				
	Course Code	**Course Title**	**L-T-P**	**Credit**
1.	**RE-600**	M Tech Dissertation (Phase II)	0-0-0	18
		Total		**18**

Electives

Departmental Electives				
S.No.	**Course Code**	**Course Title**	**L-T-P**	**Credit**
1	**RE-512**	Electric Vehicle	3-0-0	3
2	**RE-513**	Fuel Cell and Hydrogen Energy	3-0-0	3
3	**RE-514**	Solar Refrigeration and Air Conditioning	3-0-0	3
4	**RE-515**	Energy Storage	3-0-0	3
5	**RE-516**	Developing Energy Efficiency and Renewable Energy Projects	3-0-0	3
6	**RE-517**	Energy, Climate Change and Carbon Trade	3-0-0	3
7	**RE-518**	Energy Efficient Buildings	3-0-0	3
8	**RE-519**	Renewable Energy Grid Integration	3-0-0	3
9	**RE-520**	Energy Conservation by Waste Heat Recovery	3-0-0	3
10	**RE-521**	Biomass Characterization and Management	3-0-0	3
11	**RE-522**	Fuels & Combustion Technology	3-0-0	3
12	**RE-523**	Advanced Waste Water Treatment	3-0-0	3
13	**RE-524**	Power Generation, Distribution & Transmission	3-0-0	3
14	**RE-525**	Nuclear Energy	3-0-0	3
15	**RE-526**	Micro-Grid Operation and Control	3-0-0	3

Interdepartmental Electives relevant to the program				
16	**BT-501**	Bioreactor and Bioprocess Design	3-0-0	3
17	**BT-506**	Environmental Biotechnology	3-0-0	3
18	**CE-531**	Geoenvironmental Engineering	3-0-0	3
19	**CE-533**	Solid and Hazardous Waste Management	3-0-0	3
20	**CE-553**	Environmental Risk Assessment	3-0-0	3
21	**CH-520**	Energy Efficiencies in Thermal Utilities	3-0-0	3
22	**CH-522**	Advanced Heat Transfer and Fluid Dynamics	3-0-0	3
23	**CH-525**	Biomass Conversion Processes	3-0-0	3
24	**CH-529**	Environment Impact Assessment	3-0-0	3

25	**CH-535**	Petroleum Engineering and Technology	3-0-0	3
26	**CH-541**	Biorefinery and Bioproducts Engineering	3-0-0	3
27	**IC-596**	Power System Operation and Control	3-0-0	3
28	**ID-601**	Research Methodology	3-0-0	3
29	**IP-524**	Environment Management Systems	3-0-0	3
30	**IP-536**	Design and Analysis of Experiments	3-0-0	3
31	**IP-539**	Sustainable Manufacturing	3-0-0	3
32	**ME-528**	Materials and Sustainable Development	3-0-0	3
33	**ME-555**	Computational Fluid Dynamics	3-0-0	3
34	**ME-565**	Advanced IC Engines	3-0-0	3
35	**ME-566**	Advanced Power Plant Cycles	3-0-0	3
36	**ME-567**	Advanced Steam Power Plants	3-0-0	3
37	**ME-569**	Alternative Fuels for IC Engines	3-0-0	3
38	**ME-571**	Combustion Generated Pollution and Control	3-0-0	3
39	**ME-573**	Exergy Analysis of Thermal & Energy System	3-0-0	3
40	**ME-581**	Photovoltaic Cell and its Applications	3-0-0	3
41	**ME-584**	Solar Passive Design & Sustainable Buildings	3-0-0	3
42	**ME-587**	Waste Heat Utilization and Polygeneration	3-0-0	3
43	**EEEV-503**	Power Electronics and Electric Drives	3-0-0	3
44	**EEEV-505**	Embedded Systems	3-0-0	3
45	**EEEV-507**	Modeling and Simulation of E-Vehicles	3-0-0	3
46	**EEEV-502**	Digital Signal Processing	3-0-0	3
47	**EEEV-504**	Battery and Battery Management System	3-0-0	3
48	**EEEV-506**	Advanced Control System for Electric Vehicles	3-0-0	3
49	**EEEV-508**	Special Electrical machines and Control	3-0-0	3

Syllabus for M.Tech Renewable Energy Programme

Course Code	Course Title	L	T	P
RE-501	**Introduction to Renewable Energy systems**	**3**	**0**	**0**

Pre-requisites: Basic Engineering all disciplines.

Course objectives: This course has been designed to develop the understanding the understanding of the various non-conventional energy resources and technologies.

Syllabus: Introduction to world energy scenario, Renewable energy resources, Radiation, Solar Geometry, radiation models;

Solar Energy: Solar Thermal, Optical efficiency, thermal efficiency, concentrators, introduction to thermal systems (flat plate collector), solar architecture, solar still, air heater, panel systems; Photovoltaic; Introduction to semiconductor physics, doping, P_N junction, Solar cell and its I_V characteristics, PV systems components, design of a solar PV systems.

Wind Energy: Wind, Introduction, types of wind machines, Cp-λ curve & betz limits, wind recourse analysis;

Bioenergy: Types and availability of biomass resources, various methods of biomass utilisation for energy generation: gasification, briquette, palatization, syn-gas, Anaerobic/Aerobic digestion, ethanol and biodiesel production, types of Bio-gas digesters, Combustion characteristics of bio-gas and its different utilizations,

Hydro Energy: Basic principle of hydroelectric power generation, classification of hydropower projects (pico, micro, mini, small hydro sand large hydro projects), types of hydro turbine, various components of hydropower projects.

Fuel Cells and Hydrogen Energy: Introduction, principle of fuel cells, types of fuel cells, fuel cell batteries, Hydrogen as a renewable energy source, sources of hydrogen, fuel for vehicles, hydrogen production- direct electrolysis of water, thermal decomposition of water, methods of hydrogen production. Other systems, Geothermal, wave energy, ocean energy.

Course Outcomes:

1. Analyze current energy scenario and significance of renewable energy sources, to understand sustainable development, to impart knowledge about working of small hydro system.
2. Understand the solar radiation, solar thermal and solar photovoltaic.
3. To impart working of wind energy, and make Understand the basic concepts of biomass and bio -energy conversion process and applications
4. Its objectives is to give knowledge of Fuel cell, Hydrogen energy and MHD generation
5. To impart harnessing methods of Geothermal resources and Ocean and Tidal Energy

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	√	√		√	
2			√	√	√
3	√		√	√	
4	√		√	√	
5	√			√	√

Recommended books:

1. Duffie, J. A., & Beckman, W. A. (2013). Solar engineering of thermal processes, fourth edition, Wiley.
2. Tiwari, G. N., & Ghosal, M. K. (2007). Fundamentals of renewable energy sources. Alpha Science International Limited.
3. Mukherjee, D., & Chakrabarti, S. (2004). Fundamentals of renewable energy systems. New Age International.
4. Sukhatme, S. P. (2005). Solar Energy Principles of Thermal Collection and storage Tata McGraw Hill Publishing Company Ltd. New Delhi.
5. Kothari, D. P., Singal, K. C., & Ranjan, R. (2011). Renewable energy sources and emerging technologies. PHI Learning Pvt. Ltd.

Course Code	Course Title	L	T	P
RE-503	Fundamentals of Energy and Environment	3	0	0

Pre-requisites: Basic knowledge of energy and environment.

Course objectives: To inculcate among the students systematic knowledge and skill about assessing the environment impact of energy use.

Syllabus:

Environmental issues

Current challenges in terms of environmental pollutions, Sources of pollution and global warming, harmful effects of environmental pollution, preventive measures and protocols to minimize environmental damage, availability and economic aspects of renewable energy sources, effects of renewable energy sources on the environment.

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.

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, Future Energy Systems, Euro-IV and Euro-VI emission norms.

Course Outcomes:

1. Understand the basics of climate change and its parameters
2. Evaluate the relationship between Energy and Climate change
3. Create understanding of environmental impact of various energy systems
4. Recognize low carbon sustainable technology
5. Understand and apply different framework for climate and sustainability

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√	√	√
2		√		√	
3	√			√	√
4	√		√		√
5	√			√	√

Recommended books:

1. Fay, J. A., & Golomb, D. S. (2002) Energy and the Environment. Oxford University Press, New York
2. Mori, Y. H., & Ohnishi, K. (Eds.). (2012). Energy and Environment: Technological Challenges for the Future. Springer Science & Business Media.
3. Allenby, B. (2013). Reconstructing earth: Technology and environment in the age of humans. Island Press. Washington, D.C
4. Jeong, H. W. (2006). Globalization and the Physical Environment. Chelsea House Publishers. Philadelphia
5. Kaushika, N. D., & Kaushik, K. (2004). Energy, Ecology and Environment: A Technological Approach. Capital Publishing Comapny

ourse Code	Course Title	L	T	P
RE-505	**Solar Photovoltaic Devices and Systems**	**3**	**0**	**0**

Pre-requisites: Basic Engineering all disciplines.

Course objectives: The Course will be introducing the students to all the aspects of PV technology. This will enable them to understand the requirements for PV materials and PV systems for different applications. The role of PV in autonomous, hybrid and distributed generation will be emphasized.

Syllabus:

Introduction to Solar PV: Solar spectrum details, sunpath 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.

PV Array Analysis: Introduction, Solar cell 10 parameters, production of silicon, fabrication of solar cells, design of solar cells, optimization of process parameters, measurements of solar cell parameters; short circuit current, open circuit voltage, fill factor, efficiency, Photovoltaic (PV) Module and Array, Theory and Construction, Series and Parallel Combinations, Balance of PV Array, Partial Shading of Solar Cell and Module, Maximum Power Point Tracker (MPPT), Balance of PV system (BOS), Issues and Challenges of PV system operation and maintenance; Factor affecting the PV system performance;

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 &Testings:
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 envelop. 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, Agrovoltaics. Recycling of solar PV modules , Methods of recycling.

Course Outcomes:

1. Understand basics of solar PV and its manufacturing
2. Analyze solar power generation aspects
3. Evaluate different losses in solar PV systems and its components
4. Understand and apply solar PV module’s standards, reliability and degradation
5. CO5: Design small and large scale solar PV power plants with different applications

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√	√	
2	√		√	√	
3	√	√	√	√	
4	√		√	√	√

Recommended books:

1. Archer, M. D., & Green, M. A. (Eds.). (2001). Clean electricity from photovoltaics. London: Imperial College Press.
2. Solanki, C. S. (2015). Solar photovoltaics: fundamentals, technologies and applications. PHI Learning Pvt. Ltd..
3. Mukerjee, A. K., & Thakur, N. (2011). Photovoltaic Systems: Analysis and Design. PHI Learning Pvt. Ltd.
4. Mohanty, P., Muneer, T., & Kolhe, M. (Eds.). (2015). Solar photovoltaic system applications: a guidebook for off-grid electrification. Springer.
5. Mertens, K. (2018). Photovoltaics: fundamentals, technology, and practice. John Wiley & Sons.
6. Fahrenbruch, A., & Bube, R. (2012). Fundamentals of solar cells: photovoltaic solar energy conversion. Elsevier.

Course Code	Course Title	L	T	P
RE-507	Bio-Energy and Biofuels	3	0	0

Pre-requisites: Basic Engineering all disciplines.

Course objectives: This course is aimed at dissemination of important information of bioenergy to enable students to acquire knowledge on cutting-edge technologies for conversion of various biomass feedstock to bioenergy / biofuel production and their utilization in combustion engines / devices and fuel cells.

Syllabus:

Biomass resource assessment: Introduction, Classification and properties of biomass, Biomass characterization, different energy conversion methods, Bio Energy Resources, World Bio Energy Potential, India's Bio Energy Potential, Biomass Resources and classification, Physio-chemical characteristics. Biomass Combustion, Loose biomass densification, Biomass based power generation and utilization for domestic cooking, Improved biomass cookstoves.

Biogas Systems: Technology of Biogas production, Biogas Plants, Digester types, Digester design, Chemical kinetics and mathematical modeling of bio methanation process, Dung, Vegetable Waste and Municipal Waste based Biogas plants, Biogas as fuel for transportation, Lighting, Running Dual Fuel Engines, Electricity generation, Biogas Bottling Plant Technology, Application of Biogas slurry in agriculture, Design of Biogas for cold climates. Case studies and numerical.

Biomass Gasifiers: History , Principle , Design of Bio mass Gasifiers , updraft gasifier, down draft gasifier, zero carbon biomass gasification plants, Gasification of plastic-rich waste, applications for cooking, electricity generation, Gasifier Engines, Operation of spark ignition and compression ignition engine with wood gas, methanol, ethanol and biogas, Biomass integrated gasification/combined cycles systems, gasification, pyrolysis, liquification, biomass pre- treatment and processing, Case studies, biodiesel, improved biomass cookstove, biohydrogen generation, electricity generation from biomass gasifier, engine systems, bio-gasoline, bio-diesel and duel fuel engine, case studies.

Biofuel: Bioethanol production from lignocelluloses, waste material, including crop residue, sugar and starch; biodiesel production from vegetable oil and animal fat, algae; biofuel derived from; economics of biofuel production; environmental impacts of biofuels; biofuel blends; green diesel from vegetable oil; biodiesel production process, by-product utilization. Production of butanol and propanol; Production of biohydrogen; production of hydrogen by fermentative bacteria.

Bio-refinery concept: Bio-refinery concept: definition; different types of bio-refinery; challenge and opportunities; Fuel and chemical production from saccharides, lignocellulosic biomass, protein; vegetable oil; algal biorefinery.

Course Outcomes:

1. Analyze and describe the nature and principles of bioenergy systems.
2. Design and distinguish the bioenergy systems and learn technical analysis.
3. Evaluate the environmental benefits and consequences of bioenergy production.
4. Understand different testing tools for environmental analysis
5. Design and development of new generation biofuel applications

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1			√	√	
2	√	√		√	
3			√	√	√
4			√	√	√
5	√				√

Recommended books:

1. Mutha, V. K. (2010). Handbook of bioenergy and biofuel SBS Publishers, Delhi
2. Clark, J. H., & Deswarte, F. (Eds.). (2014). Introduction to chemicals from biomass. John Wiley & Sons.
3. Klass, D. L. (1998). Biomass for renewable energy, fuels, and chemicals. Elsevier.
4. Mukunda, H. S. (2011). Understanding clean energy and fuels from biomass. Wiley India.
5. Higman C. and Burgt M v d (2003); Gasification, Elsevier Science
6. Speight, J. (2008). Synthetic fuels handbook: properties, process and performance. McGraw-Hill
7. Dahiya, A. (Ed.). (2014). Bioenergy: Biomass to biofuels. Academic Press.
8. Hall, D. O., & Overend, R. P. (1987). Biomass: regenerable energy.
9. San Pietro, A. (Ed.). (2012). Biochemical and photosynthetic aspects of energy production. Elsevier. New York

Course Code	Course Title	L	T	P
RE-509	**Wind and Small Hydro Energy Systems**	**3**	**0**	**0**

Pre-requisites: Basic Engineering all disciplines.

Course objectives: This course deals with wind and hydro energy sources and systems in details. The course aimed to teach the students on various aspects of wind and hydro energy resource assessment, conversion process, applications and economics of energy generation.

Syllabus:

Basics of Wind Energy: Atmospheric circulations, classification, factors influencing wind, wind shear, turbulence, wind speed monitoring, Wind resource assessment, Weibull distribution, Betz limit, Aerodynamic theories, Axial momentum, Blade element and combine theory, Rotor characteristics, Maximum power coefficient, Tip loss correction

Wind energy conversion systems: Classification, applications, power, torque and speed characteristics Aerodynamic design principles etc, wind turbine design considerations: methodology, theoretical simulation of wind turbine characteristics.

Principle of WEG: Stand alone, grid connected; Hybrid applications of WECS; Wind pumps, performance analysis of wind pumps, design concept and testing, economics of Wind energy utilization, Wind energy Program in India.

Hydrology: Resource assessment, Potential of hydropower in India, Classification of Hydropower Plants, Small Hydropower Systems, Overview of micro, mini and small hydro systems, Status of Hydropower Worldwide and India

Hydraulic Turbines: types and operational aspects, classification of turbines, elements of turbine, selection and design criteria, geometric similarity operating characteristic curves; Speed and voltage regulation Selection of site for hydroelectric plant, Essential elements of hydroelectric power plant, environmental issues related to large hydro projects.

Course Outcomes:

1. Understand the basics of wind Energy conversion systems.
2. Understand and apply the principle of aerodynamics.
3. Understand different testing standards and its applications
4. Design, operation, control, and integration of wind turbine
5. Analyze on shore and off shore wind applications and future prospects

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1			√	√	
2	√			√	
3		√	√	√	
4	√		√	√	
5	√		√		√

Recommended books:

1. Johnson G. L. (2006). Wind Energy Systems (Electronic Edition), Prentice Hall
2. Wagner H. and Mathur J. (2011). Introduction to Hydro Energy Systems: Basics, Technology and Operation, Springer Reference Books
3. Hau E. (2000). Wind Turbines: Fundamentals, Technologies, Application and Economics, Springer
4. Mathew S. (2006). Wind Energy: Fundamentals, Resource Analysis and Economics, Springer
5. Burton T. Sharpe D. Jenkins N. and Bossanyi E. (2001). Wind Energy Handbook, John Wiley
6. Nag P. K. (2008). Power Plant Engineering, Third Edition, Tata McGraw Hill
7. Jiandong T. (et al.) (1997). Mini Hydropower, John Wiley

Course Code	Course Title	L	T	P
RE-511	**Process Modeling & Simulation in Renewable Energy Systems Energy Systems**	**3**	**0**	**0**

Pre-requisites: Basic Mathematics.

Course objectives: This course is intended to impart basic skill of model development and optimization in the field of energy. The main Objectives are to enable learners to develop basic skill of development of energy system model and to enable learners to use system modeling as tool for optimization vis-à-vis decision making on energy related field problems.

Syllabus:

Introduction to modeling: types and classification, uses, limitations, advantages of modeling; Review of computational tools/techniques used for mathematical modeling including solutions for non-linear equations, system of simultaneous equations, Conservation principles, thermodynamic principles, state and dynamic, Lumped and distributed parameter models, Block diagrams and computer simulation. Modeling of Process elements consisting of Mechanical (translational and rotational), Electrical, Electro- mechanical, Fluid flow, Thermal and Chemical reaction system elements.

Development of Models: Grey box models, Empirical model building, Statistical model calibration and validation. Population balance models, examples of energy system modeling, static and dynamic modeling; Modeling errors, accuracy and methods of model validation

Solution strategies for Lumped parameter models: Solution methods for initial value and boundary value problems, Euler's method, R-K method, Shooting method, Finite difference methods. Finite element and Finite volume methods. Solving the problems using MATLAB / SCILAB.

Optimization: Problem formulation with practical examples from energy system, constrained optimization and unconstrained problems: necessary and sufficiency conditions. Uses of Linear Programming technique for solution of problems related to Energy systems/ case studies. Constrained Optimization, Lagrange multipliers, constrained variations, Kuhn-Tucker conditions, Case studies of optimization in Energy systems problems, Dealing with uncertainty- probabilistic techniques.

Energy systems simulation Optimization: Objectives/constraints, problem formulation. Unconstrained problems, Necessary & Sufficiency conditions.

Econometric modeling: Input Output models considering energy budgeting, Sensitivity analysis, importance of parametric analysis and tools for sensitivity analysis

Course Outcomes:

1. To understand modeling, its types and principles
2. The learner will understand how to develop a model, and how to apply varies strategies for different parametric model.
3. To optimize the energy systems and to understand the working principles econometric modeling.
4. Design, develop and simulate various energy system.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1			√	√	√
2	√			√	
3	√	√	√		
4	√			√	√

Recommended books:

1. Rao S. S. (2004). Engineering Optimization: Theory and Practice, Third Edition, New Age International
2. Kennedy P. (2008). A Guide to Econometrics, Sixth Edition, Wiley-Blackwell
3. Meier P. (1984). Energy Systems Analysis for Developing Countries, Springer Verlag
4. Ravindran A. Ragsdell K. M. and Reklaitis G. V. (2006). Engineering Optimization: methods and applications, Second Edition, Wiley
5. Neufville R. De. (1990). Applied Systems Analysis: Engineering Planning and Technology Management, McGraw Hill
6. Hangos, K., & Cameron, I. (2001). Process modelling and model analysis. Academic Press
7. James, J. C. (1989). Process modeling, simulation and control for chemical engineers. McGraw-Hill.
8. Close, C. M., & Frederick, D. K. (2002). Modeling and analysis of dynamic systems. John Wiley & Sons.

Course Details **Second Semester**

Course Code	Course Title	L	T	P
RE-502	**Solar Thermal Technologies and Applications**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of solar radiation.

Course objectives: This course discusses in detail the theory and design aspects of various types of solar thermal collectors. 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

Syllabus:

Basics for solar thermal system: Different design and components; Radiation transmission and absorption through glazing; Selective surfaces: Ideal coating characteristics, Anti reflection coating;

Flat plate collector: Theory and basic design aspects; Thermal analysis and effective heat loss; Performance analysis methods; Thermal analysis and effective energy loss of evacuated tube collector; Flat plate solar dryer: Issues and challenges.

Concentrating collector: Classification of concentrating collector; concentrating collector configurations; concentration ratio: optical, geometrical; Thermal performance of concentrating collector; Optical and thermal performance of different concentrating collector designs; Parabolic trough concentrators; Compound parabolic concentrator; Concentrators with point focus.

Solar thermal power plant: Central receiver systems; Heliostats; Comparison of various designs: Parabolic trough systems, Rankine cycle, Parabolic Dish - Stirling System, Combined cycle

Solar industrial process heat: Performance analysis of miscellaneous solar applications, Codes and Standards, Applications of solar flat plate water heater & air heater for industrial process heat.

Course Outcomes:

1. Understand solar geometry and assessment of solar resources
2. Evaluate different of solar collector for different applications.
3. Apply passive heating and cooling aspects
4. Understand different testing standards and its applications
5. Design and development of new generation solar thermal applications

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1		√	√		
2	√		√		√
3	√			√	
4	√		√	√	
5	√		√		√

Recommended books:

1. Duffie J. A. and Beckman W. A. (2013), Solar Engineering of Thermal Processes, John Wiley
2. Garg H. P. and Prakash S. (2000), Solar Energy: Fundamental and Application, Tata McGraw Hill
3. Goswami D. Y. (2015), Principles of Solar Engineering, Taylor and Francis
4. Tiwari G. N. (2002), Solar Energy: Fundamentals, Design, Modeling and Applications, Narosa
5. Nayak J. K. and Sukhatme S. P. (2006), Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill
6. Serrano, M. I. R. (2017). Concentrating solar thermal technologies. In Concentrating Solar Thermal Technologies (pp. 11-24). Springer, Cham.
7. Tyagi, H., Chakraborty, P. R., Powar, S., & Agarwal, A. K. (Eds.). (2019). Solar Energy: Systems, Challenges, and Opportunities. Springer Nature.

Course Code	Course Title	L	T	P
RE-504	**Energy Conservation, Management & Audit**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Energy.

Course objectives: The course discusses about the energy scenario, energy conservation and its importance, energy strategy for the future, energy conservation act-2001 and its features, Kyoto protocol and global warming

Syllabus:

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 Conservation: Introduction, Energy and heat balances, Methods for preparing process flow chart, material and energy balance in different processes, Sankey diagram, 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 Outcomes:

1. Evaluate the techno-economic feasibility of the energy conservation technique adopted
2. Analyze and identify the efficiency improvement process in any industry
3. Apply the knowledge gained to conduct energy audit of an industry/organization
4. Prepare energy audit reports
5. Understanding different industries performance

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	√		√		
2	√		√	√	√
3	√			√	
4		√	√		
5	√		√		√

Recommended books:

1. Capehart, B. L., Turner, W. C., & Kennedy, W. J. (2006). Guide to energy management. The Fairmont Press, Inc. Atlanta, GA
2. Kumar, Anil, Om Prakash, Prashant Singh Chauhan, and Samsher Gautam. Energy Management: Conservation and Audits. CRC Press, 2020.
3. Thumann, A., & Mehta, D. P. (2001). Handbook of energy engineering. CRC Press.
4. Loftness, Robert L. “Energy Handbook.” 2d ed. New York: Van Nostrand Reinhold Co., 1984.
5. Turner, W. C., & Doty, S. (2013). Energy management handbook (Vol. 2). Lulu Press, Inc.
6. Kenney, W. F. Energy conservation in the process industries. Academic Press, 2012.
7. Kreith, F., & Goswami, D. Y. (Eds.). (2007). Energy management and conservation handbook. CRC Press.
8. Rao, P. S., & Rao, P. R. P. (2000). Environment Management and Audit. Deep and Deep Publications.

Course Code	Course Title	L	T	P
RE-506	**Economics and Financing of Renewable Energy Systems Systems**	3	0	0

Pre-requisites: Basic knowledge of mathematics.

Course objectives: The aim of this course is to understand the basics of economic principles that govern the supply and demand of energy in the context of modern civilization.

Syllabus:

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, Economic theory of demand, production and cost market structure

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 Outcomes:

1. Appreciate and understand the various energy related eats and policies of governments.
2. Calculate payback period, cost of energy generated, life cycle costing etc.
3. Calculate the tariffs on energy charged regulatory bodies.
4. Understand different policies and challenges
5. Understanding different government schemes

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√	√	√		
2			√	√	
3			√	√	
4	√	√	√		√
5	√				√

Recommended books:

1. Campbell, H. F., & Brown, R. P. (2003). Benefit-cost analysis: financial and economic appraisal using spreadsheets. Cambridge University Press.
2. Kandpal, T. C., & Garg, H. P. (2003). Financial evaluation of renewable energy technologies. MacMillam India Limited.
3. Park, C. S. (2002). Contemporary engineering economics (Vol. 4). Upper Saddle River, NJ: Prentice Hall.
4. Kroemer, K. H., Kroemer, H. B., & Kroemer-Elbert, K. E. (2001). Ergonomics: how to design for ease and efficiency. Pearson College Division.
5. Dorsman, A. B., Ediger, V. Ş., & Karan, M. B. (Eds.). (2018). Energy Economy, Finance and Geostrategy. Springer.
6. Banks, F. E. (2012). Energy economics: a modern introduction. Springer Science & Business Media.
7. Thuesen G. J. and Fabrycky W. J. (2001); Engineering Economy, Ninth Edition, Prentice Hall India
8. Ayyub, B. M. (2014). Risk analysis in engineering and economics. CRC Press.

Course Code	Course Title	L	T	P
RE-508	**Waste to Energy Conversion Processes**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

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

Syllabus:

Introduction to energy from waste: characterization and classification of waste as fuel; agro-based, forest residues, industrial waste, Municipal solid waste

Solid Waste Sources: Solid Waste Sources, types compositions and Properties, Municipal Solid Waste, Physical, chemical and biological properties, Waste Collection and transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction, Managing Waste, Status of technologies for generation of Energy from Waste.

Waste Treatment and Disposal: Aerobic composting, Furnace types and designs, Medical waste /Pharmaceutical waste treatment Technologies, concept of Bioremediation, Incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration, Land fill classifications, Types, methods and Siting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases.

Waste to energy options: Biochemical and Thermochemical routes; Biochemical Options – Anaerobic Digestion, Fermentation; Thermochemical Options – Pyrolysis, Gasification and Incineration; Other options – Biodiesel synthesis, Briquetting and Torrefaction, Hazardous waste management;

Energy Generation from Waste (Biochemical Conversion): Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, Agro residues, Anaerobic Digestion: Biogas production, Land fill gas generation and utilization, Thermochemical conversion: Sources of energy generation, Gasification of waste using gasifiers, Briquetting, Utilization and advantages of briquetting, Case studies of Commercial Waste to Energy Plants , Present status (National and International) of Technologies for Conversion of Waste into Energy, Design of Waste to Energy Plants for Cities, small townships and villages.

Properties of fuels derived from waste to energy: Producer gas, Biogas, Ethanol and Briquettes, Comparison of properties with conventional fuels; Landfills: Gas generation and collection in landfills, Introduction to transfer stations, Benefits of Biochemical and Thermochemical conversions

Course Outcomes:
1. Analyze the various aspects of waste to energy plant.
2. To apply and analyse different technologies for energy generation from waste.
3. To design a waste to energy plant based upon regulations
4. To analyse technical and management principles of waste to energy plant
5. To understand health and environmental impacts from different waste to energy conversion technologies

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		
2	√			√	
3	√	√			
4	√		√		
5			√		√

Recommended books:

1. Energy from Waste - An Evaluation of Conversion Technologies by C Parker and T Roberts (Ed),
2. Parker, C., & Roberts, T. (1985). Energy from waste: an evaluation of conversion technologies. Elsevier Applied Science, London.
3. Shah, K. L. (2000). Basics of solid and hazardous waste management technology, Prentice Hall.
4. Christensen, T. H., Cossu, R., & Stegmann, R. (Eds.). (2005). Landfilling of waste: leachate. CRC Press.
5. Kalogirou, E. N. (2017). Waste-to-Energy technologies and global applications. CRC Press.

Electives

Course Code	Course Title	L	T	P
RE-512	Electric Vehicle	3	0	0

Pre-requisites: Basic knowledge of Electrical Engineering.

Course objectives: The objective of this course is to provide an advanced level understanding on electric vehicles and batteries that are used in such vehicles. The course will impart knowledge on the fundamental electrochemistry of battery systems, design of electric vehicle, business model, policy, impact etc.

Syllabus: **Review of Conventional Vehicle**: Introduction to Hybrid Electric 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, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, Electric Propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, switched reluctance motor.

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.

Energy Storage Requirements:- Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices.

Fundamental of Rechargeable batteries: Electrochemistry, Lithium batteries, Nickel metal hydride battery, Lead-acid battery, High temperature batteries for back-up applications, Flow batteries for load leveling and large scale grid application, Battery applications for stationary and secondary use, Battery chargers and battery testing procedures, Battery management, Regulations and safety aspects of high voltage batteries, Super capacitors.

Business: E-mobility business, electrification challenges, Business- E-mobility business, electrification challenges, Connected Mobility and Autonomous Mobility- case study E-mobility Indian Roadmap Perspective.

Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs. Simulations and case studies in above mentioned areas.

Course Outcomes:

1. To understand the design of electric vehicles, business model, policy, impact etc.
2. To analyze and designing of electric vehicles
3. To evaluate the challenges of electric vehicle business and policy
4. To evaluate different aspects of design-control of EVs.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√	√	√
2	√		√	√	√
3	√	√	√	√	√
4	√		√	√	√

Recommended books:

1. Emadi, A. (Ed.). (2014). Advanced electric drive vehicles. CRC Press.
2. Larminie, J., & Lowry, J. (2012). Electric vehicle technology explained. John Wiley & Sons.
3. Fenton, J., & Hodkinson, R. (2001). Lightweight electric/hybrid vehicle design. Elsevier.
4. Dincer, I., Hamut, H. S., & Javani, N. (2016). Thermal management of electric vehicle battery systems. John Wiley & Sons.
5. Williamson, S. S. (2013). Energy management strategies for electric and plug-in hybrid electric vehicles. New York, NY: Springer.
6. Pistoia, G., & Liaw, B. (Eds.). (2018). Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost. Springer.
7. Reddy, T. B. (2011). Linden's handbook of batteries (Vol. 4). New York: Mcgraw-hill.
8. Larminie, J., & Lowry, J. (2012). Electric vehicle technology explained. John Wiley & Sons.

Course Code	Course Title	L	T	P
RE-513	Fuel cell and hydrogen energy	3	0	0

Pre-requisites: Basic knowledge of Engineering.

Course objectives:

- To learn basics of fuel cell and the fundamental principle associated with it.
- To imparts comprehensive and logical knowledge of hydrogen production, storage and utilization.

Syllabus:

Fuel cells: Introduction and overview, operating principle, polarization curves, components, types of fuel cell, low and high temperature fuel cells, fuel cell stacks.

Thermodynamics and Electrochemistry of fuel cell: application of the first and second law to fuel cells, significance of the Gibbs free energy, concept of electrochemical potential and emf, half cell potentials and the electrochemical series, Faraday's law, Nernst equation, Butler–Volmer theory thermodynamic efficiencies of fuel cell in comparison to Carnot efficiencies, thermodynamic advantage of electrochemical energy conversion

Fuel cell technology: Types of Fuel Cells, Fuel Cell systems and sub-systems, system and subsystem integration; Power management, Thermal management; Pinch analysis

Fuel cell characterization: In-situ and Ex-situ; System and components' characterization modeling a Fuel Cell

Hydrogen Production: Properties of hydrogen as fuel, General introduction to infrastructure requirement for hydrogen production, Thermal-steam reformation, Thermo-chemical water splitting, Gasification-pyrolysis, Storage, Dispensing and utilization, Hydrogen Storage, Metal hydrides, chemical hydrides, carbon nano-tubes; sea as the source of Deuterium, methane hydrate, etc.

Hydrogen Economy: Hydrogen as an alternative fuel in IC engines; Suitability of Hydrogen as a fuel, and techno-economic aspects of fuel cell as energy conversion device; Hydrogen fuel for transport

Bio-Hydrogen: Production of bio hydrogen; production of hydrogen by fermentative bacteria, Hydrogen, Methane and Other Energy Fuels Energy from Algae: Algae Cultivation, Photo-bioreactors,

Hydrogen Storage, Utilization and Safety: Physical and chemical properties, General storage methods, Compressed storage-composite cylinders, Glass micro sphere storage, Zeolites, Metal hydride storage, Chemical hydride storage, Cryogenic storage, Carbon based materials for hydrogen storage, Overview of hydrogen utilization, Hydrogen burners, Power plant, Marine applications, Hydrogen dual fuel engines, Hydrogen safety aspects, Backfire, Pre-ignition,
Hydrogen emission, NOx control techniques and strategies, Hydrogen powered vehicles.

Course Outcomes:

1. To understand the fundamentals of various types of fuel cell system, its components and characterization
2. To understand comprehensive background in fuel cell base systems and hydrogen technologies
3. To understand hydrogen generation techniques, storage and hydrogen economy.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√			√	
2			√		√
3	√	√		√	

Recommended books:

1. O'Hayre R. P., Cha S. W., Colella W., and Prinz F. B., (2008). Fuel cell fundamentals, John Wiley
2. Spiegel C. (2011), PEM Fuel Cell Modeling and Simulation Using Matlab, Elsevier Science.
3. Vielstich W., Lamm A., and Gasteiger H. A. (2003), Handbook of Fuel Cells: Fundamentals, Technology, Applications, Vol (1-4), Wiley
4. Sørensen, B., & Spazzafumo, G. (2018). Hydrogen and fuel cells: emerging technologies and applications. Academic Press.
5. Hordeski, M. F. (2009). Hydrogen & fuel cells: advances in transportation and power. The Fairmont Press, Inc..
6. Töpler, J., & Lehmann, J. (2016). Hydrogen and Fuel Cell. Springer: Berlin/Heidelberg, Germany.

Course Code	Course Title	L	T	P
RE-514	**Solar refrigeration and Air conditioning**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

Course objectives:

- To provide understanding of fundamental concepts of solar operated refrigeration and air conditions.
- To provide fundamental knowledge desiccant material and desiccant air conditioning systems.
- To provide understanding of fundamental concepts the solar adsorption refrigeration system.
- To understand the design of solar powered absorption refrigeration system and its applications.

Syllabus:

Introduction: Basics of refrigeration and air conditioning, comfort zones, potential and scope of solar cooling and heating, fundamentals of conventional vapour compression system and vapour absorption system. Solar cooling technology: solar electrical cooling, solar thermal cooling:- open cycles (liquid and solid desiccant system), closed cycle (absorption cycle, adsorption cycle, solar radiation cooling), thermo mechanical systems, steam ejector cycle, solar combined power/cooling.

Desiccant Air Conditioning: Desiccant materials, classification of desiccant material, fundamentals of desiccant material: adsorption process, regeneration process, adsorption rate, regeneration rate, factor affecting adsorption and regeneration of desiccant material, heating/humidification, cooling/dehumidification, desiccant dehumidifiers: desiccant bed, desiccant wheel, desiccant coated heat exchanger, solar powered desiccant air conditioning system.

Adsorption Refrigeration System: Introduction, principle of adsorption, thermodynamics of adsorption cycles: - basic adsorption cycle, heat recovery adsorption refrigeration cycle, mass recovery adsorption refrigeration cycle, thermal wave cycle, convective thermal wave cycle, intermittent adsorption systems: silica-gel/water and silica-gel methanol systems, zeolite–water systems, activated carbon–methanol systems, activated carbon–ammonia systems.

Absorption Refrigeration System: Absorption cycle of operation, maximum, COP, properties of solution, aqua-ammonia solution, simple absorption system, h-x diagram, ammonia enrichment process and water -lithium bromide refrigeration system, single-effect solar absorption cycle, half-effect solar absorption cooling system, double-effect solar-assisted absorption cooling systems, diffusion absorption solar cooling system, hybrid solar absorption cooling systems.

Potential and scope of solar cooling: Types of solar cooling systems, solar collectors and storage systems for solar refrigeration and air conditioning, Solar operation of vapor absorption and compression refrigeration cycles and their assessment, Solar dessicant cooling system. Open cycle absorption/desorption solar cooling alternatives, advanced solar cooling systems, refrigerant storage for solar absorption cooling systems, solar thermoelectric refrigeration and air conditioning. Economics of solar cooling

Course Outcomes:

1. Understand refrigeration and air conditioning concepts.
2. Evaluate various air conditioning and refrigeration systems.
3. Apply passive and colling aspects.
4. Understand different testing standards and its applications

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		
2	√			√	
3		√			
4	√	√			√

Recommended books:

1. Mugnier, D., Neyer, D., & White, S. D. (Eds.). (2017). The solar cooling design guide: case studies of successful solar air conditioning design. John Wiley & Sons.
2. McVeigh, J. C., & Sayigh, A. A. M. (Eds.). (2012). Solar air conditioning and refrigeration. Newnes. Pergamon.
3. Prasad, M. (2011). Refrigeration and air conditioning. New Age International.
4. Wang, R., & Ge, T. (Eds.). (2016). Advances in solar heating and cooling. Woodhead Publishing.
5. Garg, H. P. (1987). Solar Refrigeration and Air-Conditioning. In Advances in Solar Energy Technology (pp. 342-442). Springer, Dordrecht.

Course Code	Course Title	L	T	P
RE-515	**Energy storage**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

Course objectives:

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

Syllabus:

Energy availability: Demand and storage, Need for energy storage, Different types of energy storage; Mechanical, Chemical, Electrical, Electrochemical, Biological, Magnetic, Electromagnetic, Thermal; Comparison of energy storage technologies.

Thermal energy storage: principles and applications, Sensible and Latent heat, Phase change materials; Energy and exergy analysis of thermal energy storage, solar energy and thermal energy storage, case studies.

Mechanical Energy storage: Flywheel and compressed air storage; Pumped hydro storage; Hydrogen energy storage, Capacitor and super capacitor, Electrochemical Double Layer Capacitor: Principles, performance and applications

Electrochemical energy storage: Battery – fundamentals and technologies, characteristics and performance comparison: Lead-acid, Nickel-Metal hydride, Lithium Ion; Battery system model, emerging trends in batteries.

Hydrogen as energy carrier and storage: Hydrogen resources and production; Basic principle of direct energy conversion using fuel cells; Thermodynamics of fuel cells

Fuel cell types: AFC, PEMFC, MCFC, SOFC, Microbial Fuel cell, Fuel cell performance, characterization and modeling; Fuel cell system design and technology, applications for power and transportation.

Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage: Greenhouse heating; Drying and heating for process industries.

Course Outcomes:

1. To understand the theory and applications of different energy storage devices
2. To analyze and identify the optimal (appropriateness, cost and sustainability) solutions to any potential energy storage application.
3. Evaluate utilization, sizing and operation of energy storage systems.
4. To understand different aspects and parameters of electrical energy storage systems.
5. Apply the knowledge gained for energy storage integration and hybrid energy storage system.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	√	√		√	
2			√		√
3	√	√	√	√	√
4	√	√			
5	√		√	√	

Recommended books:

1. Dincer I., and Rosen M. A. (2011); Thermal Energy Storage: Systems and Applications, Wiley
2. Huggins R. A. (2015). Energy Storage: Fundamentals, Materials and Applications. Springer
3. O'Hayre R., Cha S., Colella W., and Prinz F. B. (2009). Fuel Cell Fundamentals, Second Edition, Wiley
4. Narayan R. and Viswanathan B. (1998). Chemical and Electrochemical Energy System, Universities Press
5. Rahn C. D. and Wang C. (2013). Battery Systems Engineering, First Edition, Wiley
6. Miller F. P., Vandome A. F., and John M. B. (2010). Compressed Air Energy Storage, VDM Publishing

Course Code	Course Title	L	T	P
RE-516	**Developing Energy Efficiency and Renewable Energy Projects**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

Course objectives: To introduce all relevant steps as well as the issues and challenges involved in developing projects on energy efficiency and renewable energy utilization. The course also aims at discussion on policy, regulatory and other support measures that can promote such projects.

Syllabus:

Relevance of developing energy efficiency: Renewable energy projects, Key project development concepts,

Project motivation: Key drivers-pre development, gauging market characteristics that provide motivation for the project and assessment of market readiness, Project development framework, Essential elements, project development environment including existing policy environment-relevant codes (such as ECBC),

Pre-investment phase: assessing potential sites, identifying partners, Assessment of commercially available energy technologies for improving energy efficiency and harnessing renewable energy, preparation of business plan (that includes feasibility study, engineering design, Financial closure, permitting activities and related documentation and agreements), consensus with project stakeholders

Implementation phase: Procurement, land acquisition, site preparation, construction, installation, commissioning of the project, operation of the facility, Actual implementation of the business plan, Monitoring and evaluation of the business and the project performance, Issues in implementation of energy efficiency and renewable energy projects, Essential areas for strong project development in renewable energy - site, resource, permits, technology, team and capital, Size and diversity of potential project sponsors and also of projects in the field of renewable energy and energy efficiency,

Risks Factor: Risk in energy efficiency and renewable energy projects and appropriate de- risking/ mitigation measures and approaches, dispute resolution,

Role of policies: Policy and support measures in promoting energy efficiency and renewable energy, Developing community driven projects, Developing projects for improving energy access, socially inclusive projects,

Issue and Challenges: Issues in using public lands for developing renewable energy projects, Various considerations in selecting local versus imported technologies, Challenges in implementing energy efficiency in public sector within government financial and other regulations, Environmental impact and sustainability assessment of energy efficiency and renewable energy projects and projects while addressing environmental issues, Utility scale versus local projects,

Examples and Case Studies: developing PV/wind power projects, projects for enhanced LED use in domestic, commercial, institutional and industrial sectors, environmental management projects

Course Outcomes:

1. To understand energy efficiency measures in domestic, agriculture and industrial sectors
2. To analyze financial and economical performance of energy systems
3. To understand issues and challenges with the energy efficient systems.
4. To develop energy efficient systems and policies for the same.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		
2		√	√		√
3	√		√	√	
4		√		√	√

Recommended books:

1. Lokey, E. (2012). Renewable energy project development under the clean development mechanism: a guide for Latin America. Routledge.
2. Springer, R. (2013). Framework for Project Development in the Renewable Energy Sector (No. NREL/TP-7A40-57963). National Renewable Energy Lab.(NREL), Golden, CO (United States).
3. Ontario Sustainable Energy Association. (2010). Guide to developing a community renewable energy project in North America. Montreal, Canada
4. PVPS, I. (2003). 16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries. International Energy Agency IEA-PVPS.T9-07
5. Trieb, F. (2006). Concentrating solar power now. DLR, Berlin, Germany.

Course Code	Course Title	L	T	P
RE-517	Energy, Climate Change and Carbon Trade	3	0	0

Pre-requisites: Basic knowledge of Engineering.

Course objectives:

- To impart knowledge about the renewable energy and impacts on climate
- To introduce the fundamental concepts climate change and carbon trading
- To enable the students to understand the relevance of sustainability in terms of energy.

Syllabus:

Energy and Climate Change: Global Consensus, GHGs emission and energy activities; Montreal protocol, evidence and predictions and impacts, Clean energy technologies, Energy economy, Risk and opportunities; Measures to reduce GHGs; Role of renewable energy, Evidence of economic impacts of climate change and economics of stabilizing greenhouse gases.

Climate Change Act: Kyoto Protocol and CDM, Governments policies for mitigation and adaptation, National Action Plan on Climate change, Nationally Appropriate Mitigation Actions (NAMA), Intended Nationally Determined Contributions (INDCs).

New Industrial Emissions Directive: Categorization of Scope 3 Emissions for Streamlined Enterprise Carbon Foot printing, Calculating Scope 3 Emissions

Emissions: Carbon dioxide (CO2) emissions due to energy conversion; combustion physics; case studies and comparison of (i) different technologies and (ii) different resources used for energy conversion; Role of technology up-gradation and alternative resources on reduction of CO2 emission; Methodology for CO2 assessment; UNFCCC baseline methodologies for different conversion process, estimation of emission from fossil fuel combustion; Case studies

Carbon credit: concept and examples; Commerce of Carbon Market, Environmental transformation fund; Technology perspective: Strategies for technology innovation and transformation; future prospect/limitation of carbon trading mechanism

Course Outcomes:

1. To understand the current problems of climate change, international pressure on climate change compliance and competition for energy and global initiative to address the issues.
2. To understand the concept and implications of carbon trading to reduce the emission.
3. Evaluate the relationship between Energy and Environment.
4. Understand and apply different framework for climate and sustainability.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√	√	√		
2	√		√	√	
3	√	√		√	√
4		√			√

Recommended books:

1. Mathez E. A. (2009). Climate Change: The Science of Global Warming and Our Energy Future, First edition, Columbia University Press
2. Dessler A. (2011). Introduction to Modern Climate Change, Cambridge University Press
3. Stern N. (2007). The Economics of Climate Change. The Stern Review. Cambridge University Press
4. IPCC (Intergovernmental for Climate Change), Climate Change (2007). Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press
5. Yamin F. (ed) (2005). Climate Change and Carbon Markets: A Handbook of Emissions Reduction Mechanisms, Earthscan
6. Franchetti M. J. and Apul D. S. (2013). Carbon Footprint Analysis: concepts, methods, implementation and case studies, CRC Press

Course Code	Course Title	L	T	P
RE-518	Energy Efficient Buildings	3	0	0

Pre-requisites: Basic knowledge of Engineering.

Course objectives: This course includes an overview of the main design features of different types of buildings, advantages and disadvantages and their applicability to different building types and climatic regions. This course aims to provide an understanding on the concept of reduction in energy consumption through energy efficient building design.

Syllabus:

Energy management concept in building: Energy auditing in buildings, Bioclimatic classification of India; Climate Analysis for Nat-Vent Buildings, Mixed Mode Buildings and Conditioned building; Passive design concepts for various climatic zones; Case studies on typical design of selected buildings in various climatic zones

Vernacular architecture: Vernacular architecture in Indian Context, Factors which shape the architecture, building material and construction techniques; Case studies on vernacular architecture of Rajasthan, North-East India; Low cost buildings, climate responsive buildings, energy efficient buildings, green buildings, intelligent buildings, Building Integrated Photovoltaics (BIPV), Green Buildings in India; Case studies

Building codes and Rating systems: LEED, GRIHA, ECBC, Thermal properties and energy content of building materials; Building energy simulation, Simulation tool like TRANSYS, eQuest; Building management systems/automation, Artificial and daylighting in buildings **Thermal performance studies:** concept of comfort and neutral temperatures, Thermal comfort, PMV-PPD models, Thermal comfort models, Adaptive thermal comfort models, case studies

Heat flow calculations in buildings: Unsteady heat flows through walls, roof, windows etc. Concept of sol-air temperature and its significance; heat gain through building envelope; building orientation; shading and overhangs; Ventilation and Air-conditioning systems

Passive heating concepts: Passive and low energy concepts and applications, Direct heat gain, indirect heat gain, isolated gain and sunspaces; Passive cooling concepts: Evaporative cooling, radiative cooling; Application of wind, water and earth for cooling; Shading, paints and cavity walls for cooling; Roof radiation traps; Earth air-tunnel

Course Outcomes:

1. To understand the principles of energy auditing, energy flow diagram, economics of energy conservation opportunities in buildings
2. To understand thermal performance study, building performance simulation and thermal comfort
3. To understand the energy conservation buildings codes, rating systems and case studies on energy efficient buildings in India.
4. To apply standards, codes and ratings in the design of energy efficient buildings.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes 1	2	3	4	5
1	√		√	√	
2	√	√			√
3	√		√		√
4		√		√	

Recommended books:

1. Sodha M. S. Bansal N. K. Bansal P. K. Kumar A. and Malik M. A. S. (1986). Solar Passive Building, Science and Design, Pergamon Press
2. Gallo C. Sala M. and Sayigh A. A. M. (1988). Architecture: Comfort and Energy, Elsevier Science
3. Nayak J. K. and Prajapati J. A. (2006). Handbook on Energy Conscious Buildings; Solar Energy Centre, New Delhi
4. Underwood C. P. and Yik F. W. H. (2004). Modelling Methods for Energy in Buildings, Blackwell Publishing
5. Parsons K. C. (2003). Human Thermal Environments, Second edition, Taylor and Francis
6. Majumder M. (2009). Energy Efficient Buildings, TERI, New Delhi
7. Nicol F. (2007). Comfort and Energy Use in Buildings- Getting Them Right, Elsevier

Course Code	Course Title	L	T	P
RE-519	Renewable Energy Grid Integration	3	0	0

Pre-requisites: Basic knowledge of Engineering.

Course objectives:

- To learn smart grid technology, different and advance metering infrastructure.
- To learn power quality management issues in smart grid.
- To learn the simulation for smart grid designing and analysis.

Syllabus:

Power system operation: Introduction on electric grid, Supply guarantees, power quality and Stability, Introduction to renewable energy grid integration, concept of mini/micro grids and smart grids; Wind, Solar, Biomass power generation profiles, generation electric features, Load scheduling

Power electronic systems: Introduction to basic analysis and operation techniques on power electronic systems; Functional analysis of power converters, Power conversion schemes between electric machines and the grid, Power systems control using power converters; Electronic conversion systems application to renewable energy generation systems, Basic schemes and functional advantages; Wind Power and Photovoltaic Power applications

Power control and management systems: Grid integration, island detection systems, synchronizing with the grid; Issues in integration of converter based sources; Network voltage management; Power quality management and Frequency management; Influence of PV/WECS on system transient response

Simulation: tools, Simulation of grid connected/off grid renewable energy system (PV/WECS); Design of grid-interactive photovoltaic systems for house hold applications.

Course Outcomes:

1. To understand the distributed generation systems.
2. To identify emerging issues with renewable grid integration.
3. To understand the requirements for the correct integration of renewable energies into the power grid.
4. To understand power electronic components necessary for integration to include inverters and their control, island detection systems, and maximum power point tracking.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1		√	√		
2	√		√	√	√
3	√	√		√	
4	√		√		

Recommended books:

1. Kersting W. H. (2004). Distribution System Modeling and Analysis, Second Edition, CRC Press
2. Vittal V. and Ayyanar R. (2012). Grid Integration and Dynamic Impact of Wind Energy, Springer
3. Bollen M. H. and Hassan F. (2011). Integration of Distributed Generation in the Power System, Wiley-IEEE Press
4. Keyhani A. (2011). Design of Smart Power Grid Renewable Energy Systems, Wiley–IEEE Press
5. Muhannad H. R. (2004). Power Electronics: Circuits, Devices and Applications, Pearson Prentice Hall
6. Gellings C. W. (2009). The Smart Grid: Enabling Energy Efficiency and Demand Response, First Edition, CRC Press
7. Teodorescu R. Liserre M. Rodriguez P. (2011). Grid Converters for Photovoltaic and Wind Power Systems, First Edition, Wiley-IEEE Press

Course Code	Course Title	L	T	P
RE-520	**Energy Conservation by Waste Heat Recovery**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

Course objectives: This course will provide information about the industrial energy inputs, waste heat in the form of exhaust gases, cooling water, and heat lost from equipment surfaces and heated products. Further aim of this course is to improve energy efficiency, recovering waste heat losses for an emission free and less costly energy resource.

Syllabus: **Introduction:** heat losses, its quality and quantity, potential for energy conservation. Waste heat sources: steam, compressed air, refrigeration, flue gases, furnace/air stream exhaust, high grade heat, low grade heat

Optimal utilization of fossil fuels: Total energy approach; Coupled cycles and combined plants; Cogeneration systems

Exergy analysis: Utilization of industrial waste heat; Properties of exhaust gas; Gas-to- gas, gas-to-liquid heat recovery systems; Recuperators and regenerators; Shell and tube heat exchangers; Spiral tube and plate heat exchangers

Waste heat boilers: various types and design aspects. Heat pipes: theory and applications in waste heat recovery.

Prime movers: sources and uses of waste heat; Fluidized bed heat recovery systems; Utilization of waste heat in refrigeration, heating, ventilation and air conditioning systems; Thermoelectric system to recover waste heat; Heat pump for energy recovery; Heat recovery from incineration plants

Waste Heat Recovery calculations: Quantifying available heat (kWh), Pinch analysis, typical energy costs/construction costs, pay back analysis, thermo-economic viability.

Need for energy storage: Thermal, electrical, magnetic and chemical storage systems.

Course Outcomes:

1. To understand the on basic principles and available technologies for waste heat recovery.
2. To understand industrial waste heat recovery systems.
3. Analyze and design energy efficient system to recover heat from industries.
4. To understand exergy analysis, waste heat recovery calculations and energy storage needs.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	√	√		√	
2		√			
3	√		√	√	√
4	√		√		

Recommended books:

1. Hewitt, G. F., Shires, G. L., and Bott, T. R. (1993). Process Heat Transfer, CRC Press, Florida.
2. Flynn, A. M., Akashige, T., & Theodore, L. (2019). Kern's Process Heat Transfer. John Wiley & Sons.
3. Goswami, D. Y., and Kreith, F. (2007). Energy Conversion, CRC Press.
4. Serth, R. W., & Lestina, T. (2014). Process heat transfer: Principles, applications and rules of thumb. Academic press.
5. Beith, R. (Ed.). (2011). Small and micro combined heat and power (CHP) systems: advanced design, performance, materials and applications. Elsevier.
6. Khanna, S., & Mohan, K. (Eds.). (1996). Wealth from waste. Tata Energy Research Institute.
7. Eriksen, V. L. (Ed.). (2017). Heat Recovery Steam Generator Technology. Woodhead Publishing.

Course Code	Course Title	L	T	P
RE-521	**Biomass characterization and management**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

Course objectives: This course provides overall information on concepts, tools and techniques for converting the different biomass into various energy forms for starting the biomass-based energy production and its management.

Syllabus: **Introduction:** properties of biomass, different energy conversion methods combustion, Bio Energy Resources, World Bio Energy Potential, India's Bio Energy Potential, Biomass Resources and classification, Physio - chemical characteristics

Biomass Cookstoves: Energy Systems Energy Efficient Wood Stoves, Traditional Stoves, Energy Efficient Cooking and Space heating Stoves, Metal Stoves Improved Gasifier Stoves, Current Research Status, Pollution due to smoke emissions, Improved Cookstoves, National Policy on cookstove

Characterization of biomass feedstock: physico-chemical properties, ultimate, proximate, compositional, calorific value, thermogravimetric, differential thermal and ash fusion temperature analyses; classification of biomass feedstock

Application of biomass fuel: Biomass based incineration plant for heat generation; co-firing of biomass for heat generation for industrial processes; Biomass fuelled combustion devices for cooking and heating applications; Utilization of biomass in external combustion engines including steam turbine power plant and Stirling engines; Case studies for setting up biomass based small power plant (~ 1MW) capacity for rural electrification; analysis of carbon neutral and carbon credit.

Biomass Management: Introduction to biomass management, biomass resource assessment management techniques/supply chains, Processing of paddy straw, densification-Extrusion process, pellets, mills and cubers, Bailing-classification, uses; residue management for surface mulch and soil incorporation, Paddy Straw choppers and spreaders as an attachment to combine Harvester, Mulch seeder, Paddy Straw Chopper-cum-Loader, Balar for collection of straw; Processing of straw/ fodder for animal use; Agricultural and horticultural use, Cushioning material for fruits and vegetables, Mulching and Composting, Paper and cardboard manufacturing, Straw as a fuel.

Biomass resource assessment management techniques/supply chains: Elements of an Assessment or Feasibility Study , Objectives of biomass resource assessment, Biomass resource from agricultural and residues, Biomass resource from forestry, Biomass resource from live stock (animals), Technologies available for the conversion of biomass, Techno-economic feasibility of suitable renewable energy generation system

Course Outcomes:
1. To understand the on basics of biomass resources and it composition
2. To understand biomass sample preparation, methods of pre-treatments and characterization
3. To understand and analyze the biochemical and ultimate properties of biomass.
4. To understand supply chain methods of biomass management.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		√
2	√	√		√	
3	√	√	√	√	
4			√		√

Recommended books:

1. Cheng, J. (Ed.). (2017). Biomass to renewable energy processes. CRC press.
2. Strezov, V., & Anawar, H. M. (Eds.). (2018). Renewable Energy Systems from Biomass: Efficiency, Innovation and Sustainability. Crc Press.
3. Holm-Nielsen, J., & Ehimen, E. A. (Eds.). (2016). Biomass supply chains for bioenergy and biorefining. Woodhead Publishing.
4. Jeguirim, M., & Limousy, L. (Eds.). (2019). Char and Carbon Materials Derived from Biomass: Production, Characterization and Applications. Elsevier.
5. Mukunda, H. S. (2011). Understanding clean energy and fuels from biomass. Wiley India.
6. Tumuluru, J. S. (Ed.). (2018). Biomass preprocessing and pretreatments for production of biofuels: mechanical, chemical and thermal methods. CRC Press.

Course Code	Course Title	L	T	P
RE-522	Fuels & Combustion Technology	3	0	0

Pre-requisites: Basic knowledge of Engineering.

Course objectives:
- To impart knowledge on fossil fuel and their combustion characteristics.
- To make students inquisitive about the problems of combustion.

Syllabus:

Basics of fuels: Modern concepts of fuel, Solid, liquid and gaseous fuels, composition, basic understanding of various properties of solid fuels - heating value, ultimate analysis, proximate analysis, ash deformation points; liquid fuels - heating value, density, specific gravity, viscosity, flash point, ignition point (self, forced), pour point, ash composition and gaseous fuels.

Coal as a source of energy: Coal reserves – World and India, Coal liquefaction process, various types of coal and their properties, Origin of coal, composition of coal, analysis and properties of coal, Action of heat on coal, caking and coking properties of coal; Processing of coal: Coal preparations, briquetting, carbonization, gasification and liquefaction of coal, Coal derived chemicals.

Petroleum as a source of energy: Origin, composition, classification of petroleum, grading of petroleum; Processing of petroleum: Distillation of crude petroleum, petroleum products, purification of petroleum products – thermal processes, catalytic processes, specifications and characteristics of petroleum products.

Natural gas and its derivatives: Classification of gaseous fuels – natural gas and synthetic gases, Natural gas reserves - World and India, properties of natural gas – heating value, composition and density

Principles of combustion: Chemistry and Stoichiometric calculation, thermodynamic analysis and concept of adiabatic flame temperature; Combustion appliances for solid, liquid and gaseous fuels: working, design principles and performance analysis.

Emissions from fuel combustion systems: Pollutants and their generation, allowed emissions, strategies for emission reduction, Euro and BIS norms for emission, recent protocols

Course Outcomes:
1. To understand the fuel combustion process.
2. Apply fundamental aspects of combustion related problems and an understanding on the combustion appliances.
3. Evaluate the environmental benefits and consequences of available fuel technology.
4. Analyze and describe the nature of transportation and stationary engines and fuels.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1		√		√	
2	√	√	√		√
3	√		√	√	
4	√				√

Recommended books:

1. Raghavan, V. (2016). Combustion technology: essentials of flames and burners. John Wiley & Sons.
2. Sharma, S. P., & Mohan, C. (1984). Fuels and combustion. Tata McGraw Hill
3. Sarkar, S. (1974). Fuels and combustion. Universities Press. Orient Longman
4. Sharma, B. K. (1998). Fuels and Petroleum Processing. Krishna Prakashan Media.
5. Hsu, C. S., & Robinson, P. R. (Eds.). (2017). Springer handbook of petroleum technology. Springer.
6. Zheng, C., & Liu, Z. (Eds.). (2017). Oxy-fuel Combustion: Fundamentals, Theory and Practice. Academic Press.
7. Maurya, R. K., Maurya, R. K., & Luby. (2018). Characteristics and control of low temperature combustion engines. Springer.

Course Code	Course Title	L	T	P
RE-523	**Advanced Wastewater Treatment**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

Course objectives: This subject aims to give knowledge to the students regarding advanced wastewater treatment technologies

Syllabus:

Overview of Advanced Waste Water Treatment: Introduction, Need of Advanced Waste Water Treatment, Purpose of Advanced Waste Water Treatment

Waste water collection: sewerage systems and sewage pumping, natural drainage system and waste water disposal; Typical sewage quality, its composition and health hazards of handling and disposal

Waste Removal: Nitrogen & Phosphorus Nitrogen Removal, Nitrification, Denitrification Phosphorus removal by Biological Precipitation, Bioremediation, Microorganisms involved in the process, Process configurations, screening, grit removal, flow equalisation, sedimentation; aerobic, anaerobic, attached and suspended growth processes.

Processes: Fundamentals of adsorption, Type of adsorbents, Development of adsorption isotherms, Membrane Process Terminology, Microfiltration, Ultrafiltration, Nano filtration, Reverse Osmosis, Electrodialysis Membrane Configurations, Plate-and-frame module , Spiral- wound module, Tubular module, Hollow-fiber module Membrane Fouling, Modes of membrane fouling , Control of membrane fouling Application of membrane processes: Microfiltration , Ultrafiltration, Nanofiltration, Reverse Osmosis

Membrane Bio Reactor: Introduction MBR Process, Description, Membrane Bioreactor with Membrane Module Submerged in the Bioreactor, Membrane Bioreactor with Membrane Module Situated Outside the Bioreactor MBR System Features Membrane Module Design Considerations Process Applications : Industrial Wastewater Treatment, Municipal Wastewater

Ion Exchange: Fundamentals of Ion Exchange Types of Ion Exchange Resins Theory of Ion Exchange Applications, Removal and recovery of heavy metals , Removal of nitrogen , Removal of phosphorus , Organic chemical removal

Electrochemical Wastewater Treatment Processes: Introduction Electro-coagulation: Factors affecting Electrocoagulation, Electrode materials , Reactor configurations Electro-floatation : Factors affecting electro floatation Comparison with other technology, Reactor configurations Electro-oxidation : Electro oxidation process, Reactor configurations

Advanced Oxidation Processes: Theory of advanced oxidation, Types of oxidizing agents, ozone based and non ozone based processes Fenton and photo-Fenton Oxidation Solar Photo Catalytic Treatment Systems

Operation and maintenance of waste water treatment plants: polishing of treated waste water, disinfection, natural treatment systems; Treatment of sludge, disposal of treated effluent and sludge; Resource generation by way of biogas generation, sale of treated water and sludge, tertiary treatment, reuse of treated water in agriculture/horticulture/construction work, CDM of conservation facilities like STPs, toilets, crematoria to generate additional revenues;

Course Outcomes:

1. To apply advanced technologies in Wastewater treatment.
2. To select the most appropriates types of membrane processes for tertiary treatment of wastewater.
3. To apply advanced oxidation processes to treat concentrated non-biodegradable wastewater.
4. To apply tertiary treatment processes like adsorption, ion exchange for optimum removal of pollutants.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		
2	√	√	√	√	√
3					√
4		√			

Recommended books:

1. Davis, M. L., & Cornwell, D. A. (2008). Introduction to environmental engineering. McGraw-Hill.
2. Metcalf, L., Eddy, H. P., & Tchobanoglous, G. (1979). Wastewater engineering: treatment, disposal, and reuse (Vol. 4). New York: McGraw-Hill.
3. Davis, M. L. (2010). Water and wastewater engineering: design principles and practice. McGraw-Hill.
4. Judd, S. (2010). The MBR book: principles and applications of membrane bioreactors for water and wastewater treatment. Elsevier.
5. Aziz, H. A., & Mojiri, A. (Eds.). (2014). Wastewater engineering: Advanced wastewater treatment systems. IJSR Publications.
6. Henze, M., van Loosdrecht, M. C., Ekama, G. A., & Brdjanovic, D. (Eds.). (2008). Biological wastewater treatment. IWA publishing.
7. Nath, K. (2017). Membrane separation processes. PHI Learning Pvt. Ltd.

Course Code	Course Title	L	T	P
RE-524	**Power Generation, Distribution & Transmission**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of Engineering.

Course objectives: The subject will enhance the understanding of the students on power system dynamic stability, generation control, AC and DC transmission, and reactive power control, distribution systems along with conventional and intelligent controls.

Syllabus:

Generation: Synchronous generator operation, Power angle characteristics and the infinite bus concept, dynamic analysis and modeling of synchronous machines, Excitations systems, Primemover governing systems, Automatic generation control;

Auxiliaries: Power system stabilizer, Artificial intelligent controls, Power quality;

AC Transmission: Overhead and cables, Transmission line equations, Regulation and transmission line losses, Reactive power compensation, Flexible AC transmission;

HVDC transmission: HVDC converters, advantages and economic considerations, converter control characteristics, analysis of HVDC link performance, Multi-terminal DC system, HVDC and FACTS;

Distribution: Distribution systems, conductor size, Kelvin's law, performance calculations and analysis, Distribution inside and commercial buildings entrance terminology, Substation and feeder circuit design considerations, distribution automation, Futuristic power generation.

Course Outcomes:

1. To understand the on basic principles of power Generation, Distribution & Transmission
2. To understand techniques to optimize transmission losses.
3. Analyze and design power generation systems.
4. To develop integrated planning model for electricity infrastructures.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1			√	√	
2	√	√			√
3	√	√		√	
4	√		√		√

Recommended books:

1. Kim, C. K., Sood, V. K., Jang, G. S., Lim, S. J., & Lee, S. J. (2009). HVDC transmission: power conversion applications in power systems. John Wiley & Sons.
2. Gonen, T. (2011). Electrical power transmission system engineering: Analysis and design. CRC press.
3. Wood, A. J., Wollenberg, B. F., & Sheblé, G. B. (2013). Power generation, operation, and control. John Wiley & Sons.
4. Anderson, P. M., & Fouad, A. A. (2008). Power system control and stability. John Wiley & Sons.
5. Kundur, P., Balu, N. J., & Lauby, M. G. (1994). Power system stability and control (Vol. 7). New York: McGraw-hill.
6. Elgerd, O. I. (1982). Electric energy systems theory: an introduction, Tata McGraw-Hill.

Course Code	Course Title	L	T	P
RE-525	Nuclear Energy	3	0	0

Pre-requisites: Basic knowledge of Engineering.

Course objectives: This course provides an introduction to nuclear reactor technology with particular emphasis of power generation. It introduces the students to the key disciplines of reactor physics and thermal hydraulics as applied in the design of nuclear reactor system, nuclear fuel cycle. This course describes the development of new-generation reactors and key safety issues associated with nuclear power generation.

Syllabus:

Review of Nuclear Energy: Nuclear Fission, Types of nuclear fission reactors, nuclear fusion and its prospects, Radio topic generation and its applications, Nuclear power generation, Operation efficiency of steam cycles for nuclear power plants. The world-wide nuclear renaissance; comparison with other energy sources; public perception; non-proliferation and nuclear safeguards; financial costing; Nuclear energy program in India

Reactor Physics: Mechanism of Nuclear Fission and Fusion, Nuclides, Radioactivity, Decay chains, Neutron reactions (scattering, absorption, fission), Fission process and product distribution; neutron energy distribution; moderation; delayed neutrons; neutron cycle reactor types, Fast Breeding, Design and construction of nuclear reactors, Heat transfer techniques in nuclear reactors; Reactor shielding, boiling water reactors (BWR) Light water and heavy water pressurized water reactors (PWR) Light water heavy water, Gas cooled reactors, liquid cooled reactors.

Nuclear Fuel Cycle: Characteristics of nuclear fuels and various cycles, mining; conversion; enrichment; refueling; transport; reprocessing; waste handling; storage; geological disposal

Thermal-hydraulics and Fuel Design: Radial and axial flux profiles; general thermodynamic considerations; heat transfer processes from fuel to coolant; primary coolant system: fluid flow; frictional losses in pipes; pumped flow; heat exchanger types; steam generation; coolant/moderator selection; coolant circuit considerations

Reactor material properties and requirements: Fast breeder (FBR), Fissile and fertile materials, Breeding process, Gas cooled (He or CO2) FBR, Liquid metal cooled FBR (LMEBR), scope of FBR in power generation. Nuclear engineering design, Materials selection, Availability and cost, Computer programming for material election and reactor design.

Nuclear Waste Management: Scientific and engineering aspects of the management of spent fuel, Reprocessed high-level waste, Low-level wastes, Decommissioning wastes, Characteristics of nuclear wastes, Classification of nuclear wastes and waste forms, Discussion on performance assessment.

Course Outcomes:

1. To understand the principle of power generation from nuclear reactor
2. To understand and analyze the working of various types of reactors and materials properties that are used in it.
3. To understand the optimization of nuclear waste.
4. To design and use of nuclear energy for different applications.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1		√	√		
2	√			√	
3	√	√	√		√
4		√			

Recommended books:

1. Raymond M and Keith E. H. (2014); Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Seventh Edition, Butterworth-Heinemann
2. Bodansky D. (2008). Nuclear Energy: Principles, Practices and Prospects, Second Edition, Springer
3. John K. S. and Richard E. F. (2007). Fundamentals of Nuclear Science and Engineering, Second Edition, CRC Press
4. Lamarsh J. R. and Baratta A. J. (2001). Introduction to Nuclear Engineering, Third Edition, Pearson
5. Oka Y. and Kiguchi T. (2014). Nuclear Reactor Design, Fourth Edition, Springer.

Course Code	Course Title	L	T	P
RE-526	**Micro-Grid Operation and Control**	**3**	**0**	**0**

Pre-requisites: Basic Engineering all disciplines.

Course objectives : This course has been designed to develop the understanding of the Micro-Grid configuration, operation in various modes, integration of various RESs sources, protection and control design perspectives.

Syllabus:

Microgrid Concept: Introduction, Power system structure, Traditional Grid, Microgrid definition and characteristics, Typical micro grid configuration, Distributed renewable energy technologies, Interconnection of microgrids, Technical & Economical advantages of microgrid and key challenges,

IEEE Standard for Interconnection: Concept of area electric power system, Point of common coupling, General interconnection technical specifications and performance requirements, Reactive power capability and voltage/power control requirement, Voltage and Frequency disturbance ride-through requirements.

Integration of Solar Sources: Modeling of the entire PV energy conversion system, PV controller, EES controller, Grid Connection Control. Steps of control of entire PV energy system.

Integration of Wind Power Sources: Speed and power relations, Power extracted from the wind, Aerodynamic torque control, Control of a PMSG based wind energy generation system.

Microgrid Control: Hierarchical Microgrid Control, Local or primary Control: Droop Control, Droop Control in Inverter-based Distributed Generators, performance of primary controller, Secondary Control and Tertiary Control. Centralized and decentralized energy management system (EMS) in microgrids.

Microgrid Protection: Challenges in microgrid protection systems, Classification for microgrid protection: current limiter, centralized protection, distance protection. Islanding: Non-detection zone, Anti-islanding techniques, and different islanding scenarios.

Course Outcomes:

1. To explain the factors that required to design a MicroGrid for society and industry.
2. To apply IEEE standard for various interconnections.
3. To impart working, operation and control of solar and wind energy, and the integration of various sources in MicroGrid.
4. To understand and design control schemes and evaluate their performance.
5. To explain the islanding detection techniques and Microgrid protection.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	√		√	√	√
2	√		√		
3	√		√	√	√
4	√	√	√	√	√
5	√		√	√	

Recommended books:

1. Hatziargyriou, N. (Ed.). (2014). Microgrids: architectures and control. John Wiley & Sons.
2. Luo, F. L., & Hong, Y. (2017). Renewable energy systems: advanced conversion technologies and applications. CRC Press.
3. Zheng, D., Zhang, W., Netsanet, S., Wang, P., Bitew, G. T., Wei, D., & Yue, J. (2021). Microgrid Protection and Control. Academic Press.
4. Bevrani, H., François, B., & Ise, T. (2017). Microgrid dynamics and control. John Wiley & Sons.

Course Code	Course Title	L	T	P
RE-510	**Renewable Energy Lab**	**0**	**0**	**3**

Pre-requisites: Basic knowledge of energy systems.

Course objectives: The main focus of this laboratory is to provide exposure and hands-on-skills practice to the students on various aspects of renewable energy sources and technology. The students would be able to get detailed insights into the design and operational aspects of renewable energy devices and systems.

Syllabus:

1.To demonstrate the I-V and P-V characteristics of series and parallel combination of PV modules.
2.Determine the Performance (UL, FR, η) of the Parabolic Trough collector with fixed parameters with (i) Water and (ii) Oil as working fluid.
3.Determine the Performance (UL, FR, η) of the Parabolic Trough collector with varying parameters with (i) Water and (ii) Oil as working fluid.
4.Evaluation of UL, FR, η in thermosphonic mode of flow with fixed input parameters
5.Evaluation of UL, FR, η in thermosphonic mode of flow different radiation level
6.To find the Thermal Efficiency of natural draft cookstove as per BIS standards
7.To find the Thermal Efficiency of force draft cookstove as per BIS standards.
8. Charging period analysis of system containing PCM-1 (Organic Fatty Acid)
9.Discharging period analysis of system containing PCM-1 (Organic Fatty Acid)
10.Charging period analysis of system containing PCM-2 (Paraffin Wax)
11.Discharging period analysis of system containing PCM-2 (Paraffin Wax)
12.To evaluate the efficiency of charge controller in wind energy training system.

Course Outcomes:

1. To impart knowledge on fundamentals of economic principles and their applications in the broad field of supply and demand of energy
2. To make students inquisitive about the problems of energy economics and arousing their interest on practical problem-solving skills.
3. Able to gain knowledge on the application of renewable resources.

Mapping of course objectives (CO) & program outcomes (PO)					
	Program Outcomes				
Course Outcomes	**1**	**2**	**3**	**4**	**5**
1	√		√		√
2		√	√	√	
3		√			√

Course Code	Course Title	L	T	P
RE-530	**Computational Techniques & Data Analysis lab**	**0**	**0**	**3**

Pre-requisites: Basic knowledge of energy systems.

Course objectives: The main focus of this laboratory is to provide exposure and hands-on-skills practice to the students on various aspects of renewable energy sources and technology. The students would be able to get detailed insights into the design and operational aspects of renewable energy devices and systems.

Syllabus:

1.Measurement of Solar Radiation on horizontal and tilted surface and comparison with estimated values.
2.Analysis of wind and solar data from different data base.
3.Design standalone PV system using Simulation tool.
4.Design Hybrid system using Simulation tool.
5.Analysis of actual load demand using different methods.
6.Design PV Power plant using Simulation tool.
7.Model development of Renewable sources in MATLAB or Simulink.
8.Design a wind Power System using Simulation tool.
9.Design biomass-based energy system using simulation tools.
10.Energy data analysis using statistical software tools.

Course Outcomes:

1.To impart knowledge on designing and analysis of different renewable systems.
2.To understand the concept of modelling input and methods of renewable Energy Systems
3.To analyze energy systems under various design and off-design operating conditions.
4.To optimize the performance of different energy systems.
5.To understand different forecasting techniques and apply them to real conditions.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1			√		√
2	√		√	√	
3	√	√		√	√
4			√		
5	√			√	