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

Abstract

In a very fast changing world, energy demand is increasing which is to meet through sustainable and environmental benign energy sources. Biofuels are truly sustainable fuel sources which can be grown in short time span; use of biofuels can reduce carbon emissions. Advanced biofuels can contribute significantly to energy security in the transport sector, reduce GHG emissions and provide a long-term sustainable alternative to fossil fuels by minimizing other impacts, like food production and ecological diversity. Bio-based gasoline, diesel, and jet fuel can all be produced at lower carbon intensity than the traditional petroleum version using a variety of feed stocks and technological processes. In this course, an attempt has been made to give an overview of the advanced biofuels, their production technologies and applications in various energy utility routes. This course also discusses the application of bio refinery concept on valorization of biomass wastes for fuels and chemicals.

Course Outcomes

CO1: Extend the knowledge of biofuels: production, technologies and applications.

CO2: Apply bio-refinery concept for conversion of biomass to biofuels.

CO3: Determine the challenges and prospects of modern biofuel.

Course contents

Biofuel: Biofuel derived from cellulose, hemi-cellulose, or lignin; vegetable oil and animal fat**;** Biofuel derived from sugar and starch; Biofuel derived from waste material, including crop residue, other vegetative waste material, animal waste, food waste and yard waste

Biodiesel: Trans-esterification, esterification and feedstock issues, economics of biodiesel production; Environmental impacts of bio-diesel; Biodiesel blends; biodiesel from algae; components and operation of a biodiesel processing system; standards for biodiesel quality; Green diesel from vegetable oil; Biodiesel process by-product utilization

Bio-Methane: Formation of bio-methane or biogas from landfill; energy crops and manure; Biogas digester design; Chemical kinetics and mathematical modeling of bio-methanation process; Economics of biogas plant with their environmental and social impacts; Methane enrichment technologies; Integration of biomass technologies with fuel cells; DME

Bio-ethanol & Bio-hydrogen: Production of ethanol by yeast and bacteria; Substrate range and ethanol tolerance; flocculence in yeasts; thermophilic Clostridias; *Zymonomonasmobilis;* Ethanol blends; ethanol based engines; ethanol derived fuel and chemicals; economics of ethanol production from sugarcane and molasses; Production of butanol and propanol; Production of hydrogen from photosynthesis; production of hydrogen by fermentative bacteria; Micro-organisms that produce hydrogen; Genetic engineering to enhance hydrogen production rates

Gasification & Pyrolysis Technologies: Gasification processes and the main types of gasifier designs; production of electricity by combining a gasifier with a gas turbine or fuel cell; Combined-cycle electricity generation with gas and steam turbines; generation of heat and steam for district heating systems or CHP; Fast pyrolysis technology to produce liquid bio-oil or pyrolysis oil (synthetic oil) from biomass; refined to produce a range of fuels, chemicals, and fertilizers; bio-refineries; FTS process

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

Green Chemical technologies: Green Chemistry and Green Engineering, alternative solvents, supercritical fluids, water, ionic liquids, biphasic and bio-resourced solvents; Microwave–assisted chemistry, sonochemistry, electrochemistry, photochemistry; Catalysis, Homogenous catalysts, heterogeneous catalyst, Biocatalysts

Biomaterials: Wood and natural fibers: molecular constituent, wood and timber, plant fibers; Cellulose, Cellulose Esters, Cellulose Ethers, starch, chitin and chitosan, Zein, lignin derivatives; Agromaterials, blend and composites; Biodegradable plastics: Polyglycolic Acid (PGA), Polylactic acid(PLA), Polycaprolactone (PCL), Polyhydroxyalkanoates (PHA), Cellulose Graft-polymers.

Text Books

[1] Mutha V. K. (2010); *Handbook of Bioenergy and Biofuels*, SBS Publishers, Delhi

[2] Clark J. and Deswarte F. E.I. (ed) (2008); *Introduction to chemicals from biomass*, John Wiley

Suggested Readings

[1] Klass D. L. (1998); *Biomass for Renewable Energy, Fuels, and Chemicals*, Academic Press, USA

[2] Mukunda H. S. (2011); *Understanding Clean Energy and Fuels from Biomass*, Wiley India

[3] Higman C. and Burgt M v d (2003); *Gasification*, Elsevier Science

[4] Speight J. (2008); *Synthetic Fuels Handbook: Properties, Process, and Performance*, McGraw-Hill

[5] Dahiya A. (ed.) (2014); *Bioenergy: Biomass to Biofuels*, Academic Press

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

Abstract

This course discusses in details the theory and design aspects of various types of solar thermal collectors. Details of thermal performance of different thermal collector configurations are included. Emphasis has been given to the concentrating collector for power generation and the application of solar energy for industrial process heat. Solar thermal energy storage through different mechanics and processes and also discussed. The course is designed with objectives to make the students capable to analyze the performance of solar thermal systems.

Prerequisite of the course

Must have understanding on fundamentals of solar energy engineering and application.

Course Outcomes

CO1: Discuss different aspects of solar thermal systems and applications CO2:

Design solar thermal system for domestic and commercial applications CO3:

Assess the performance of solar thermal system for power generation

Course contents

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: Integration of solar thermal system with industrial processes; Mechanical design considerations; Economics of industrial process heat

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

Text 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

Suggested Readings

[1] Twidell J, Weir T (2015); *Renewable Energy Resources*, Routledge

[2] Goswami D. Y. (2015); *Principles of Solar Eng*ineering, Taylor and Francis

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

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

[5] Sorensen B. (2010); *Renewable Energy*, Fourth Edition, Academic press

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

Abstract

This course designed for a detail discussion on the topics related to principle of solar photovoltaic technology to system design. It includes the understanding of physical theories and phenomena of solar cell with inclusion of semiconductor physics. Moreover, fabrication processes of different solar cell technologies along with the PV module manufacturing techniques are included. The course also discusses different aspects of solar photovoltaic technologies for applications in building integrated PV, standalone system and power plant system. The course is designed with objectives to prepare students having capabilities of serving photovoltaic industry as well as to develop competency for research in photovoltaic system.

Prerequisite of the course

Must have understanding on fundamentals of solar energy engineering and application.

Course Outcomes

CO1: Discuss the properties of various energy materials used for solar cell fabrication.

CO2: Analyse the parameter for improvement of solar cell efficiency.

CO3: Design standalone and grid connected photovoltaic systems.

CO4: Assess and predict the performance of PV systems.

Course contents

Solar Cell Physics: 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, Dark and illumination characteristics of solar cell; Efficiency limits, Issues and challenges of solar cell, Factors affecting the efficiency of solar cell, Strategies to enhance the efficiency of solar cell

Solar cell fabrication: Wafer based solar cell fabrication: Czochralski Process, Multi-crystalline Si ingot fabrication; PN Junction formation; Metal contacts; Thin film PV device fabrication; Thin film deposition techniques: LPCVD, APCVD, PECVD; Tandem Solar cell fabrication; Photovoltaic module fabrication and optimization

Solar photovoltaic system: PV system design and optimization; Array design; PV System installation, operation and maintenances; Balance of PV system (BOS); Issues and Challenges of PV system operation and maintenance; Factor affecting the PV system performance; Performance measurements and characterization of PV power plant.

Centralized and decentralized PV systems; Stand alone, hybrid and grid connected system; Grid connected PV system design and optimization, Rooftop PV systems, Net and Feed-in-Tariff mechanism, Energy generation analysis, Power control and management systems for grid integration, Issues and challenges of grid integrated PV system; BiPV systems, PV system simulation tools; PV market analysis and economics; National Solar Energy Mission.

Text Books

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

[2] Mukerjee A. K. and Thakur N. (2011); *Photovoltaic Systems Analysis and Design*, PHI

Suggested Readings

[1] Luque A, Hegedus S (2011); *Handbook of Photovoltaic Science and Engineering*, Wiley

[2] Wenham S.R. Green M. A. Watt M. E. and Corkish R. (2007); *Applied Photovoltaics*, Earthscan.

[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] Mertens K. (2013); *Photovoltaics: Fundamentals, Technology and Practice*, Wiley

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

Abstract

Fuel cell is an electrochemical device that converts chemical energy to electrical energy. Significant attention has been put of late to the research and development of fuel cell systems for the application in stationary, portable, automotive, and infrastructure. The basics of fuel cell and the fundamental principle associated with it are presented in this course. However, the primary focus of the course is on the fundamental principles and processes in proton exchange membrane fuel cells, direct methanol fuel cells, and solid oxide fuel cells. Special topics in the cutting-edge technologies including the future direction of fuel cell and hydrogen technology are also covered.

Course Outcomes

CO1: Identify different routes for hydrogen production and storage

CO2: Apply fundamentals of electrochemistry to design components of fuel cells and system

CO3: Analyse and simulate the performances of fuel cell system

Course contents

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

Thermodynamics 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, Nernst equation, thermodynamic efficiencies of fuel cell in comparison to Carnot efficiencies, thermodynamic advantage of electrochemical energy conversion

Electrochemistry of fuel cell: electrochemical cells, oxidation and reduction processes, half-cell potentials and the electrochemical series, Faraday's law, faradaic and non-faradaic processes, current and reaction rate, Butler–Volmer theory for electrode kinetics, exchange current, polarization and over potential, cell resistance, mass transport in electrochemical cells

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

Fuel cell electrolytes: different types of electrolytes used, ionomeric membrane in PEFC, mechanism of ion transfer in ionomeric membranes, relation between proton conductivity and water content, alternative membranes

Fuel cell electrocatalysts: types of catalysts, synthesis and characterization, HOR and ORR kinetics of catalysts, half-cell and full cell reaction, and effect of impurities

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

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

Text Books

[1] O'Hayre R. P., Cha S.W., Colella W., and Prinz F. B., (2008); *Fuel cell fundamentals*, John Wiley

[2] Larminie J., Dicks A. and McDonald M. S. (2003); *Fuel cell systems explained. Vol. 2*, Wiley

Reference Books

[1] Zhang J. (2008); *PEM Fuel Cell Electrocatalysts and Catalyst Layers: Fundamentals and Applications*, Springer

[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] Gupta R. B. (2008); *Hydrogen Fuel: Production, Transport and Storage,* CRC Press

[5] Bard A. J., Faulkner L. R., Leddy J., and Zoski, C. G. (1980). *Electrochemical methods: fundamentals and applications (Vol. 2)*, 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**

Abstract

Alternative fuels are different from the conventional fuels on different aspects. Comprehensive understandings of these fuels concerning these aspects are essential due to increased interests on these fuels. Uses of these fuels are at different levels of maturity and thus, knowledge is essentially required for further improvement of this fuel system. This course is designed to impart knowledge on all major non- fossil fuels (alternative fuels) covering important aspects of applications including the engine.

Course Outcomes

CO1: Recognize the importance of alternative fuels

CO2: Assess the challenges of alternative fuels

CO3: Analyse the performance and economic issues of alternative fuels

Course contents

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 Books

[1] Heywood J. (1988); *Internal Combustion Engine Fundamentals*, McGraw Hill

[2] Demirbas A. (2010); *Biodiesel: A Realistic Fuel Alternative for Diesel Engines*, Springer

Reference Books

[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**

Abstract

Gradual depletion of the conventional energy reserves and exploration of new energy resources have been the matter of worldwide attention and significant research over few decades. As the energy demands continue to increase, there is an urgent necessity to apply the advancements of technology in exploration, production and refinery for paving the path of sustainable developments through increasing the reserve of petroleum fuels. This course is useful and has immense values to the students for acquiring knowledge and skill on diverse topics and recent development of the next generation technologies in oil & gas and refinery industries.

Course outcomes

CO1: Identify appropriate technologies of petroleum exploration, production and refining CO2:

Review modern techniques involved in petroleum exploration, production and refining CO3:

Assess challenges of petroleum exploration, production and refining

Course contents

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

Drilling of Oil-gas Wells: Types of wells – Exploratory, Appraisal and Development; Different drilling methods, directional and horizontal drilling, offshore drilling, drilling complications, formation evaluation; Drilling fluids: Composition; Properties and types; Well completion methods; Well equipment: Christmas tree, Tubing head, Casing head, Flow control devices, Packers and Tubular

Reservoir Engineering: Definitions and classification of reserves – Proved, unproved, probable and possible reserves, distinction between In-place and Recoverable reserves; Consideration of different reservoir parameters for exploration, development, and exploitation of petroleum; Reservoir fluid characteristics; Flow of Fluids through Porous Media &Darcy's law; Gas reservoir; Driving Mechanisms &

Recovery Factor: Depletion drive, gas cap drive, water drive, combination drive; Gravity drainage, Water & Gas Coning; Secondary recovery of oil and enhanced oil recovery methods

Processing, Storage and Transportation: Surface gathering systems; Gas processing; liquid processing; Storage & Transportation of petroleum.

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; Quality control of refined products.

Text Books

[1] Ray Chaudhuri U. (2010); *Fundamentals of Petroleum and Petrochemical Engineering*, CRC Press

[2] Richard A. Dawe (Ed.) (2000); Modern Petroleum Technology, Volume 1 Upstream, Sixth Edition, Institute of Petroleum (IP), England

Reference Books

[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] Fahim M. A. Al-Sahhaf T. A. and Elkilani A. S. (2010); *Fundamentals of Petroleum Refining*, First Edition, Elsevier

Elective course I				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 521	**Nuclear Energy**	**3 0 0**	**3**	**3**

Abstract

Nuclear energy renaissance as an energy source to combat the climate change related issues. 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.

Course outcomes

CO1: Describe nuclear fission, nuclear fusion, and radioactive decay

CO2: Analyze various stages of nuclear fuel cycle

CO3: Assess the nuclear power plants and associated safety issues

CO4: Design aspects of nuclear reactors

Course contents

Introduction: The world-wide nuclear renaissance; comparison with other energy sources; public perception; non-proliferation and nuclear safeguards; financial costing; Nuclear energy programme 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.

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 Systems: Introduction to reactor system & Three stage Indian nuclear power programme. Classification of reactors, Characteristics, Selection criteria; Core configuration & cycle diagrams of thermal reactors (BWR, PWR, PHWR, AGR, HTGR, and AHWR) and Fast Reactors; process heat applications; transmutation of nuclear waste; safety systems and accidents.

Text 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

Reference Books

[1] John K. S. and Richard E. F. (2007); *Fundamentals of Nuclear Science and Engineering*, Second Edition, CRC Press

[2] Lamarsh J. R. and Baratta A. J. (2001); *Introduction to Nuclear Engineering*, Third Edition, Pearson

[3] Oka Y. and Kiguchi T. (2014); *Nuclear Reactor Design*, Fourth Edition, Springer

[4] Bayliss C. and Langley K. (2003); *Nuclear Decommissioning, Waste Management, and Environmental Site Remediation*, First Edition, Butterworth-Heinemann

[5] Brookes L. G. (2013); *The Economics of Nuclear Energy*, Springer

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

Abstract

The course is designed to impart knowledge on thermal power plant covering types of power plant and basic principles of power generation. Performance analysis of all types of power plants is taught in this course using numerical examples. Overall, broader understanding of the learners is ensured incorporating practical examples connecting related theoretical principles.

Course outcomes

CO1: Review working principle of different thermal power plants CO2:

Examine operational and safety issues of thermal power plants CO3:

Compare performances of different types of power plants

Course contents

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 Books

[1] Veatch B.Drbal L. F. Boston P. G. Westra K. L. and Erickson R. B. (2005); *Power Plant Engineering*,

[2] Nag P. K. (2014); *Power Plant Engineering*, Fourth Edition, McGraw Hill Education India

Reference Books

[1] Rajput R. K. (2007); *A Textbook of Power Plant Engineering*, Fourth edition, Laxmi

[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] Sarkar D. (2015); *Thermal Power Plant: Design and Operation*, Elsevier

Elective course II and III				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 526	**Energy Efficient Buildings**	**30 0**	**3**	**3**

Abstract

Buildings consume energy both in construction and operations. However, energy consumption in operation of buildings is approximately more than 80% of total energy consumption. Principles of building physics that are required for understanding the thermal performance of buildings will have specific focus for the design of the energy efficient buildings. 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.

Course Outcomes

CO1: Understand the principles of energy conservation opportunities in buildings

CO2: Analyze the thermal comfort of buildings based on engineering and economic principles

CO3: Assess the thermal performance of buildings

Course contents

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 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

Text 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

Reference Books

[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 and III				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 527	**Renewable Energy Grid Integration**	**3 0 0**	**3**	**3**

Abstract

The generation of electricity from renewable energy sources includes technologies such as hydropower, wind power, solar power, tidal and wave power, geothermal power, and power from renewable biomass. These sources are termed as distributed power generators and they need to be integrated among themselves and with the conventional power grid for storage and uninterrupted power flow. Grid integration is an important aspect of renewable energy engineering and needs to be formally studied.

Course Outcomes

CO1: Explain power system structure in single line and per unit system

CO2: Assess power generation from renewable energy sources

CO3: Analyze grid integrated power quality and stability

Course contents

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, 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.

Text 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

Reference Books

[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

[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 and III				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 528	**Decentralized Energy Systems**	**3 0 0**	**3**	**3**

Abstract

Decentralized energy systems provide promising opportunities for deploying renewable energy sources locally available as well as for expanding access to clean energy services to remote communities. This kind of energy systems can be used as a supplementary measure to the existing centralized energy system. The aim of this course is to make the students understand and appreciate the importance and pivotal role of decentralized base energy systems towards attaining energy security, access to clean energy in the villages. The course deals with rural energy planning, hybrid energy system design, micro-grid concepts and case studies/experiences to acquaint the students with the practical issues of energy access programme.

Course Outcomes

CO1:Distinguish decentralized and centralized generation

CO2:Explain micro-grid configurations

CO3:Assess power generation from off-grid systems

Course contents

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. renewable energy based Micro-grid

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

Text Books

[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 Books

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

Abstract

The role of energy is increasingly important with growing environmental constraints, international pressure on climate change compliance and increasing trend in energy consumption. This course deals with science of climate change, factors causes' climate to change across different time scales and possible consequences of climate change. Carbon trading is a market mechanism designed to put a price on carbon in order to reduce carbon dioxide emissions and helps to reduce the emission. Carbon trading forms a part of the wider sustainability issue and it is helpful for students to understand the concept and implications of carbon trading.

Course Outcomes

CO1: Understand the climate change and its local and global dimension

CO2: Assess the different mechanisms of carbon trading for mitigation of climate change

CO3: Analyze the international initiatives to curb climate change

Course contents

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

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; 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

Text 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

Reference Books

[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

[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 and III				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 530	**Instrumentation and Control for Energy Systems**	**3 0 0**	**3**	**3**

Abstract

This course presents the instrumentation and control techniques which are usually required in field of energy system studies. This course deals with the background knowledge of principles of measurements and errors in the context of energy systems. An overview of applications of electronics and microcontroller in control systems as well as software intervention is also presented. Some of the typical measuring and control instruments related to energy systems are discussed. The objective of this course is to provide the students from different discipline a better foundation in instrumentation as well as control system in the context of energy system studies.

Course Outcomes

CO1: Explain components of instrumentation and control systems

CO2: Analyse monitoring, signal conditioning and control circuits

CO3: Develop micro controller programmes for sensing and triggering events

Course contents

Overview of Instruments and Measurement Systems: Principles of measurements and measurement errors, Classification of instruments, static and dynamic characteristics, Input output configurations of measurement system

Sensor and transducers: Types, characteristics and applications of Mechanical transducers, Types, characteristics and applications of electrical transducers, Principles of Modern sensors and typical applications

Introduction to Control Systems: Overview of control systems, types and components, Feedback and non-feedback systems and their applications, Transfer function, block diagram representation and reduction techniques

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

Data Acquisition Systems: Types of Instrumentation Systems and components, working principle and application of Single Channel A /D converter, Working principle and application of multi-channel A/D converter, Digital data processing and display

Microcontrollers and compilers: Overview of microprocessor and microcontroller, Microcontroller Types and architecture, Use of compilers for data acquisition, processing and display, typical microcontroller Applications for monitoring and control of electrical and non–electrical parameters/processes

Text Books

[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 Books

[1] Bentley J. P. (2005); *Principles of Measurement Systems*, Fourth Edition, Pearson Prentice Hall

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

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

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

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

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Tezpur University
Tezpur, Assam

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

Abstract

In this course a comprehensive analysis of classifications of partial differential equations, different discretization schemes and different algorithms will be taught. Basics of heat transfer, fluid flow, mathematical description of fluid flow and heat transfer (conservation equations for mass, momentum, energy) will also be discussed in the initial classes. Broader understanding of the learners is ensured incorporating practical examples of heat transfer and fluid mechanics problem.

Course Outcomes

CO1: Review of various numerical schemes for solving heat transfer and fluid mechanics Problems

CO2: Interpretation of the numerical results in heat transfer and fluid dynamics

CO3: Analyze fluid flow problems with the application of the momentum and energy equations

Course contents

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 Books

[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 Books

[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] NecatiÖzışık M. (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 and III				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 532	**Energy Conservation by Waste Heat Recovery**	**3 0 0**	**3**	**3**

Abstract

The industrial sector accounts for about 40 percent of the total energy consumed in India and are responsible for around one fourth of the total greenhouse gas emissions. This share is more than half of the total GHG emissions, if energy industries are considered together. It is estimated that somewhere between 30 to 50% of industrial energy input is lost as waste heat in the form of exhaust gases, cooling water, and heat lost from equipment surfaces and heated products. As the industrial sector continues efforts to improve its energy efficiency, recovering waste heat losses provides an attractive opportunity for an emission free and less costly energy resource.

Course Outcomes

CO1: Review of the technologies for waste heat recovery practiced at industries CO2:

Assess the challenges of Waste Heat Recovery

CO3: Analyse the principles and significance of waste heat recovery

Course contents

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.

Text Books

[1] Hewitt, G. F., Shires, G. L., and Bott, T. R. (1993); *Process Heat Transfer*, CRC Press, Florida.

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

Reference Books

[1] Goswami, D. Y., and Kreith, F. (2007); *Energy Conversion*, CRC Press.

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

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

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

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

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

Abstract

This course covers all types of currently-available energy storage systems, which are, or can be, used in the electricity, heat and transport sectors. The various technologies discussed may be categorized as mechanical/kinetic, thermodynamic, electrical, chemical, electrochemical or thermal processes.

Course Outcomes

CO1: Review of different energy storage devices pertaining to working principles and applications CO2: Identify the optimal solutions to potential energy storage application

CO3: Evaluate different energy storage systems based on engineering problems

CO4: Assess relative costs and sustainability of energy storage technology

Course contents

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.

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.

Text 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

Reference Books

[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] Rahn C. D. and Wang C. (2013); *Battery Systems Engineering*, First Edition, Wiley

[4] Moseley P. T., andGarche J. (2014); *Electrochemical Energy Storage for Renewable Sources and Grid Balancing*, Elsevier Science.

[5] Miller F. P., Vandome A. F., and John M. B. (2010); *Compressed Air Energy Storage*, VDM Publishing.

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

Abstract

Modeling has been extensively used in a variety of applications to mimic real life problems and their subsequent solutions. Thus, models serve as useful tool for decision making. Scope of applications of models in energy studies is of paramount importance. This course is intended to impart basic skill of model development and optimization in the field of energy. The learners will be familiarized to variety of energy related field problems associated mostly with economy and environment.

Course Outcomes

CO1: Understand the technique of development of energy system model

CO2: Assess various techniques of model validation

CO3: Apply energy system model for decision related to field problems

Course contents

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 Books

[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 Books

[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

Elective course II and III				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 535	**Energy Environment Interaction**	**3 0 0**	**3**	**3**

Abstract

Energy is a key ingredient for all round development of a society. However, energy extraction, conversion and uses create environmental problems in terms of pollution, global warming etc. Energy – Environment interaction is one of the major challenges in both developed and developing countries. This course is designed to give an idea about the impact of energy on the environment and the natural habitat. The energy developmental linkages are also discussed on this course including sustainability issues.

Course Outcomes

CO1: Understand different energy sources, ecosystem theories and pollution related issues CO2: Indicate the energy flow and transformation of different energy types in an ecosystem CO3: Analyse the role of energy uses in different types of pollutions and measures

Course contents

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)

Transition to modern energy services, Energy poverty and Human Development Indices, Energy and Human Development, Energy development index; Understanding the link between economic growth and energy consumption

Text Books

[1] GoldembergJ. (Ed) (2008); Interactions: Energy and Environment, Eolss Publishers

[2] Saxena A.B. (2011); A Textbook of Energy, Environment, Ecology and Society, New Age International

Reference Books

[1] Wilson R. and Jones W. J. (1974); Energy, Ecology, and the Environment, Elsevier

[2] Fowler J. M. (1984); Energy and the Environment, Second Edition, McGraw Hill

[3] Kaushika N. D. and Kaushik K. (2004); Energy, Ecology and Environment: A Technological Approach, Capital Publishing

[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

Elective course II and III				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 536	**Materials and Devices for Energy Applications**	**3 0 0**	**3**	**3**

Abstract

This course aims to introduce materials that revolutionize the current world with various energy options. The materials that control the performance of various energy sources such as photovoltaic devices, fuel cells and energy storage are explored. This course covers the theory, design, fabrication and applications of materials and devices for energy applications. Device processing topics include crystal growth, substrate engineering, thin film deposition, etching and process integration for silicon and compound semiconductor materials. The course also covers different material characterization techniques and working principles of various measuring devices. This course will introduce students to the rapidly developing field of nano-engineered materials with special focus on energy related applications.

Course Outcomes

CO1: Understand energy materials pertaining to synthesis, characterizations and applications in energy devices

CO2: Analyze the material design related to fabrication of fuel cell systems, energy storage devices, and photovoltaic devices

CO3: Develop skills and creativity towards material design for various energy harvesting devices CO4: Test and evaluate the performance of different energy harvesting devices

Course contents

Device fabrication technologies: diffusion, oxidation, photolithography, sputtering, physical vapor deposition, chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), hot wire CVD (HWCVD) High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III-V, II-VI thin-film solar cells; Amorphous silicon thin-film (and/or flexible) technologies, multi-junction (tandem) solar cells, organic/flexible solar cells, polymer composites for solar cells, Spectral response of solar cells, quantum efficiency analysis, dark conductivity, I-V characterization Introduction to material characterization: Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), X-ray diffraction (XRD), Raman spectroscopy, Atomic force microscopy (AFM); device fabrication and characterization;

Materials and devices for energy storage; Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNTs for hydrogen storage, CNT-polymer composites, ultra-capacitor; Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells

Text Books

[1] Robert F. P. (2002). *Advanced Semiconductor Fundamentals*, 2nd Edition, Pearson

[2] Duncan W. B., Dermot O., and Richard I. W. (2011). *Energy Materials*, 1st Edition, Wiley

Reference Books

[1] Fahrenbruch A. L. and Bube R. H. (1983); *Fundamentals of Solar Cells: PV Solar Energy Conversion*, Academic Press

[2] Tom M. and Luis C. (2005). *Solar Cells: Materials, Manufacture and Operation,* 1st Edition, Elsevier Science

[3] Christoph B. Ullrich S. and Vladimir D. (2014). *Organic Photovoltaics: Materials, Device Physics, and Manufacturing Technologies*, 2nd Edition, Wiley-VCH

[4] San P. J. and Pei K. S. (2013). *Nanostructured and Advanced Materials for Fuel Cells*, 1st Edition, CRC Press

[5] Daniel C. and Besenhard J. O. (2011). *Handbook of Battery Materials*, 1st Edition Wiley-VCH

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Tezpur, Assam

Elective course II and III				
Course code	Course Name	L T P	CH	Credit
EN 537	Power Generation and System Planning	3 0 0	3	3

Abstract

Matching the power generation with the increasing energy demand becomes very crucial for the electrical utilities. In the same, economics of the energy from different sources of generation or variation in energy pricing from state/central sector in the deregulated market makes the utility management is very crucial. This course will enable the students to understand the process and operation of restructured power system, load management, sharing of resources, demand side management etc. This course also deals on smart grid, different options of architectural design and communication technology for various aspects of smart grid, renewable energy sources and storage integration with smart grid.

Course Outcomes

CO1: Understand principles of power generation planning and economics

CO2: Analyze power industry and market models

CO3: Design smart grid incorporating modern gadgets

Course contents

Overview of the Indian power sector; Demand and supply analysis, Load growth patterns; Deregulation of the electricity supply industry, power system operation in competitive environment; transmission open access and pricing issues, reliability and deregulation, power quality issues, application of power system stabilizers, demand side management

Analysis of System load curve; plant load factor, availability, Loss of load Probability calculations for a power system, Maintenance Scheduling; Pricing of Power, Project cost components, Power Purchase Agreements (PPA), Optimal Dispatch - Scheduling of Hydro-Thermal plants; Load Forecasting: Time series, Econometric, end use techniques. Least Cost Power Planning; Integration of DSM, Renewable energy integration with grid; Government Policies

Distribution system planning, planning and forecasting techniques, load characteristics, forecasting and management, tariffs-distribution; distribution system automation; Deregulation, Reconfiguring Power systems, unbundling of electric utilities, competitive electricity market; Power wheeling, Transmission open access, pricing of power transactions, security management in deregulated environment

Concept and function of Smart Grid; Opportunities& Barriers of Smart Grid, Difference between conventional & smart grid; Smart Meters, Real Time Pricing, Automatic Meter Reading(AMR); Concept of micro grid, need & applications of micro-grid; Issues of interconnection, protection & control of micro grid

Text Books

[1] Wood A. J. Woolenberg B. F. and Sheblé G. B. (2013); *Power Generation, Operation and Control*, Third

Edition, Wiley-Interscience

[2] Hadi S. (2011); *Power System Analysis*, Third Edition, PSA Publishing

Reference Books

[1] Kirschen D. S. and Strbac G. (2004); *Fundamentals of Power System Economics*, First Edition, Wiley

[2] Stoft S. (2002); *Power System Economics: Designing Markets for Electricity*, First Edition, Wiley-IEEE Press

[3] Ekanayake J., Jenkins N., Liyanage K., Wu J., and Yokoyama A. (2012); *Smart Grid: Technology and Applications*, First Edition, Wiley

[4] Lei L. L. (2001); *Power System restructuring and deregulation*, First Edition, Wiley

[5] Ilic M., Galiana F., and Fink L. (1998); *Power Systems Restructuring: Engineering and Economics*, Springer

Elective course II and III				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 538	**Hybrid Renewable Energy System Design**	**3 0 0**	**3**	**3**

Abstract

Small-size hybrid wind-hydro-diesel-solar power generation systems are attractive to solve the power supply problem in rural areas where no grid connection is available. Optimal design models are necessary to design the hybrid generation systems including battery banks and to provide the optimum system configuration. It is to be ensured that the annual cost of the system is minimized while satisfying the required loss of power supply probability.

Course Outcomes

CO1:Understanding characteristics of renewable energy sources for effective integration

CO2:Design hybrid energy system with control strategies for operation

CO3:Assess performance of hybrid energy system using simulation tools

Course contents

This course will review technical characteristics of various renewable energy sources and develop the skills and knowledge for designing, sizing and specifying hybrid renewable energy systems. Renewable energy systems covered include biomass, electrical and wind energy systems. The course will present various hybrid system architectures and examine their advantages and disadvantages. System components, control strategies, and the use of storage (thermal and electrical) and other demand-side technologies will be analyzed and evaluated. Students will learn how to model energy sources and use simulation tools to design and optimize systems, and apply these techniques to develop a hybrid energy system to provide electricity to a small to medium rural village.

Text Books

[1] Fu Y., Yang J. and Zuo T. (2011); *Optimal sizing design for hybrid renewable energy systems in Rural Areas*, Springer

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

Suggested Reading

[1] Funabashi T. (Ed.) (2016); *Integration of Distributed Energy Resources in Power Systems: Implementation, Operation and Control*, Academic Press

[2] HOMER Simulation Tool; http://www.homerenergy.com/, HOMER Energy, NREL, USA

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

[4] Mahmoud M.S. and AL-Sunni F. M. (2015); *Control and Optimization of Distributed Generation Systems*, Springer

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

[6] 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 aims 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.

Course Outcomes

CO1: Identify a research area for new and useful knowledge in the field of energy

CO2: Review of literature and identify research gaps in the field of energy

CO3: Formulate objectives and adopt methodology for the proposed work

CO4: Design of the experiments/simulation/field survey protocols related to the work, prepare report

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

The project work started in the third semester will be extended in 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 and/or reputed conferences.

Course Outcomes

CO1: Demonstrate in-depth of knowledge through experiments/modeling/field works

CO2: Analyze, validate, and interpret the results of the work

CO3: Prepare thesis and publish articles/papers for effective communication with engineering community and society at large

Elective course II and III				
Course code	**Course Name**	**L T P**	**CH**	**Credit**
EN 541	**Electricity Regulations and Reforms in India**	**3 0 0**	**3**	**3**

Abstract

This course is designed to meet the industry specific skills required to cater the needs of trained manpower for PSUs/SEBs/Power Utilities/IPPs etc. This course would facilitate in understanding the electricity law, policy, reforms and regulatory framework that the Power sector has gone through since independence. The course will expose the students to the current regulations and policies governing power sector in India. The course would enrich the students in providing a holistic understanding of Regulatory & Commercial concepts like tariff calculations, power trading etc.

Course Outcomes

CO1: Understand the Electricity Acts, electricity reforms and policies

CO2: Review electricity tariff determination methodologies and role of electricity regulatory commission CO3: Assess the power trading and power exchange mechanisms in India

CO4: Analyze the performance of electricity Distribution Company in India

Course contents

Overview of Indian Power Sector & Phase wise Sectoral Reforms: Power sector structure in Country, Significance of Regulatory Overview, Indian Electricity Act 1910, Electricity Supply Act1948, Electricity Regulatory Commission Act 2003: Salient features & Regulatory provisions, Electricity Amendment Act 2007, Electricity Amendment Bill 2014, National Electricity Policy & National Tariff Policy

Regulatory Institutions in Indian Power Sector & their functioning: Objectives, Constitution & Function of CERC & SERC's, Role of APTEL & Forum of Regulators (FOR), Regulatory initiatives undertaken by CERC & respective SERC's

Tariff determination methodology: Regulatory norms for computation of Tariff of Thermal and Hydro, Comparison of CERC & SERC Tariff norms, Tariff determination exercise on Computer for Thermal Power Plant and Renewable Energy, Tariff based bidding for Power Projects

Regulatory framework for Renewable Energy (RE), RE policy prescriptions: Central and State; CERC guidelines on RE development, Regulatory issues and challenges; Comparative state regulations and RE

Power Market transactions: Concept of Power Trading, Power Exchange mechanism in India, Availability Based Tariff & Concept of UI, Open access in Power sector, Multi Year Tariff(MYT) framework

Text Books

[1] Kumar A., and Chatterjee S. K. (2012); *Electricity Sector in India: Policy and Regulation*, Oxford University Press

[2] Daniel S. K., and Goran S. (2004); *Fundamentals of Power System Economics,* Wiley

Suggested Reading

[1] NPTEL E-Learning; *Restructured Power Systems*, http://nptel.ac.in/syllabus/108101005/

[2] Rao S L. (Ed), (2011); *Powering India*, Academic Foundation

[3] Bhattacharya K., Bollen M., Daalder J. E. (2001); *Operation of Restructured Power Systems,* Springer

[4] Ruet J., and Kaushik P. D. (2005); *Privatising Power Cuts? Ownership and Reform of State Electricity Boards in India*, Academic Foundation

[5] Lai L L. (editor), (2001); *Power System Restructuring and Deregulation: Trading, Performance and Information Technology*, Wiley.

Controller of Examinations
Tezpur University
Tezpur, Assam

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 560	**Foundation for Energy Technology**	**3 0 0**	**3**	**3**

Abstract

Energy being an interdisciplinary field of study, it is intended to provide the basic knowledge in different engineering disciplines to the students with different background. This course deals with the fundamentals of thermodynamics, fluid mechanics and electrical engineering. The course also presents an overview of analogue and digital electronics, as well as microcontroller fundamentals, which is necessary for energy system instrumentation and control devices. This course will help in developing foundation towards energy technology studies.

Course Outcomes

CO1: Understand the forms and conversion of energy

CO2: Identify different power cycles and analyze its thermodynamics

CO3: Review of fluid mechanics and relevance for energy conversion processes

CO4: Analyse performance of electrical components, power transmission and distribution

CO5: Assessment of environmental impact and Life cycle analysis (LCA)

Course contents

Basics of energy: Different forms of energy, energy conversion process, indirect and direct energy conversion; Different energy sources; Conventional energy systems: engines, power plants, various methods of power generation; Thermodynamic analysis of conventional power plants

Thermodynamics: Laws of thermodynamics and applications, Concepts of internal energy, entropy, enthalpy; Gas laws, Thermodynamic cycles, Irreversible and Reversible processes, Carnot cycle, Carnot engine; Heat engines and heat pumps/refrigeration, Psychometrics and use of psychrometric chart

Fluid Mechanics: Properties of fluids, Bernoulli's equation, Navier-stokes equation, conservation equations for mass, momentum and energy; Uses of non-dimensional numbers to describe flow conditions; Theory and principles of flow measuring devices; Viscous flow in a pipe, Flow through packed and fluidized bed; Introduction to turbulence

Electrical Machines: Principles of Transformer, motor and generators, characteristics and applications; DC machines: characteristics and Applications

Power systems: Load and load duration curves, selection of generating units, Introduction to power generation, transmission and distribution, power systems losses and compensation, High voltage AC (HVAC) and High voltage DC (HVDC) transmission; Interconnected grid system

Energy and environment correlations, Environmental degradation due to energy production and utilization, global warming; Environmental Impact Assessment, Life cycle analysis (LCA) and sustainability issues

Text Books

[1] Nag P.K. (2014); *Basic and Applied Thermodynamics*, McGraw Hill.

[2] Theraja B. L. and Theraja A. K. (1998); *A Text Book in Electrical Technology*, S. Chand and Co.

Suggested Readings

[1] Kothari D. P. and Nagrath I. (2009); *Basic Electrical Engineering*, Third Edition, McGraw Hill, India

[2] Zemansky M. and Dittman R. (2011); *Heat and Thermodynamics*, McGraw Hill, India

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

[4] Balachandran P. (2010); *Engineering Fluid Mechanics*, Prentice Hall India

[5] Dessler A. (2011); *Introduction to Modern Climate Change*, Cambridge University Press

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 561	**Fuel and Combustion**	**3 0 0**	**3**	**3**

Abstract

Combustion of fuel remains the main source of primary energy for human civilization. At the same time, it is the main source of environmental pollution. Hence, it is very important for the students to understand the fuel conversion process. However, combustion is a complicated process so it needs to be discussed step by step procedure starting with various fuels, combustion theory, combustion appliances and practical combustion problems. This course is an introductory course on fossil fuels and combustion chemistry. It covers fundamental aspects of combustion, combustion related problems and an understanding on the combustion appliances. Overall, the course aims to provide an understanding on fossil fuels, their properties, combustion chemistry, combustion appliances and problems solving.

Course Outcomes

CO1:Understanding the importance of fossil fuels and their properties

CO2:Analyse the combustion mechanisms of fossil fuels

CO3:Design and performance analysis of combustion devices CO4: Assessment of emissions in combustion systems

Course contents

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 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 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

Text Books

[1] Sarkar S. (2010); *Fuels and Combustion*, Third Edition, CRC Press

[2] Jaccard M. (2006); *Sustainable Fossil Fuels*, Cambridge University Press

Suggested Readings

[1] Turns S. R. (2011); *An Introduction to Combustion: Concepts and Applications*, Third Edition, McGraw Hill

[2] Mukunda H. S. (2009); *Understanding Combustion*, Second Edition, Universities Press

[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 562	**Heat Transfer**	**3 0 0**	**3**	**3**

Abstract

Comprehensive analysis of all the three modes of heat transfer (conduction, convection and radiation) is described in this course. The numerical tools and techniques, used to estimate the transfer of heat for all the three modes, are elaborately discussed. The dependency of heat transfer on material and environmental factors/properties are critically discussed with examples. Broader understanding of the learners is ensured incorporating practical examples of heat transfer.

Course Outcomes

CO1:Understanding heat transfer modes for solution of thermal energy applications CO2:Design and analysis of the performance of heat transfer devices

CO3: Determine the optimal parameters through numerical solution of heat transfer problems

Course contents

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 geometries

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: Design and selection methodology of different types of heat exchangers. Performance analysis (LMTD and NTU methodology) and solving design problems

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

Text Books

[1] Incropera F. P., DeWitt D. P., Bergman T. L. and Lavine A. S. (2006); *Introduction to Heat Transfer*, 5th Edition, Wiley

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

Suggested Readings

[1] Lienhard J. (2011); *A Heat Transfer Textbook*, Fourth Edition, Dover Publication

[2] Holman J. P. (2009); *Heat Transfer*, Tenth Edition, McGraw Hill

[3] Gupta V. (1995); *Elements of Heat and Mass Transfer*, New Age International

[4] Ghajar A. J. and Cengel Y. A. (2014); *Heat and Mass Transfer: Fundamentals and Applications*, Fifth Edition, McGraw Hill

[5] Dutta B. K. (2009); *Heat Transfer: Principles and Applications*, First Edition, PHI

Core course						
Course code	**Course name**	**L**	**T**	**P**	**CH**	**Credit**
EN 563	**Solar Energy Engineering and Applications**	**3**	**0**	**0**	**3**	**3**

Abstract

The course is designed with objectives to prepare students for designing and different solar energy utilization technologies as well as to develop competency for research in solar energy. This course discusses the fundamentals of solar radiation, solar energy conversion devices and applications. Solar thermal and Photovoltaics fundamentals, utilization of solar energy for thermal and electric applications are covered. The course also includes the application of solar energy in photo-catalysis including the issues and challenges for system level utilization of solar energy in this aspect.

Course Outcomes

CO1: Estimate and measure solar irradiance

CO2: Examine different types of solar energy technologies and systems

CO3: Analyse solar thermal and photovoltaic systems

Course contents

Solar radiation: Extra-terrestrial and terrestrial radiation; Earth-Sun relation: Solar angles, Sunpath diagram; Shadow determination, Solar spectrum, Effect of earth atmosphere on solar radiation,

Measurement and estimation of solar radiation on horizontal and tilted surfaces, Solar radiation measurement devices, Solar radiation data analysis

Solar thermal conversion: Theory and Basics; Introduction to different solar thermal energy systems: Solar flat plate collector, Concentrating collector, Solar cooker, Solar pond, Solar passive heating and cooling system; Design and components and flat plat collector; Flat plate collectors-liquid and air type; Development of solar thermal collectors; Solar cooling and refrigeration; Concentrating solar collector: optical design of concentrators, solar water heaters, solar dryers; Solar thermal power generation and economics.

Photovoltaic: Principle of photovoltaic conversion; Solar cell basics and materials; Different solar cell technologies: Crystalline silicon solar cell, Thin Film solar cell, Tandem solar cell; Photovoltaic system: Component and configurations; off grid and grid connected PV systems, PV system design and economics; Solar Energy Mission

Solar Photo-catalysis: Solar photo-catalysis mechanism, kinetics and application

Text Books

[1] Duffie J. A. and Beckman W. A. (2013); *Solar Engineering of Thermal Processes*, John Wiley

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

Suggested Readings

[1] Garg H. P. and Prakash S. (2000); *Solar Energy: Fundamental and Application*, Tata McGraw Hill

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

[3] Goswami D. Y. (2015); *Principles of Solar Eng*ineering, Taylor and Francis

[4] Green M. (1992), *Solar Cells: Operating Principles, Technology and System Applications* 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 564	**Biomass Energy and Applications**	**3 0 0**	**3**	**3**

Abstract

Biomass is any organic material derived from recently living organisms, which includes plants, animals and their byproducts that can store sunlight in the form of chemical energy. It is a renewable energy source based on the carbon cycle, unlike other natural resources such as petroleum, coal, and nuclear fuels. One of the advantages of biomass fuel is that it is often a by-product, residue or waste-product of other processes, such as farming, animal husbandry and forestry. In its most narrow sense it is a synonym to biofuel, which is fuel derived from biological sources. The energy derived from biomass sources is termed as bioenergy or boarder sense called biomass energy. This course has been prepared to give an overview of biomass as fuel along with various biomass energy conversion routes and their energy utilization.

Course Outcomes

CO1: Understand biomass production and energy conversion systems

CO2:Investigate different biomass based energy conversion systems

CO3: Assess the performance of different biomass based energy conversion systems

Course contents

Introduction: Overview of biomass as energy source; World and India's Bio-energy Scenario, Production of biomass, Photosynthesis, efficiency of C_3& C_4 plants on biomass production; Assessment of biomass resources, types of biomass, Long-term sustainability as feedstock; Environmental issues on biomass based energy generation

Biomass and Biofuel: Biomass composition and energy content; Biofuels, types of biofuels and production technologies; Advanced bio-systems and biofuel production

Bioenergy systems: Biomass conversion routes: biochemical, chemical, thermochemical and physical processes; Energy efficient wood stoves: Traditional Stoves, Energy Efficient Cooking and Space heating Stoves, Metal stoves, Improved gasifier stoves, Current Research Status, Pollution due to emissions; Physical processes: Dewatering and drying, Size reduction, densification, separation; Direct combustion: Fundamentals, Biomass combustion for energy production, Emission and combustion characteristics Biochemical conversion: Aerobic and Anaerobic conversion, Fermentation; Bio-methanation: 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

Liquid biofuel: Biodiesel– feedstock for biodiesel production; mechanism of transesterification, fuel characteristics of biodiesel, technical aspects of biodiesel engine utilization; Alcohol production from biomass-types of materials of alcohol production-process description, utilization, fuel-characteristics of alcohol, comparison with other liquid fuel, alcohol based chemicals and fuel; Methanol production, fuel properties and utilization

Thermochemical conversion: Pyrolysis, Carbonization, Charcoal production, Biomass gasification, Liquefaction; Torrefaction and pyrolytic oil, typical composition, engine application; Biomass Gasifiers: types of gasifiers and mechanisms of operation, gasifier product gas analysis, gasifier stoves, heat and mass balance of gasification system; Gasification based power generation, IGCC, cost benefit analysis, case studies

Modern biofuel and bio-refinery: Next generation biofuel production: biochemical, gasification, hydrogenation and FT process; Bio-butanol, bio-propanol and bio- hydrogen production, fuel characteristics and utilization; Integrated Bio-refinery approach for biofuel and chemical production

Text Books

[1] Sorensen B. (2010); *Renewable Energy*, Fourth Edition, Academic press

[2] Mukunda H. S. (2011); *Understanding Clean Energy and Fuels from Biomass*, Wiley India

Suggested Readings

[1] Klass D. L. (1998); *Biomass for Renewable Energy, Fuels, and Chemicals*, Academic Press, USA.

[2] Higman C. and Burgt M v d (2003); *Gasification*, Elsevier Science, USA.

[3] Stassen H. E. Quaak P. and Knoef H. (1999); *Energy from Biomass: A Review of Combustion and Gasification Technologies*, World Bank Publication.

[4] Mittal K. M. (1996); *Biogas systems: Principles and Applications*, New Age International.

[5] Rosillo-Calle F. and Francisco R. (2007); *The Biomass Assessment Handbook: Bioenergy for a Sustainable Environment*, Earthscan.

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 565	**Wind and Hydro Energy**	**3 0 0**	**3**	**3**

Abstract

This course deals with wind and hydro energy sources and systems in details. These are two most important renewable energy sources in India. The installed capacities of these two renewable energy base conversion system is highest and it also proved that the energy generation cost from these resources are economical competitive. This is broad course aimed to teach the students on various aspects of wind and hydro energy resource assessment, conversion process, applications and economics of energy generation.

Course Outcomes

CO1: Explain wind and hydro energy resource assessment techniques

CO2: Use of wind and hydro energy conversion principles for power generation

CO3: Analyze the performance and cost of wind and hydro energy conversion devices

CO4: Assess the environmental issues related to wind and hydro energy systems

Course contents

Atmospheric circulations, classification, factors influencing wind, wind shear, turbulence, wind speed monitoring, Wind resource assessment, Weibull distribution; 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.

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

Text 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

Suggested Readings

[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 566	**Energy Laboratory**	**0 0 3**	**6**	**3**

Abstract

This course includes the laboratory experiments and simulation study to be carried out by the students under the supervision of Technical staff and course coordinator. The experiments are formulated to perform in groups by the students. With these experiments students will get firsthand experience of the demonstration set-up for the full scale system uses in Industry or Research. Furthermore, data analysis and error analysis are important section of these experiments to be performed in this course.

Course Outcomes

CO1: Operate measuring devices of energy conversion and management systems

CO2: Analyse and discuss the experimental results

CO3: Interpret the experimental results and present a technical report

Course contents

A. Preparation for Laboratory Experiments and report writing

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

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

B. Experiments

Solar: Experimental study on thermal performance of solar water heater, solar dryers, solar cooker; solar PV module characterization with different configuration

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

Suggested Readings

[1] Holman J. P. (1984); *Experimental Methods for Engineers*, McGraw Hill

[2] Polak P. (1979); *Systematic Errors in Engineering Experiments*, Macmillan

[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*, Narosa

[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 570	**Energy Management and Auditing**	**3 1 0**	**4**	**4**

Abstract

This course deals with the understanding on energy management, and conservation and energy auditing. It deals with energy conversion processes in various utilities, energy cost optimization etc. It also deals the various features of Energy Conservation Act and the duties of Energy Manager and Energy Auditors. Apart from these, this course deals with electrical and thermal energy management in industry and residential sectors. This is a broad course aimed to expose the students on various aspects of energy auditing and conservation techniques.

Course Outcomes

CO1: Discuss the principles of energy management, conservation and auditing in thermal and electrical utilities

CO2: Assess scope of energy conservation in electrical and thermal utilities

CO3: Analysis of economics of energy conservation opportunities in electrical and thermal utilities and reporting of energy audit

Course contents

Concept of energy management programme, basic components of an energy audit, types of energy audit, energy audit flow chart; Understanding energy use patterns and costs, Fuel and energy substitution; concepts of energy conservation and energy efficiency

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

Material and energy balance, Sankey diagram; 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

Electricity tariff analysis, load management and maximum demand management, Reactive power management, Power factor and its improvement, Electric Power systems analysis, Energy efficient motors, Soft starters, Variable speed drives

Performance assessment and energy conservation opportunities in compressed air systems, Refrigeration plants, Fans and blowers, pumping systems and cooling towers; Performance assessment of DG Systems, Case studies

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 in steam systems, Performance assessments; Performance analysis of furnaces, Analysis of losses and energy conservation opportunities

Heat exchanger networking, concept of pinch; Waste heat recovery systems, 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

Text Books

[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

Suggested Readings

[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 571	**Energy Economics and Planning**	**3 0 0**	**3**	**3**

Abstract

Economics of energy and its planning is a broad scientific area which includes topics related to economic aspects of supply and use of energy in society in general and the nation as a whole for its growth and development needs. Hence, it is very important for the students to understand the basics of economic principles that govern the supply and demand of energy in the context of modern civilization. This course aims at bridging the technological aspects of energy resources to that of its economic principles.

Course Outcomes

CO1: Discuss the energy economic principles

CO2: Formulate policy and planning for energy security

CO3: Assess energy projects using financial evaluation techniques

Course contents

Energy economics: Basic concepts, energy data, energy cost, energy balance.

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

Concepts of economic attributes involving renewable energy, Calculation of unit cost of power generation from different sources with examples, different models and methods

Application of econometrics; input and output optimization; energy planning and forecasting - different methods

Concepts of economic attributes involving renewable energy, Calculation of unit cost of power generation from different sources with examples, different models and methods

Application of econometrics; input and output optimization; energy planning and forecasting - different methods

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, Planning for energy security and renewable energy innovations; Regional, National and Global aspirations and requirements; Role of Governments, Societies and NGOs.

Text Books

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

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

Suggested Readings

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

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

[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.andFabrycky W. J. (2001); *Engineering Economy*, Ninth Edition, Prentice Hall India

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Tezpur, Assam

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 572	**Energy Systems and Simulation Laboratory**	**0 0 3**	**6**	**3**

Abstract

This course contents the laboratory experiments and simulation study to be carried out by the students under the supervision of Technical staff and course coordinator. The experiments are formulated to perform in groups by the students. With these experiments students will get firsthand experience of the demonstration set-up for the full scale system uses in Industry or Research. Furthermore, data analysis and error analysis are important section of these experiments to be performed in this course.

Course Outcomes

CO1: Operate equipment/devices/software associated with Energy systems

CO2: Analyse and discuss the experimental and simulation results

CO3: Interpret the experimental and simulation results and present a technical report

Experiments

Bio Energy and Biofuel: Biogas production and application (Part I: Lab scale reactor design); Biogas production and application (Part II: analysis of feedstock (input) and gas (output)); Characterization of bio-gas using gas chromatograph

Biodiesel production and characterization from non-edible vegetable oil – Part I: feedstock preparation and characterization, Part II: Conversion and characterization

Thermo-chemical conversion & characterization of biomass

Thermal energy conservation and performance assessment: Thermal energy audit of thermal energy conversion unit

Building Energy: Measurement and analysis of heat gain and air-conditioning load in a building

Thermal performance assessment of a gasifier system

Engine performance analysis: CI engine performance using Diesel fuel, Engine performance analysis using synthesis gas

Energy System: Fuel cell characterization and analysis of polarization curve and calculate kinetic, ohmic, and transport losses; estimate internal resistance and hydrogen cross-over of the fuel cell Characterization devices and systems: Transmission and absorption analysis of a liquid sample for energy applications using UV-Vis spectrometer

Solar Energy: PV system characterization under the influence of varying radiation and shadow

Energy system Simulation: Photovoltaic system performance analysis using PVsyst simulation tool; Hybrid energy systems using HOMER simulation tool; Building design and thermal performance analysis using TRANSYS simulation tool

Suggested reading materials

Necessary laboratory instruction related to lab experiment and brochure will be provided by the lab instructor

Core course				
Course code	**Course name**	**L T P**	**CH**	**Credit**
EN 573	**Energy Study with Community Engagement**	**0 0 2**	**4**	**2**

Abstract

This course will enable the learners to apply theories in a way that promotes understanding on real life problems through community engagement. The learners will be able to integrate the knowledge, skills, and attitudes towards the solution of field problems related to access of energy through community engagement. Learners will gain practical and real life understandings of key issues of energy supply and demand pattern in the communities. The course will enable them to understand the best practices and processes towards successful application of energy related systems. The course will develop critical thinking of the learners towards protection of environment and livelihood improvement in the villages.

Course Outcomes

CO1: Recognize the linkage between socio-economic factors and energy consumption pattern through community engagement

CO2: Apply appropriate knowhow related to energy for improvement of livelihood of the community

CO3: Assess the impact of energy systems on rural livelihood and present reports

Activities

The learners will carry out the study through field visit and community engagement in groups (maximum five students per group). A suggestive plan of activities is listed below

- Identification of the thematic area of study (some examples are, but not limited to: assessment of energy resources, energy consumption pattern, study on energy conversion technologies/ devices used by community, economics of energy services, comparisons of energy systems and technologies) (to be done by first month of the semester).
- Preparation of the work plan including (i) objective of study, (ii) study area, (iii) schedule of visit, (iv) data, (v) methods of analysis and (vi) expected know-how to be generated
- Presentation of work plan (to be done by mid-term)
- Execution of the study. Technological innovation towards application specific system design and community participation in the design process. System must integrate the community's requirements and present practices
- Report submission and final presentation (by end-term)