M. Tech. in Energy Technology

Course structure

Department of Energy
Tezpur University
Tezpur, Assam, India

M. Tech. in Energy Technology Programme Syllabus w. e. f. 2013-2014 Session
Academic Council Approval: AC.20/2013/1/2.3 dated 11th May 2013

Course Structures

The students of M. Tech Programme in Energy Technology are offered:

(a) Core courses including both theoretical and experimental in different areas of energy
(b) Elective courses from diverse areas of energy studies for specialized knowledge
(c) IDC courses offered by other Departments to enhance the knowledge in domains parallel to energy studies
(d) Project work, where special emphasis is placed on the application of the knowledge and training for theoretical and experimental research in diverse areas of energy depending on student's interest

First Semester

Code	**Course Title**	**CH**	**Credit**
EN 501	Foundation for Energy Engineering	2	2
EN 502	Energy, Ecology and Environment	3	3
EN 503	Fuel and Combustion	3	3
EN 504	Heat Transfer	3	3
EN 505	Solar Energy Utilization	3	3
EN 506	Biomass Energy Utilization	3	3
EN 507	Wind and Hydro Energy	3	3
EN 508	Energy Laboratory	4	2
	IDC I	3	3
Total		**27**	**25**

Second Semester

Code	**Course Title**	**CH**	**Credit**
EN 510	Energy Management and Auditing	4	4
EN 511	Energy Economics and Planning	3	3
EN 512	Energy Systems and Simulation Laboratory	6	3
EN 513	Seminar	2	1
	Elective I	3	3
	Elective II	3	3
	IDC II	3	3
	IDC III	3	3
Total		**27**	**23**

Third Semester

Code	Course Title	**Credit**
EN 539	Project (Part - I)	8
Total		**8**

Fourth Semester

Code	Course Title	**Credit**
EN 540	Project (Part - II)	16
Total		**16**

Electives

Elective I		
Code	**Course Title**	**Credit**
EN 515	Advanced Bio-Energy	3
EN 516	Advanced Solar Thermal Energy	3
EN 517	Advanced Solar Photovoltaic Energy	3
EN 518	Hydrogen Energy and Fuel Cell	3
EN 519	Alternative Fuels for IC Engines	3
EN 520	Petroleum Exploration, Production and Refining	3

Elective II		
Code	**Course Title**	**Credit**
EN 525	Thermal Power Plant Engineering	3
EN 526	Energy Efficient Buildings	3
EN 527	Renewable Energy Grid Integration	3
EN 528	Decentralized Energy Systems	3
EN 529	Energy, Climate Change and Carbon Trade	3
EN 530	Instrumentation and Control for Energy Systems	3
EN 531	Numerical Heat Transfer and Fluid Flow	3
EN 532	Energy Conservation and Waste Heat Recovery	3
EN 533	Energy Storage Systems	3
EN 534	Energy Modeling and Optimization	3

Detailed Course Structures

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 501	**Foundation for Energy Engineering**	**2 0 0**	**2**	**2**

Thermodynamics: Laws of thermodynamics their applications, Concepts of internal energy, entropy, enthalpy and irreversibility, Gas laws, Thermodynamic cycles: theoretical and actual cycles, Heat engines and heat pumps/refrigeration

Fluid Mechanics: Properties of fluids and their measurements, conservation equations for mass, momentum and energy and their practical examples, Theory and principles of major flow measuring devices (Venturi meter, orifice meter, Pitot tube etc); Bernoulli's Equation: theory and applications, Boundary layer theory and practical significance, Uses of non-dimensional numbers to describe flow conditions, Understanding energy conversion principles of major hydraulic machines including turbines, pumps, fans, blower etc.

Electrical Networks: AC, DC Network components, Network theorems, Network reduction and analysis

Electrical Machines: Transformer, Induction motor and generators, Synchronous generators, Introduction to modern speed control techniques, DC machines, Characteristics and Applications; Torque Characteristic, Speed Control

Power systems: Introduction to power generations, power transmission and distribution, High voltage AC (HVAC) and High voltage DC (HVDC); power systems

Text Book

[1] Chakrabarti A. Nath S. and Chanda C. K. (2009); *Basic Electrical Engineering*, Tata McGraw Hill

[2] Dittman R. H. and Zemansky M. W. (2007); *Heat and Thermodynamics*, Spl. Indian Edition, Tata-McGraw Hill

Reference Book

[1] Balachandran P. (2011); *Engineering Fluid Mechanics*, Prentice Hall India

[2] Potter M. and Somerton C. (2009); *Thermodynamics for Engineers,* Second Edition, McGraw Hill

[3] Kundu P. K. Cohen I. M. and Dowling D. R. (2011); *Fluid Mechanics*, Fifth Edition, Academic Press

[4] Wadhwa C. L. (2012); *Generation, Distribution and Utilization of Electrical Energy,* Third Edition, New Age International

[5] Kadambi V. and Prasad M. (2008); *An Introduction to Energy Conversion: Basic Thermodynamics Vol. I*, New Age International

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 502	**Energy, Ecology and Environment**	**3 0 0**	**3**	**3**

Origin of the earth; Earth's temperature and atmosphere; Sun as the source of energy; Energy sources: classification of energy sources: conventional (coal, oil and gas) and renewable sources (solar, biomass, wind, hydro, geothermal, tidal, OTEC); quality and concentration of energy sources; World energy scenario; Fossil fuel reserves: estimation, India's energy scenario; energy and development linkage

Biological processes, photosynthesis, food chains; Ecological principles of nature, concept of ecosystems, different types of ecosystems, ecosystem theories; energy flow in the ecosystems; biodiversity

Environmental effects of energy extraction, conversion and use, Sources of pollution: primary and secondary pollutants; Consequence of pollution growth: Air, water, soil, thermal, noise pollution- cause and effect; Causes of global, regional and local climate change; Pollution control methods; Environmental laws on pollution control

Global warming: Green House Gas emissions, impacts, mitigation; Sustainability, Externalities, Future energy systems, Clean energy technologies, United Nations Framework Convention on Climate Change (UNFCC), Sustainable development, Kyoto Protocol, Conference of Parties (COP), Clean Development Mechanism (CDM), Prototype Carbon Fund (PCF)

Text Book

[1] Fowler J. M. (1984); *Energy and the Environment*, Second Edition, McGraw Hill
[2] Sorensen B. (2010); *Renewable Energy*, Fourth Edition, Academic press

Reference Book

[1] Masters G. (1991): *Introduction to Environmental Engineering and Science*, Prentice Hall
[2] Kaushika N. D. and Kaushik K. (2004); *Energy, Ecology and Environment: A Technological Approach*, Capital Publishing
[3] De A. K. (2005); *Environmental Chemistry*, New Age International
[4] Dessler A. (2011); *Introduction to Modern Climate Change*, Cambridge University Press
[5] Yamin F. (ed.) (2005); *Climate Change and Carbon Markets: A Handbook of Emissions Reduction Mechanisms*, Earthscan

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 503	**Fuel and Combustion**	**3 0 0**	**3**	**3**

Basics of fuels: Modern concepts of fuel, Solid, liquid and gaseous fuels, 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 and chemicals: Coal reserves – World and India, Coalification 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

Petroleum as a source of energy and chemicals: 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, density

Principles of combustion: Chemistry and Stoichiometry, 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

Text Book

[1] Sarkar S. (2009); *Fuels and Combustion*, Third Edition, Universities Press
[2] Sharma S. P. and Chander M. (1984); *Fuels and Combustion*, Tata McGraw Hill

Reference Book

[1] Mukunda H. S. (2009); *Understanding Combustion*, Second Edition, Universities Press
[2] Turns S. (2011); *An Introduction to Combustion: Concepts and Applications*, Third Edition, McGraw Hill
[3] Glassman I. and Yetter R. (2008); *Combustion*, Fourth Edition, Academic Press
[4] Sharma B. K. (1998); *Fuels and Petroleum Processing*, First Edition, Goel publishing
[5] Gupta O. P. (1996); *Elements of Fuels, Furnaces and Refractories*, Third Edition, Khanna Publishers

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 504	**Heat Transfer**	**3 0 0**	**3**	**3**

Heat transfer and its importance in energy study: Practical examples of conduction, convection and radiation

Theory and analysis of conduction heat transfer: analytical and numerical analysis of three-dimensional heat conduction – general solutions for different geometry

Thermo-physical properties of materials and role on conduction heat transfer, Insulation: concept and selection of insulation

Steady state conduction problems for cases concerning “with internal heat generation” and “without internal heat generation”

Heat transfer through fins/extended surface: examples of some typical industrial cases – numerical examples; Performance evaluation

Analytical and numerical analysis of transient and periodic state heat conduction, Concept of lump capacitance method and practical examples
Theory and analysis of convective heat transfer: natural and forced convection – practical examples

Velocity and thermal boundary layers analysis for external and internal flows (laminar and turbulent flow conditions): simplification and development of correlations

Physical significance of dimensionless numbers used in convective heat transfer, Boiling and condensation as heat transfer processes - uses of correlations for boiling and condensation

Heat exchangers: theory and performance analysis, Theory of radiation heat transfer: black body and real surfaces and gray body analysis: materials surface characteristics, Laws of radiation heat transfer, Concept of view factors – numerical examples, Numerical solution of radiation network analysis

Text Book

[1] Özışık M. N. (1985); *Heat transfer: A basic approach*, McGraw Hill
[2] Incropera F. P. and Dewitt D. P. (2006); *Fundamentals of Heat and Mass Transfer,* Fifth Edition, John Wiley

Reference Book

[1] Lienhard V J. H. and Lienhard IV J. H. (2011); *A Heat Transfer Textbook,* Fourth Edition, Dover Publication
[2] Holman J. P. (1992); *Heat Transfer*, Seventh Edition, McGraw Hill
[3] Gupta V. (1995); *Elements of Heat and Mass Transfer*, New Age International
[4] Ghajar A. J. and Cengel Y. A. (2011); *Heat and Mass Transfer*, Tata McGraw Hill
[5] Dutta B. K. (2009); *Heat Transfer: Principles and Applications*, First Edition, Prentice Hall India

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 505	**Solar Energy Utilization**	**3 0 0**	**3**	**3**

Solar radiation: Extra-terrestrial and terrestrial, radiation, radiation measurements; Earth-Sun relation: Solar angles, day length, angle of incidence on tilted surface; Sunpath diagrams; Shadow determination; Extraterrestrial characteristics; Effect of earth atmosphere; Measurement and estimation on horizontal and tilted surfaces; Indian solar radiation data analysis

Solar thermal conversion: Basics, Flat plate collectors-liquid and air type, Theory of flat plate collectors, selective coatings, advanced collectors, Concentrators: optical design of concentrators, solar water heaters, solar dryers, solar stills, solar cooling and refrigeration
Thermal storage; Active and passive conditioning of buildings; Conversion of heat into mechanical energy; Solar thermal power generation

Solar Photovoltaics: principle of photovoltaic conversion, fabrication of photovoltaic devices; PV system applications, PV power plant; PV system design and economics; new generation solar cells and emerging technologies

Solar Photocatalysis: Mechanism; Kinetics; Nano-catalysts, System design; Performance parameters; Applications

Text Book

[1] Nayak J. K. and Sukhatme S. P. (2006), *Solar Energy: Principles of Thermal Collection and Storage*, Tata McGraw Hill

[2] Solanki C. S. (2009); *Solar Photovoltaics: Fundamentals, Technologies and Applications*, Prentice Hall India

Reference Book

[1] Duffie J. A. and Beckman W. A. (2006); *Solar Engineering of Thermal Processes*, John Wiley

[2] Goswami D. Y. Kreith F. and Kreider J. F. (1999); *Principles of Solar Eng*ineering, Taylor and Francis

[3] Garg H. P. and Prakash S. (1997); *Solar Energy: Fundamental and Application*, Tata McGraw Hill

[4] Green M. (2005), *Third Generation Photovoltaics: Advance Solar Energy*, Springer

[5] Tiwari G. N. (2002); *Solar Energy: Fundamentals, Design, Modeling and Applications*, Narosa

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 506	**Biomass Energy Utilization**	**3 0 0**	**3**	**3**

Energy from biomass: sources of biomass, different species, production of biomass, photosynthesis, C_3 and C_4 plants on biomass production; classification of biomass; conversion of biomass into fuels; physicochemical characteristics of biomass as fuel; CO_2 fixation potential of biomass

Biomass resource assessment, application of remote sensing for resource assessment; biomass productivity study, energy plantation; basis of selection of plants for energy plantation; potential of biomass as energy sources: Worldwide and India

Biomass conversion process: biochemical, chemical and thermo-chemical

Biochemical conversion process: anaerobic digestion, biogas production mechanism and technology, types of digesters, design of biogas plants, installation, operation and maintenance of biogas plants, biogas slurry utilization and management, biogas applications, cost benefit analysis of biogas for cooking, lighting, power generation applications, Case studies

Chemical conversion process: hydrolysis and hydrogenation; Bio-fuels different processes of production, Biodiesel production, different types of raw materials, non-edible oilseeds, oil extraction process, mechanism of trans-esterification, fuel characteristics of biodiesel; Alcohol production: types of materials for alcohol production, process description, distillation etc

Thermochemical conversion: Pyrolysis, combustion and gasification; gasifiers: updraft, downdraft, fluidized bed, biomass carbonization, natural draft and gasification based biomass stoves, gasification based power generation, cost benefit analysis, case studies

Text Book

[1] Sorensen B. (2010); *Renewable Energy*, Fourth Edition, Academic press
[2] Mukunda H. S. (2011); *Understanding Clean Energy and Fuels from Biomass*, Wiley India

Reference Book

[1] Stassen H. E. Quaak P. and Knoef H. (1999); *Energy from Biomass: A Review of Combustion and Gasification Technologies*, World Bank Publication
[2] Kishore V. V. N. (2009); *Renewable Energy Engineering and Technology*, TERI
[3] Khandelwal K. C. and Mahdi S. S. (1986); *Biogas Technology - A Practical Handbook*, Tata McGraw Hill
[4] Rosillo-Calle F. and Francisco R. (2007); *The Biomass Assessment Handbook: Bioenergy for a Sustainable Environment*, Earthscan
[5] Mittal K. M. (1996); *Biogas systems: Principles and applications*, New Age International

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 507	**Wind and Hydro Energy**	**3 0 0**	**3**	**3**

Atmospheric circulations, classification, factors influencing wind, wind shear, turbulence, wind speed monitoring, Wind resource assessment, Weibull distribution, Simulation tool: WAsP; Betz limit, Wind energy conversion systems: classification, applications, power, torque and speed characteristics

Aerodynamic design principles; Aerodynamic theories: Axial momentum, Blade element and combine theory, Rotor characteristics, Maximum power coefficient, Tip loss correction, Wind turbine design considerations: methodology, theoretical simulation of wind turbine characteristics, test methods

Wind pumps, performance analysis of wind pumps, design concept and testing, Principle of WEG: stand alone, grid connected; Hybrid applications of WECS; Economics of Wind energy utilization, Wind energy in India, Case studies

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, Economics: cost structure, Initial and operation cost, environmental issues related to large hydro projects, Potential of hydro power in North East India

Text Book

[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 Book

[1] Hau E. (2000); *Wind Turbines: Fundamentals, Technologies, Application and Economics*, Springer
[2] Mathew S. (2006); *Wind Energy: Fundamentals, Resource Analysis and Economics*, Springer
[3] Burton T. Sharpe D. Jenkins N. and Bossanyi E. (2001); *Wind Energy Handbook*, John Wiley
[4] Nag P. K. (2008); *Power Plant Engineering*, Third Edition, Tata McGraw Hill
[5] Jiandong T. (et al.) (1997); *Mini Hydropower*, John Wiley

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 508	**Energy Laboratory**	**0 0 2**	**4**	**2**

A. Introduction

Basic concepts: Terminology used in experimental methods i.e. sensitivity, accuracy, uncertainty, calibration and standards; experimental system design and arrangement.

Analysis of experimental data: Analysis of causes and types of experimental errors, uncertainty and statistical analysis of experimental data; Error analysis

Data acquisition and processing: Data acquisition methods, data storage and display, examples of application in typical energy system.

Experiment design: Conceptual, substantive and detail designs of experiments; illustration of thermal energy equipment/devices and their accessories.

Experiment plan and execution: Preparatory work for carrying out experiments; range of experimental study, choice of measuring instruments, measurement system calibration, data sheets and log books, experimental procedure, etc; applications.

BIS/MNRE Test standards for solar cooker, Flat Plate collector, stoves, gasifiers etc

Technical Communication: Report preparation of experimental work, use of graphs, figures, tables, software and hardware aids for technical communication.

B. Laboratory

Solar: Solar radiation analysis, Experimental study on thermal performance of solar water heater, solar dryers, solar PV cell characterization and its networking, solar cooker

Biomass: Experimental study on thermal performance and efficiency of biomass downdraft gasifier and sampling and analysis of air and flue gas from biomass energy systems i.e. gasifier, combustor and cook stoves using gas chromatography technique; Liquid bio-fuel production and characterization; Biogas production by anaerobic digestion and analysis

Fuel: Density, Viscosity, Flash-point, Fire-point Pour-point, ASTM distillation of liquid fuels; Proximate and Ultimate analysis, calorific value of solid fuels

Instrumentation and control: Use of microprocessor kit, microcontroller, data acquisition and display experiments, performance evaluation of renewable energy systems (solar thermal, solar PV, Wind turbine, biomass gasifier) using microprocessor/microcontroller based data acquisition systems

Reference
[1] Polak P. (1979); *Systematic Errors in Engineering Experiments*, Macmillan
[2] Holman J. P. (1984); *Experimental Methods for Engineers*, McGraw Hill
[3] Doebelin E. O. (1995); *Engineering Experimentation – Planning, Execution, Reporting*, McGraw Hill
[4] Garg H. P. and Kandpal T. C. (1999); *Laboratory Manual on Solar Thermal Experiments*, Narora
[5] Annual Book of ASTM standards, Section I – V, Vol. 05.01-05.05, 2002-2003.

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 510	**Energy Management and Auditing**	**3 1 0**	**4**	**4**

Concept of energy management programme, basic components of an energy audit, types of energy audit, Industrial, commercial and residential audit planning; Understanding energy used pattern and costs, Fuel and energy substitution; concepts of energy conservation and energy efficiency

Energy conservation act and its features, Duties and responsibilities of energy managers and auditors; Energy audit tools; Financial analysis techniques and options, Energy service companies, Project planning techniques; case studies

Material and energy balance, Sankey diagrams; Material balances for different processes; Energy and heat balances, Methods for preparing process flow chart, Procedure to carry out the material and energy balance in different processes

Energy management systems, energy conservation policy and performance assessment, baseline and benchmarking, Action planning, monitoring and targeting, Energy management information systems, CUSUM techniques, case studies

Electrical load management, Maximum demand management, Reactive power management, Role of power factor and its improvement, Electric Power systems analysis, Energy Efficient Motors, Soft starters, Variable speed drives

Performance assessment and Energy conservation opportunities of Compressed Air systems, Refrigeration plants, Fans and blowers, Pumping systems and cooling towers; Performance assessment of DG Systems, Case studies

Lighting systems : Basic terms of lighting systems; Lamp and Luminaries types, recommended illumination level; Methodology of lighting systems energy efficiency study, Energy conservation opportunities; Case studies

Energy conservation in buildings, Building heating and cooling load management, Buildings code, solar passive and green building concepts

Energy conservation in boilers, Performances evaluation, Energy conservation opportunities; Steam Systems: pipe sizing and designing, Steam traps: Operation and maintenance, Performance assessments; Performance analysis of furnaces, Analysis of losses and Energy conservation opportunities; Cogeneration performance parameters, Case studies

Waste heat recovery systems, Case studies; Insulations and Refractory **:** Types and applications; insulation thickness; Economic thickness of insulations; Types and properties of refractory; Industrial use of refractory; Heat losses from furnace walls; Energy Performance assessment of heat exchangers

Text Book

[1] Doty S. and Turner W. C. (2012); *Energy Management Handbook*, Eighth Edition, Fairmont Press

[2] Kreith F. and West R. E. (1996); *Handbook of Energy Efficiency*, First Edition, CRC Press

Reference Book

[1] Thumann A. and Mehta D. P. (2008); *Handbook of Energy Engineering*, Sixth Edition, Fairmont Press

[2] Capehart B. L. Turner W. C. and Kennedy W. J. (2011); *Guide to Energy Management*, Seventh Edition. Fairmont Press

[3] Kao C. (1999); *Energy Management in Illumination System*, First Edition, CRC Press

[4] Bureau of Energy Efficiency (BEE) (2012); Study material for Energy Managers and Auditors Examination: Paper I to IV

[5] Thumann A. Niehus T. and Younger W. J. (2012); *Handbook of Energy Audits*, Ninth Edition, CRC Press

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 511	**Energy Economics and Planning**	**3 0 0**	**3**	**3**

Energy economics: Basic concepts, Energy data and energy balance

Energy accounting framework; Economic theory of demand, production and cost market structure; National energy map of India

Concepts of economic attributes involving renewable energy, Calculation of unit cost of power generation from different sources with examples, energy technology diffusion modeling

Application of econometrics; input and output optimization and simulation methods to energy planning and forecasting problems

Dynamic models of the economy and simple theory of business fluctuation; Evaluation of National and Regional energy policies; oil import, energy conservation, rural energy economics, integrated energy planning

Conflict between energy consumption and environmental pollution, Economic approach to environmental protection and management, Energy-Environment interactions at different levels, energy efficiency, cost-benefit risk analysis; Project planning and implementation

Text Book

[1] Bhattacharyya S. C. (2011): *Energy Economics*, Springer

[2] Ferdinand E. B. (2000): *Energy Economics: A Modern Introduction*, First Edition, Kluwer

Reference Book

[1] Kandpal T. C. and Garg H. P. (2003): *Financial Evaluation of Renewable Energy Technology*, Macmilan

[2] Stoft S. (2000); *Power Systems Economics*, Willey-Inter Science

[3] Munasinghe M. and Meier P. (1993): *Energy Policy Analysis and Modeling*, Cambridge University Press

[4] Samuelson P. A. and William D. N. (1992): *Economics*, 14th edition, McGraw Hill

[5] Thuesen G. J. and Fabrycky W. J. (2001): *Engineering Economy*, Ninth Edition, Prentice Hall India

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 512	**Energy Systems and Simulation Laboratory**	**0 0 3**	**6**	**3**

A. Energy Systems

Fuel Cell characteristics; Solar Photocatalysis; Hydrogen production and storage

Engines: Performance tests on IC Engine, Diesel engine test set-up; Duel-fuel engine, 100% producer gas engines, Biogas based engines

Performance tests on Microhydel power plant, Microhydel test-set-up

Performance tests on Wind energy generator

Experiments on measurements of Electrical parameters, use of digital power analyser, measurement and study the effects of power factor

Thermal energy audit: Measurement of variables such as, temperature, pressure, air flow, etc in selected energy equipment and analysis

Building Energy use and phenomena; Measurement and analysis of heat gain and air-conditioning load in a building

Estimation of energy using conduction, convection and radiation mode of heat transfer

Uses of instruments and control system for accessing performances of (i) solar, (ii) wind and (iii) biomass energy system/devices

B. Simulation Laboratory

Review of computational/numerical methods used for (i) solutions of linear and non-linear equations (including system of equations); (ii) interpolation, regression and curve fitting; (iii) differentiation and integration (iv) solutions of differential equations and partial differential equations (Practical examples of each of the above from Energy field)

Modeling of energy systems and investigation of dynamic behavior (Examples of renewable energy system using available data for solar, wind, hydro and biomass): concept of input, parameters, output, errors, tools for validation

Use of application software (TRANSYS, PVSyst, RETSCREEN, HOMER, WAsP etc.) for energy system analysis; Simulation of major energy experiments using real time data acquired through data acquisition system

Core course			
Course code	**Course name**	**CH**	**Credit**
EN 513	**Seminar**	**2**	**1**

Each student shall present at least two seminars on any topic of interest based on the core/elective courses being undergone in the area of Energy. He/she shall get the seminar topic approved by the Faculty in-charge of seminar class /Faculty Members in the concerned area of specialization and present it in the class in the presence of Faculty in-charge of seminar class /Faculty/ Students. Grade will be awarded on the basis of the report preparation, presentation, understanding on the topic and overall participation in the seminar class.

Core course		
Course code	**Course name**	**Credit**
EN 539	**Project (Part - I)**	**8**

The student will be encouraged to finalize the area of the project work during the end of second semester itself. The project work will start in the third semester. The project work will aim to generate new and useful knowledge in the field of energy. The project works related to industry specific problem solving are also encouraged. The project can be carried out in the University or in collaboration with an industry/research organization/other University. If a student undergoes his/her project work outside the University, one External Supervisor form the organization will be there along with one faculty member from the Department as an Internal Supervisor. The students are expected to complete a good quantum of the work in the third semester. In the end of the third semester, student has to present a seminar on the progress of his/her research work. A brief project report needs to be submitted during the presentation of the work. There shall be evaluation of the work carried out at the end of the third semester.

Core course		
Course code	**Course name**	**Credit**
EN 540	**Project (Part - II)**	**16**

The project work started in the third semester will be extended to the end of the fourth semester. On completion of the project work, the student shall submit a thesis to the Department for examination. There shall be evaluations of the project work by a committee constituted by the department with an external examiner. The thesis will be examined by external and/or internal examiners. The candidate has to appear an open *viva-voce* examination on his/her thesis. The students will be encouraged to publish research papers based on his/her findings in Indexed Journals/Conferences.

Elective course I				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 515	**Advanced Bio Energy**	**3 0 0**	**3**	**3**

Thermochemical conversion: Different processes: combustion, pyrolysis, gasification and liquefaction; types of reactor for pyrolysis, characteristics of pyrolysis products, design optimization; different types of gasifiers, updraft, down draft, fluidized bed, reaction kinetics, modeling of gasification systems, design aspects, air/oxygen/steam gasification systems; performance analysis

Power generation: Utilization of gasifier for electricity generation; Operation of spark ignition and compression ignition engine with producer gas, power generation systems: decentralized, grid interactive; Economics of power generation; Biomass integrated gasification combined cycle system; Sustainable co-firing of biomass with coal

Biological conversion: Biochemistry and process parameters of biomethanation; Biogas digester design; Chemical kinetics and mathematical modeling of biomethanation process; Economics of biogas plant with their environmental and social impacts

Ethanol production from cellulose and algae, issues and problems, ethanol blends, ethanol based engines; Economics of ethanol production from sugarcane and molasses; Environmental impacts of ethanol use, bioethanol industry in India and selected countries

Biodiesel : Manufacturing processes for biodiesel, economics of biodiesel production; Environmental impacts of bio-diesel., biodiesel blends, recent trends in bio-diesel production, biodiesel from algae, biodiesel engines; India's biofuel policy and programmes, International experiences in biofuels, issues with biofuel production and use

Energy generation from waste: types of waste, classification of waste as fuel: agro-based, forest residues, industrial organic waste, municipal solid waste; technologies for utilization of organic wastes and waste-to-energy options: anaerobic digestion, briquetting/pelletization, pyrolysis, combustion, gasification, bio-refineries; Land fill gas generation and utilization

Text Book

[1] Mukunda H. S. (2011); *Understanding Clean Energy and Fuels from Biomass*, Wiley India
[2] Brown R. C. and Stevens C. (2011); *Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals and Power*, Wiley

Reference Book

[1] Wyman C. (1996); *Handbook on Bioethanol: Production and Utilization*, CRC Press
[2] Sarin A. (2012); *Biodiesel: Production and Properties*, Royal Society of Chemistry
[3] Demirbas A. (2010); *Biodiesel: A Realistic Fuel Alternative for Diesel Engines*, Springer
[4] Basu P. (2010); *Biomass Gasification and Pyrolysis: Practical Design and Theory*, Academic Press
[5] Borowitzka M. A. and Moheimani N. R. (2013); *Algae for Biofuels and Energy*, Springer

Elective course I				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 516	**Advanced Solar Thermal Energy**	**3 0 0**	**3**	**3**

Flat-plate and evacuated tubular collectors: Effective energy losses; Thermal analysis; Heat capacity effect; performance testing methods: Evacuated tubular collectors, Air flat-plate Collectors: Thermal analysis; Thermal drying

Selective surfaces: Ideal coating characteristics; Types and applications; Anti-reflective coating: Preparation and characterization.

Concentrating collector: Classification, design and performance parameters; Tracking systems; Compound parabolic concentrators; parabolic trough concentrators; Concentrators with point focus; Solar furnaces

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

Solar heating and cooling system: Liquid based solar heating system; Natural, forced and gravity flow, mathematical modeling, Vapour absorption refrigeration cycle; Water, ammonia and lithium bromide-water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling

Solar thermal energy storage: Sensible storage; Latent heat storage; Thermo-chemical storage; High temperature storage, Designing thermal storage systems

Performances of solar collectors: ASHRAE code; Modeling of solar thermal system components and simulation; Design and sizing of solar heating systems: f–chart method, solar thermal system evaluation method; Simulation tool for solar heating and cooling applications; Introduction to TRNSYS simulation applications

Solar energy for industrial process heat, Temperature requirements, consumption pattern; solar flat plate water heater and air heater for industrial process heat applications

Solar thermal energy systems: Solar still; Solar cooker: Solar pond; Solar passive heating and cooling systems: Trombe wall; Greenhouse technology: Fundamentals, design, modeling and applications

Text Book

[1] Goswami D. Y. Kreith F. and Kreider J. F. (1999); *Principles of Solar Engineering*, Taylor and Francis
[2] Duffie J. A. and Beckman W. A. (2013); *Solar Engineering of Thermal Processes*, Fourth Edition, Wiley

Reference Book

[1] Tiwari, G. N. (2002); *Solar Energy, Fundamentals design, modeling and Applications*, Narosa
[2] Garg H. P. (1985); *Solar Thermal Energy storage*, D Reidel Publishing Co
[3] Norton B. (1992); *Solar Thermal Energy Technology*, Springer Verlag
[4] Kalogirou S. A. (2009); *Solar Energy Engineering: Processes and Systems*, Academic Press
[5] Boyle G. (2012); *Renewable energy: power for a sustainable future*, Third Edition, OUP

Elective course I				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 517	**Advanced Solar Photovoltaic Energy**	**3 0 0**	**3**	**3**

Solar cell: basics and materials, properties of semiconductor: Intrinsic, extrinsic and compound semiconductor; energy levels; electrical conductivity; Fermi energy level; Probability of occupation of allowed states; Dynamics of energy density of allowed states; Density of electrons and holes; Carrier transport: Drift, diffusion, continuity equations; Absorption of light; Recombination process; Basic equations of semiconductor devices physics; new generation solar cell materials

Solar cell physics: p-n junction: homo and hetro-junctions, Metal-semiconductor interface; Dark and illumination characteristics; Figure of merits of solar cell; Efficiency limits; Factors affecting the efficiency; Performance parameters and their measurements; Strategies to enhance the efficiency of solar cell

Solar cell fabrication technology: Preparation of metallurgical, electronic and solar grade Silicon; Production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) method: Procedure of masking, photolithography and etching; Design of a complete silicon, GaAs, InP solar cell; High efficiency III-V, II-VI multijunction solar cell; a-Si-H based solar cells; Quantum well solar cell, Thermophotovoltaics

New generation solar cells, Organic PV cells, Dye-sensitized solar cells; Working and efficiency limits; emerging solar cell technologies

Solar photovoltaic system design and simulation: Solar cell array system analysis and performance prediction; Shadow analysis: Reliability; Solar cell array design concepts; PV system design; Design process and optimization; Detailed array design; Storage autonomy; Voltage regulation; Maximum tracking; simulation tool in array design; Quick sizing method; Array protection and troubleshooting; Introduction to System Advisor Model (SAM) and PVSyst simulation applications

PV applications: Centralized and decentralized PV systems; Stand alone, hybrid and grid connected system, System installation, operation and maintenances; Field experience; PV market analysis and economics

Solar Photocatalytic Detoxification: Mechanism; Advantages; Kinetic model; Nanoparticle Catalyst: Physical properties, sensitization; System design methodology; Performance parameters; Application for liquid and gas phase organic pollutant mitigation and disinfection

Text Book

[1] Solanki C. S. (2009); *Solar Photovoltaics: Fundamentals, Technologies and Applications*, Prentice Hall India
[2] Goetzberger A. and Hoffmann V. U. (2005); *Photovoltaic Solar Energy Generation*, Springer

Reference Book

[1] Fahrenbruch A. L. and Bube R. H. (1983); *Fundamentals of Solar Cells: PV Solar Energy Conversion*, Academic Press
[2] Bube R. H. (1989); *Photovoltaic Materials*, Imperial College Press
[3] Partain L. D. (ed.) (1995*); Solar Cells and their Applications*, John Wiley
[4] Rauschenbach H. S. (1980); *Solar Cell Array Design Handbook*, Van Nostrand Reinfold
[5] Wenham S .R. Green M. A. Watt M. E. and Corkish R. (2007); *Applied Photovoltaics*, Second Edition, Earthscan

Elective course I				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 518	**Hydrogen Energy and Fuel Cell**	**3 0 0**	**3**	**3**

Hydrogen Economy: Hydrogen and fuel cell; Suitability of Hydrogen as a fuel and fuel-cell as energy conversion device

Hydrogen Production: fossil fuels, electrolysis, thermal decomposition, photochemical, photocatalytic, hybrid

Hydrogen Storage: Metal hydrides, Metallic alloy hydrides, Carbon nano-tubes; Sea as the source of Deuterium, methane hydrate

Hydrogen Transport: Road, railway, pipeline, and ship

Fuel Cell: Principle of working, Basic thermodynamics, Reaction kinetics, Charge and mass transport. Modeling a Fuel Cell, Fuel Cell Characterization: In-situ and Ex-situ; System and components' characterization

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

Text Book

[1] O'Hayre R. Cha S. Colella W. and Prinz F. B. (2006); *Fuel Cell Fundamentals*, John Wiley
[2] Sorensen B. (2005); *Hydrogen and Fuel Cells*, Academic Press

Reference Book

[1] Yurum Y. (ed.) (1994); *Hydrogen Energy Systems*, NATO ASI Series
[2] Singhal S. Singhal S. C. and Kendall K. (2003); *High-temperature Solid Oxide Fuel Cells: Fundamentals, Design and Applications*, Elsevier
[3] Sammes N. (2006); *Fuel Cell Technology: Reaching Towards Commercialization*, Springer
[4] Larminie J. and Dicks A. (2003); *Fuel Cell Systems Explained*, Second Edition, Wiley
[5] Reich S. Thomsen C. and Maultzsch J. (2004); *Carbon nanotubes – Basic Concepts and Physical Properties*, John Wiley

Elective course I				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 519	**Alternative Fuels for IC Engines**	**3 0 0**	**3**	**3**

Basic understanding of IC engines: ideal and actual cycles of IC engine operations; Assessment of engine performance: efficiencies and exhaust emission

Engine systems and their components, fuel supply, lubrication cooling, intake and exhaust, combustion and power transmission

Important fuel characteristics and need of characterization; Standards used for fuel characterization

Characteristics of alternate fuels: biodiesel, ethanol, biogas, producer gas, hydrogen

Alternate fuels for automobile: technological issues in connection with handling and storage, delivery, combustion, emission and pollution, corrosion

Alternate fuels for electrical power generation: technological issues in connection with handling and storage, delivery, combustion, emission and pollution, corrosion

Text Book

[1] Heywood J. (1988); *Internal Combustion Engine Fundamentals*, McGraw Hill
[2] Demirbas A. (2010); *Biodiesel: A Realistic Fuel Alternative for Diesel Engines*, Springer

Reference Book

[1] Ferguseaon C R. (2000); *Internal Combustion Engines*, Second Edition, John Wiley
[2] Ganesan V. (2001); *Internal Combustion Engines*, Tata McGraw Hill
[3] Speight J. G. and Loyalka S. K. (2007); *Handbook of Alternative Fuel Technologies*, CRC Press
[4] Speight J. G. (2008); *Synthetic Fuels Handbook: Properties, Process and Performance*, McGraw Hill
[5] ASTM and EN standards for Alternate Fuel Characteristics, 2007

Elective course I				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 520	**Petroleum Exploration, Production and Refining**	**3 0 0**	**3**	**3**

Introduction: Origin, migration, and accumulation of oil and gas fields; Methods of petroleum exploration: Geological, geophysical, geochemical, and hydrogeological surveys; Classification of traps: Structural, stratigraphic, and combination traps

Drilling of Oil-gas Wells: Different methods, directional and horizontal drilling, offshore drilling, drilling complications, formation evaluation; Drilling fluids: Composition; Properties and types; Well completion methods

Reservoir Engineering: Consideration of different reservoir parameters for exploration, development, and exploitation of petroleum; Reservoir fluid characteristics; Gas reservoir, Driving Mechanisms: Depletion drive, gas cap drive, water drive, combination drive; Gravity drainage; Secondary recovery of oil and enhanced oil recovery methods

Processing and Transportation: Surface gathering systems; Gas processing; liquid processing; Transportation of oil and gas.

Physical properties and chemical composition, Classification of crude oil; Various processes for preparation of crude oil for refining, Production: Atmospheric and vacuum distillation; Production of straight run fuels; Refining processes of crude; Treating processes for products improvement; Manufacturing of other ancillary products; Petroleum product's tests

Text Book

[1] Ray Chaudhuri U. (2010): *Fundamentals of Petroleum and Petrochemical Engineering*, CRC Press
[2] Fahim M. A. Al-Sahhaf T. A. and Elkilani A. S. (2010): *Fundamentals of Petroleum Refining*, First Edition, Elsevier

Reference Book

[1] Knoring L. D. Chilingar G. V. and Gorfunkel M. V. (1999); *Strategies for Optimizing Petroleum Exploration*, Elsevier
[2] Mian M. A. (1992); *Petroleum Engineering Handbook of Practicing Engineer*, Pennwell
[3] Berger, Bill D. and Kenneth E. Anderson, (1992): *Modern Petroleum: A Basic Primer of Industry*, Pennwell
[4] Speight J. G. (ed.) (1998); *Petroleum Chemistry and Refining*, Taylor and Francis
[5] Meyers R. (2003); *Handbook of Petroleum Refining Processes*, Third Edition, McGraw Hill

Elective course II				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 525	**Thermal Power Plant Engineering**	**3 0 0**	**3**	**3**

Overview of power plant, Types of thermal power plants, Steam power plant based on fossil fuels

Thermal power plant equipment: boilers, superheaters, reheaters, economiser, condensers, and gas loops, turbines etc. Performance of steam power plant and its components
Gas turbine power plant: different components, operating principles and design of Gas Turbine power plant, Gas Turbine-Steam Turbine combined cycle power plant

Diesel electric power plant: different components, operating principles and design of Diesel electric power plant.

Economics, load management and environmental implications, Recent advances in power plants: Clean coal technologies such as Fluidized Bed, IGCC etc.

Text Book

[1] Veatch B. Drbal L. F. Boston P. G. Westra K. L. and Erickson R. B. (2005); *Power Plant Engineering*, CBS Publishers
[2] Nag P. K. (2007); *Power Plant Engineering*, Third Edition, Tata McGraw Hill

Reference Book

[1] Shepherd D. G. (1969); *Principles of Turbomachinery*, Macmillan
[2] EI-Wakil M. M. (2010); *Power Plant Technology*, Tata McGraw-Hill
[3] Ganesan, Y. (2003); *Internal Combustion Engines*, Tata McGraw-Hill
[4] Gupta M. K. (2012); *Power Plant Engineering*, Prentice Hall India
[5] Blaisdell A. H. and Estep T. G. (2007); *Problems in Thermodynamics and Steam Power Plant Engineering,* Merchant Books

Elective course II				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 526	**Energy Efficient Buildings**	**3 0 0**	**3**	**3**

Energy management concept in building, Energy auditing in buildings, classification of climate zones, Bioclimatic classification of India; Climate Analysis for Nat-Vent Buildings, Mixed Mode Buildings and Conditioned building; Passive design concepts for various climatic zones; Integrations of landscape to building design; urban heat island, 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, alternate building materials, climate responsive buildings, energy efficient buildings, green buildings, intelligent buildings, Building Integrated Photovoltaics (BIPV)

Building codes and Rating systems: LEED, GRIHA, ECBC, Thermal properties and energy content of building materials; Building energy simulation, Tool like TRNSYS etc, Building management systems/automation, Artificial and daylighting in buildings

Thermal performance studies, concept of comfort and neutral temperatures, Thermal comfort, Psychrometric chart; Thermal indices and comfort zones; PMV-PPD models, Thermal comfort models, Adaptive thermal comfort models, case studies, Comfort and indoor air quality in buildings (office, residential, schools, hospitals, commercial buildings); climate change effect on thermal comfort

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

Passive and low energy concepts and applications, Passive heating concepts: 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; Design of efficient daylighting systems

Green Building – definition and attributes; Genesis of Green Building; Design aspects of green buildings, Economic aspects of green buildings, Energy and Environmental management; Green Buildings in India; Case studies

Text Book

[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

Reference Book

[1] Nayak J. K. and Prajapati J. A. (2006); *Handbook on Energy Conscious Buildings*; Solar Energy Centre, New Delhi
[2] Underwood C. P. and Yik F. W. H. (2004); *Modelling Methods for Energy in Buildings*, Blackwell Publishing
[3] Parsons K. C. (2003); *Human Thermal Environments*, Second edition, Taylor and Francis
[4] Majumder M. (2009); *Energy Efficient Buildings*, TERI, New Delhi
[5] Nicol F. (2007); *Comfort and Energy Use in Buildings- Getting them Right*, Elsevier

Elective course II				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 527	**Renewable Energy Grid Integration**	**3 0 0**	**3**	**3**

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

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 for grid integration, Synchronizing with the grid; Issues in integration of synchronous generator, induction generator and converter based sources; Network voltage management; Power quality management and Frequency management; Influence of PV/WECS on system transient response

Electric Systems Modeling: Modeling and simulation of electric systems; Simulation tools, Simulation of grid connected/off grid renewable energy system (PV/WECS); Optimization and grid planning

Text Book

[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

Reference Book

[1] Bollen M. H. and Hassan F. (2011); *Integration of Distributed Generation in the Power System*, Wiley-IEEE Press
[2] Keyhani A. (2011); *Design of Smart Power Grid Renewable Energy Systems*, Wiley–IEEE Press
[3] Muhannad H. R. (2004); *Power Electronics: Circuits, Devices and Applications*, Pearson Prentice Hall Publisher
[4] Gellings C. W. (2009); *The Smart Grid: Enabling Energy Efficiency and Demand Response*, First Edition, CRC Press
[5] Teodorescu R. Liserre M. Rodriguez P. (2011); *Grid Converters for Photovoltaic and Wind Power Systems*, First Edition, Wiley-IEEE Press

Elective course II				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 528	**Decentralized Energy Systems**	**3 0 0**	**3**	**3**

Need and advantage of decentralized energy systems, Decentralized generation technologies, Costs and choice of technology, demand and benefits, forecasting and program development, Economic and financial analysis of decentralized electrification projects, Decentralized versus Centralized generation, Traditional power systems, Load curves and Load curve analysis of a village, Demand scheduling

Optimal design of hybrid energy systems, energy economics and cost optimization of integrated energy systems; Sample problems and case studies, Simulation tools like HOMER, RETSCREEN etc.

Scope and challenges in implementing off grid solutions; Policy and regulatory framework for decentralized electricity in India: Gokak Committee. Integrated Energy Policy, Power for All, Electricity Act, RGGVY, Village Energy Security Programme (VESP), Status of grid connected and off grid distributed generation (national and International), Case studies on various distributed energy generation systems in India and South-East Asia

Integrated Rural Energy Planning (IREP); rural electrification, Linkages with rural livelihoods, rural industries and social development; efficient/appropriate renewable energy technologies for rural areas, GIS based study on energy potential in villages

Smart Grid: Definition, applications; smart grid communications, power line communications, advanced metering infrastructure, demand response, energy consumption scheduling; renewable energy generation based Micro-grid

Text Book

[1] Bollen M. H. and Hassan F. (2011); *Integration of Distributed Generation in the Power System*, Wiley-IEEE Press

[2] Zerriffi H. (2011); *Rural Electrification: Strategies for Distributed Generation*, Springer

Reference Book

[1] Jenkins N. Strbac G. and Ekanayake J. (2009); *Distributed Generation*, The Institution of Engineering and Technology

[2] Keyhani A. (2011); *Design of Smart Power Grid Renewable Energy Systems*, Wiley–IEEE Press

[3] Tester J. W. (et al.) (2012); *Sustainable Energy: Choosing among Options*, Second Edition, The MIT Press

[4] Bhattacharyya S. (Ed.) (2013); *Rural electrification through decentralised Off-grid systems in Developing Countries*, Springer

[5] Zerriffi H. (2011); *Rural Electrification: Strategies for Distributed Generation*, Springer

Elective course II				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 529	**Energy, Climate Change and Carbon Trade**	**3 0 0**	**3**	**3**

Energy and Climate Change: Global Consensus, GHGs emission and energy activities; evidence and predictions and impacts, Clean Energy Technologies, Energy economy, Risk and opportunities; Measures to reduce GHGs; Role of Renewable Energy

Climate Change Act, Kyoto Protocol and CDM, CDM activities in Industries; Emission benchmarks; Governments policies for mitigation and adaptation, National Action Plan on Climate change

Carbon dioxide (CO_2) 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 CO_2 emission; Methodology for CO_2 assessment; UNFCC 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

Text Book

[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

Reference Material

[1] Stern N. (2007); *The Economics of Climate Change. The Stern Review*. Cambridge University Press

[2] IPCC (Intergovernmental for Climate Change), (2007). Climate Change (2007): Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, NewYork.

[3] Yamin F. (ed) (2005); *Climate Change and Carbon Markets: A Handbook of Emissions Reduction Mechanisms*, Earthscan

[4] Clean Development Mechanism, UNFCC Website; *http://cdm.unfccc.int/*

[5] Franchetti M. J. and Apul D. S. (2013); *Carbon Footprint Analysis: concepts, methods, implementation and case studies*, CRC Press

Elective course II				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 530	**Instrumentation and Control for Energy Systems**	**3 0 0**	**3**	**3**

Overview of Instruments and Measurement Systems: Principles of measurements and methods, elements of measurements system, errors in measurements, Classification of instruments, modes of operation, functions and applications, static and dynamic characteristics; Input output configurations of measuring instruments and measurement system

Primary Sensing elements and transducers: Mechanical devices: types, pressure, flow rate sensing elements and their applications; Electric transducers: types and characteristics, resistive, capacitive, piezoelectric, optoelectronic transducers and their applications; Modern sensors

Introduction to Control Systems: Control systems: Feedback and non-feedback systems, reduction of parameter variations, block diagram of control system, regenerative feedback; Control systems and components

Introduction to Digital Electronics Basics: Number systems, logic families, Boolean algebra, Combinational Logic designs, Multiplexers and demultiplexers, Registers

Signal conditioning: Operational amplifier types and characteristics, Application circuits-inverter, adder, substacter, multiplier and divider, Analog /digital/analog conversion techniques

Data Acquisition Systems: Types of Instrumentation Systems, components, Applications, Single chanel and multichanel Analog to Digital and Digital to Analog converter (0804/0808/0809)

Microprocessors and Applications of Microcontrollers: Overview of microprocessor, microntroller (8951) architecture and Applications for monitoring and control of parameter and processes

Typical measuring and control instruments/devices for electric and non-electric quantities: Electronic voltmeter, Digital Power Analyser, Annemometer, Rotameter, Exhaust Gas analyzer, Automatic Bomb calorimeter, Junkers Calorimeter, Pyranometer, Pyrheliometer, Oxidation Stabilty Apparatus, Maximum Demand Controller, Automatic light dimmer and on-off controller

Text Book

[1] Morris A. S. (1998); *Principles of Measurements and Instrumentation*, Prentice Hall of India

[2] Sawhney A. K. (2011); *A Course in Electrical and Electronics Measurements and Instrumentation*, Dhanpat Rai

Reference Book

[1] Jain R. P. (1998); *Modern Digital Electronics*, McGraw Hill

[2] Gaonkar R. (2012); *Microprocessor Architecture, Programming and Applications with 8085*, Penram International Publishing

[3] Raman C. S. Sharma G. R. and Mani V. S. V. (1983); *Instrumentation Devices and systems*, Tata McGraw Hill

[4] Kalsi H. S. (1995); *Electronic Instrumentation,* Tata McGraw Hill

[5] Babu J. C. and Xavier S. E. (2004); *Principles of Control Systems,* S Chand and Co Ltd.

Elective course II				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 531	**Numerical Heat Transfer and Fluid Flow**	**3 0 0**	**3**	**3**

Basics of heat transfer, fluid flow. Mathematical description of fluid flow and heat transfer: conservation equations for mass, momentum, energy

Classification of partial differential equations, coordinate systems, Mathematical nature of PDEs and flow equations. Discretisation techniques using finite difference methods: Taylor-Series and control volume formulations. One dimensional steady state diffusion problems

Solution methodology for linear and non-linear problems: Point-by-point iteration, TDMA, Two and three dimensional discretization, Discretization of unsteady diffusion problems: Explicit, Implicit and Crank-Nicolson's algorithm; stability of solutions, One dimensional convection-diffusion problem: Central difference scheme, Discretization based on analytical approach (exponential scheme)

Hybrid and power law discretization techniques; Higher order schemes (QUICK algorithm), Discretization of incompressible flow equations. Pressure based algorithm: SIMPLE, SIMPLER etc.

Introduction to FVM with unstructured grids, modelling of multiphase problems: enthalpy method, volume of fluid (VOF) and Level Set Methods, Large Eddy Simulation (LES). Direct Numerical Simulation (DNS)

Solving simplified problems: formulation, discretization with coarse grids, applying appropriate boundary and initial conditions and solving by hand calculations, Solving practical problems through software: writing user sub-routines; post-processing and interpretation of results

Text Book

[1] Anderson D. A, Tannehill J. C. and Pletcher R. H. (1997); *Computational Fluid Mechanics and Heat Transfer*, Second Edition, Taylor and Francis

[2] Patankar S. V. (1980); *Numerical Heat Transfer and Fluid Flow*, Hemisphere Publishing Corporation

Reference Book

[1] Ferziger J. H. and Peric M. (1999); *Computational Methods for Fluid Dynamics*, Second Edition, Springer

[2] Versteeg H. K. and Malalasekera W. (1995*); An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, Longman Scientific and Technical

[3] Özışık M. N. (1985); *Heat transfer: A basic approach*, McGraw-Hill

[4] White F.M. (2011); *Fluid Mechanics*, Seventh Edition, Tata McGraw-Hill

[5] Anderson J. D. (2012); *Computational Fluid Dynamics: The Basics with Applications*, First Edition, Tata McGraw Hill

Elective course II				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 532	**Energy Conservation and Waste Heat Recovery**	**3 0 0**	**3**	**3**

Waste heat recovery classification, waste heat utilization, 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, Utilization of low grade rejects heat from power plants.

Need for energy storage: Thermal, electrical, magnetic and chemical storage systems. Thermo-economic optimization

Text Book

[1] Nag P. K. (2006); *Power Plant Engineering*, Tata McGraw-Hill

[2] Li K. W. and Priddy A. P. (1985); *Power Plant System Design*, John Wiley

Reference Book

[1] Harlock J. H. (1987); *Combined Heat and Power*, Pergaman Press

[2] Kreith F. and West R. E. (1999); *Handbook of Energy Efficiency*, CRC Press

[3] Kays W. M. and London A. L. (1984); *Compact Heat Exchangers*, Third Edition, McGraw-Hill

[4] Jensen J. (1980); *Energy Storage*, Newnes-Butterworths

[5] Beghi G. (1981): *Thermal Energy Storage*, D. Reidel Publishing Co

Elective course II				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 533	**Energy Storage Systems**	**3 0 0**	**3**	**3**

Energy Demand and Storage, Different types of energy storage; Mechanical, Chemical, Biological, Magnetic, Thermal energy storage, 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

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

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, PAFC, PEMFC, MCFC, SOFC, Microbial Fuel cell; Fuel cell performance, characterization and modeling; Fuel cell system design and technology, applications for power and transportation

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

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

Text Book

[1] Huggins R. (2010); *Energy Storage*, Springer
[2] Ter-Gazarian A. (2011); *Energy Storage for Power Systems*, Second Edition, The Institution of Engineering and Technology

Reference Book

[1] O'Hayre R. Cha S. Colella W. and Prinz F. B. (2009); *Fuel Cell Fundamentals*, Second Edition, Wiley
[2] Narayan R. and Viswanathan B. (1998); *Chemical and Electrochemical Energy System*, Universities Press
[3] Dincer I. and Rosen M. A. (2010); *Thermal Energy Storage: Systems and Applications*, Second Edition, Wiley
[4] Rahn C. D. and Wang C. (2013); *Battery Systems Engineering*, First Edition, Wiley
[5] Tiwari G. N. (2012); Greenhouse Technology for Controlled Environment, Narosa

Elective course II				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 534	**Energy Modeling and Optimization**	**3 0 0**	**3**	**3**

Introduction to modeling: types and classification, uses, limitations, advantages of modeling; Review of computational tools/techniques used for mathematical modeling including solutions for non-leaner equations, system of simultaneous equations, differential equations, partial differential equations. Curve fitting, multiple regression analysis and interpretation of results

Model development: steps of modeling, descriptions of system boundary, input, output, model coefficient and model parameters. Examples of energy system modeling: static and dynamic modeling; Modeling errors, accuracy and methods of model validation

Econometric modeling: Input Output models considering energy budgeting

Sensitivity analysis: importance of parametric analysis and tools for sensitivity analysis

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.

Text Book

[1] Rao S. S. (2004); *Engineering Optimization: Theory and Practice*, Third Edition, New Age International

[2] Sundaram R. K. (1996); *A First Course in Optimization Theory*, Cambridge University Press

Reference Book

[1] Kennedy P. (2008); *A Guide to Econometrics*, Sixth Edition, Wiley-Blackwell

[2] Sarkar S. (2011); Optimization Theory, Laxmi Publications

[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

****