M. Tech. in Energy Technology

Course structure

Department of Energy
Tezpur University
Tezpur, Assam, India

January 2013

Course Curriculum

The students undergoing the M. Tech course in Energy Technology will be offered:

(a) Core courses including both theoretical and experimental courses in different areas of energy
(b) IDC courses from other Departments, and
(c) Project work, where special emphasis is placed on the application of knowledge and training to solve real problems

First Semester

Code	Course Title	Credit
EN566	Fuel Technology	3
EN595	Biomass Energy Utilization	3
EN569	Solar Energy Utilization	3
EN570	Heat Transfer	3
EN596	New & Renewable Energy Sources	3
EN576	Energy Lab-I	2
EN593	Basic Sciences & Engineering for Energy Study	3
	IDC I	3
Total		23

Second Semester

Code	Course Title	Credit
EN567	Power Plant Engineering	3
EN572	Energy, Ecology & Environment	3
EN573	Energy Management & Auditing	3
EN574	Energy Economics & Planning	3
EN575	Numerical Methods & Computational Techniques for Energy System Modeling	3
EN577	Energy Lab-II	2
	IDC II	3
	IDC III	3
Total		23

Code	Course Title	Credit
Third Semester		
EN578	Major Project (Part-I)	8
Fourth Semester		
EN579	Major Project (Part-II)	16

IDC Courses offered by Department for students of other Department

Code	Course Title	Credit
EN584	Advanced Bio-energy	3
EN585	Advanced Solar Thermal Energy	3
EN586	Solar Photovoltaic Energy	3
EN587	Petroleum Refining	3
EN588	Petroleum Exploration, Drilling & Production	3

EN589	Wind Energy Utilization	3
EN590	Hydrogen Energy & Fuel Cell	3
EN592	Energy, Climate Change and Carbon Trade	3
EN597	Alternative fuels for IC Engines	3
EN598	Energy and Society	3

In the third and fourth semesters, students will be required to undertake a research project related to his/her field of specialization under the supervision of a faculty member of the Department. In the end of the third semester student has to present a seminar on the progress of his/her research work. On Completion of the project work the student shall submit a thesis to the Department for examination. The thesis will be examined by external and internal examiners. The candidate has to appear a *viva-voce* examination on his/her thesis

Detail Syllabus of the Courses

EN566	**Fuel Technology**	**3-0-0**	**CR 3**

Principles of combustion. Solid, liquid and gaseous fuels.
Petroleum as a source of energy and chemicals, Petroleum refining, petroleum products and their specifications and characteristics.
Coal as a source of energy and chemicals. Coal preparations, carbonization, gasification and liquefaction to oil.
Natural gas and its derivatives. Combustion appliance for solid, liquid and gaseous fuels. Introduction to nuclear fuels.

Text Books:

[1] Sharma S.P. & Chander Mohan, (1984); *Fuels & Combustion*, Tata McGraw Hill Publishing Co. Ltd.,
[2] Sarkar Samir, (1990); *Fuels & Combustion*, 2nd Edition, Orient Longman,
[3] Sharma B. K. *(*1998); *Fuels and Petroleum Processing, 1st ed*. Goel publishing, Meerut

References:

[1]. Blokh A.G, (1988); *Heat Transmission in Steam Boiler furnaces*, Hemisphere Publishing Corpn
[2]. Gupta O.P, (1996); *Elements of Fuels, Furnaces & Refractories*, 3rd edition, Khanna Publishers.
[3]. Bhatt ,Vora., *Stoichiometry*, 2nd Edition, Tata Mcgraw Hill, 1984
[4]. Civil Davies, (1966); *Calculations in Furnace Technology*, Pergamon Press, Oxford,
[5]. Khartchenko Nikolai V. ed (1998), *Advanced Energy Systems*, Taylor Francis Washington D.C.

EN595	**Biomass Energy Utilization**	**3-0-0**	**CR 3**

Introduction to biomass
Principles of biomass energy conversion processes: biological, chemical & thermo-chemical
Technologies for biomass conversion processes and their utilization covering: Biogas, Producer gas, Alcohol, Biodiesel, Pyrolytic oils.

Waste land utilization through energy plantation

Text Books:

[1] Sorensen Bent, Renewable Energy, (2nd Ed 2000), Academic press, New York
[2] Johansson Thomas B, (1993): Renewable Energy: Sources for fuels and electricity, Earthscan Publishers, London
[3] Rai G.D, (2007), Non-conventional energy sources, Khanna Publishers, New Delhi

References:

[1] Anthony San Pietro (1980); Biochemical and Photosynthetic aspects of Energy Production, Academic Press, New York,
[2] Berman, ER Geothermal Energy, Noyes Data Corporation, New Jersey
[3] Parker, Colin & Roberts, (1985); Energy from Waste- An Evaluation of Conversion Technologies, Elsevier Applied Science London
[4] Boyle Godfrey ed. (1996): Renewable Energy: Power for a sustainable future, Oxford, OUP
[5] Ralph E.H. Sims ed. (2004); Bioenergy options for cleaner environment by World Renewable Energy Network.
[6] Ravindranath N.H. and Hall D.O. (1995); Biomass, Energy and Environment, A developing country perspective from India by, Oxford University Press,
[7] Brown Robert C. (2003); Biorenewable Resources: Engineering New Products from Agriculture, Iowa State University Press ,USA
[8] Khandelwal KC, Mahdi SS, (1986); Biogas Technology - A Practical Handbook, Tat Mcgraw Hill
[9] Rosillo-Calle Frank, Francisco Rosillo, 2007; The Biomass Assessment Handbook: Bioenergy for a Sustainable Environment Published by Earthscan
[10] Mittal K. M, (1996); Biogas systems: Principles and applications, New Age International
[11] Maheswari R. C., (1997); Bio Energy for Rural Energisation, Concepts Publication

EN569	Solar Energy Utilization	3-0-0	CR 3

Solar radiation, its measurements and prediction. Flat plate collectors: liquid and air type. Theory of flat plate collectors, advanced collectors, optical design of concentrators, selective coatings, solar water heaters, solar dryers, solar stills, solar cooling and refrigeration. Thermal storage. Conversion of heat into mechanical energy. Active and passive heating of buildings. Solar thermal power generation.

Solar photovoltaics, principle of photovoltaic conversion of solar energy. Technology for fabrication of photovoltaic devices. Applications of solar cells in PV power generation systems. Organic PV cells.

Solar Photocatalysis: Mechanism; Kineticsl; Nano-catalysts: Systems; Performance parameters; Applications.

Text Books:

[1] S.P. Sukhatme, *Solar Energy: principles of Thermal Collection and Storage*, Tata McGraw-Hill

[2] J. A. Duffie and W. A. Beckman, (2006); *Solar Engineering of Thermal Processes,* Johnn Wiley
[3] Green, Martin (2005), 3rd Generation Photovoltaic: Advance Solar Energy, Springer
[4] Goswami D Y, Frank Kreith and J F Kreider, Taylor & Francis (1999) ; Principles of Solar Engineering, Taylor & Francis, USA
[5] Garg H.P. and Prakash S (1997) ; Solar Energy: Fundamental and Application Tata McGrow-Hill, New Delhi

References:

[1] Kreith F. and J. F. Kreider, (1978); *Principles of Solar Engineering* , McGraw-Hill
[2] Kreider J.F. and F. Kreith, (1981) ; *Solar Energy Handbook* McGraw-Hill
[3] T.N. Veziroglu, (1978); *Alternative Energy Sources*, Vol 5 and 6, McGraw-Hill
[4] Bent Sorensen (2000) ; Renewable Energy, Academic press, New York.

EN570	Heat Transfer	3-0-0	CR 3

Theory of heat conduction. Mathematical and numerical analysis of two dimensional heat conduction problems with and without internal heat generation and extended surfaces. Mathematical and numerical analysis of transient and periodic state heat conduction.
Theory of convective heat transfer. Boundary layer theory. Heat transfer in duct flows laminar and turbulent.
Boiling, condensation and heat exchangers.
Radiation heat transfer between black and grey bodies. Laws of radiation heat transfer.
Numerical solution of radiation network analysis

Text Books:

[1] Sukhatme S. P., (1996) ; *A Text book on Heat Transfer*, University Press
[2] Incropera F.P. and Dewitt D. P. (2006) ; Fundamentals of Heat and Mass Transfer, 5th ed. John Wiley

References:

[1] Zemansky M. W., (1968); *Heat and Thermodynamics* 4th Ed. McGraw Hill,.
[2] Prasuhn A. L., (1980) ; *Fundamentals of Fluid Mechanics*, Prentice Hall
[3] Gupta V (1995) ; Elements of Heat and Mass Transfer, New Age International Publishers, New Delhi
[4] Holman J. P. (1992); Heat Transfer, 7th ed. Mc Graw-Hill, London.

EN596	New & Renewable Energy Sources	3-0-0	CR 3

Small Hydropower Systems: Overview of micro, mini and small hydro systems; Hydrology; Elements of turbine; Assessment of Hydro Power; Selection and design criteria of turbines; Site selection and civil works; Speed and voltage regulation; Investment issues load management and tariff collection; Distribution and marketing issues: case studies; Potential of small hydro power in North East India

Wind energy: Wind energy potential measurements, principles of wind energy conversion, wind energy conversion systems, wind electric generator
Ocean energy: Ocean energy resources, ocean energy routes. Principle of ocean thermal energy conversion systems, ocean thermal power plants. Principles of ocean wave energy and tidal energy conversion
Geothermal energy: Origin of geothermal resources, types of geothermal energy deposits, site selection, geothermal power plants
Hydrogen energy & other new energy conversion, storage: Hydrogen as a source of energy, fuel cell.
Batteries, Capacitors, and Magnetic Energy Storage Magneto hydro-dynamic energy conversion system; Fusion Energy: Nuclear reactions, confinement schemes, current status, environmental safety with nuclear fusion

Text Books:

[1] Kruger P. (2006) Alternative Energy Resources: The Quest for Sustainable Energy, Wiley publication
[2] Rosa Aldo V. (2009) Fundamentals of Renewable Energy Processes, Second Edition, Academic Press
[3] Boyle G. (2004) Renewable Energy: Power for a Sustainable Future, Second Edition, Oxford University Press

References:

[1] Freris L. L., (1990), Wind Energy Conversion Systems, Prentice Hall.
[2] Maheswari R.C., (1997); Bio Energy for Rural Energisation , Concepts Publication
[3] Davis S. (2003) Microhydro: Clean Power from Water. New Society Publishers
[4] Sarangpani, S. J. A. Kosek and A. B. LaConti(1995) Handbook of Solid State Batteries and Capacitors, World Scientific Publications, NJ, USA.
[5] Harris, Peter J. F. (1999) Carbon Nanotubes and Related Structures-New Materials for the Twenty-first Century, Cambridge University Press, UK.
[6] Sorensen Bent (2nd Ed. 2000) ; Renewable Energy, Academic press, New York
[7] Johansson Thomas B. ed (1993) ; Renewable energy: sources for fuels and electricity, Earthscan Publishers, London.
[8] Harvey A. & Brown A. (1993) Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes. Practical Action publication
[9] Newman, J. (1991) Electrochemical systems, Prentice Hall, Engelwood Cliffs, NJ,USA.
[10] Reich, Stefan, C. Thomsen, and J. Maultzsch(2004) Carbon nanotubes – Basic Concepts and Physical Properties, John Wiley and sons, Canada.

EN575	**Numerical Methods and Computational Techniques for Energy Systems Modeling**	**2-0-1**	**CR 3**

Introduction to Numerical Methods: Solution of algebraic and transcendental equations; Solution of simultaneous algebraic equations; Empirical laws and curve-fitting; Regression method for forecasting; Interpolation. Finite Difference Method: Methods: Forward difference, backward difference, central difference; The Δ, ∇, δ, E, and μ operators and their interrelations.

Numerical Differentiation and Integration: Differentiation using forward, backward and central difference formulae. Integration using trapezoidal, Simpson's one-third and Simpson's three-eighth rule. Numerical Solution of Differential Equation :Methods: Taylor's series, Euler, Modified Euler, Runge-Kutta and Predictor-corrector method; Numerical solution of Partial Differential Equation: Solution of Laplace's equation, Poisson's equation; Solution of one-dimensional heat equation using Schmidt and Crank-Nicholson method; Solution of two-dimensional heat equation; Solution of wave equation.
Optimization Techniques :Introduction; Linear programming methods: Simplex method, artificial variables and dual phase method. Computational Techniques: Computer programming using C; Use of computational software packages like MATLAB, Mathematica etc.

Text Books:

[1] Balagurusamy, E (1999) *Numerical Methods*, Tata Mc Graw Hill , New Delhi
[2] Jain M K., Iyengar S R K., Jain R K (1993) ; *Numerical Methods for Scientific and Engineering Computation*, New Age International (P) Ltd. New Delhi

References:

[1] Rajsekaran, S. (1994) *Numerical Methods in Science and Engineering*,Wheeler, Allahabad.
[2] Hilderbrand, F B (1974*) Introduction to Numerical Analysis*, Tata McGraw Hill, New Delhi.
[3] Harman, T. L., J. B. Dabney, N. J. Richert (2000) *Advanced Engineering Mathematics with MATLAB.*
[4] Redfern, Darren and Colin Campbell (1997) *The MATLAB-5 Handbook*, Springer, NY.
[5] Mathews, John H. (1994) Numerical *Methods for Mathematics, Science and Engineering*, Prentice Hall of India Pvt. Ltd., New Delhi.
[6] Sastry, S. S. (1994) *Introductory Methods of Numerical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi
[7] Deb, Kalyanmoy (1997) *Optimization for Engineering Design- Algorithms and Examples,* Prentice Hall of India Pvt. Ltd., New Delhi
[8] William H., S. A. Teu klosky and W. T. Vellerling, and B. P. Flannery (1992); *Numerical Recipes in C- The Art of Scientific Computing*, Cambridge University Press.

EN567	**Power Plant Engineering**	**3-0-0**	**CR 3**

Types of thermal power plants
Steam power plant based on fossil fuels. Thermal power plant equipments: boilers, superheaters, condensers, combustion chambers and gas loops, turbines etc.
Gas turbine power plant, steam gas power plant
Elements of hydro power generation.
Elements of Nuclear fission reaction – power plant
Diesel electric power plant
Recent advances in power plants.

Text Books:

[1] Black and Veatch, (1998) ; *Power Plant Engineering*, CBS Pub and Distributors, N Delhi.
[2] Nag P K.(2006); *Power Plant Engineering*; Steam & Nuclear, Tata McGrawHill, N Delhi.

References:

[1] Gupta, B.R. (2001); *Generation of Electrical Energy* ; Eurasia Publishing House
[2] Deshpande, M.V. (1998); *Elements of Power Station Design* ; Wheeler Publishers ;
[3] Wadhwa C. L.,(1991) ; *Electrical Power systems*, 2nd ed, New age, New Delhi,
[4] Pabla A .S. (1998) ; *Electrical power systems planning*, Macmillan, Delhi,
[5] Wood A. J. and B F Wallenberg (1986) ; *Power Generation, Operation and Control, 2nd Ed*. John Wiley and Sons, New York,
[6] Venikov V. A, B V Put Yatin (1984) ; *Introduction of Energy Technology, Electric Power Engineering,* MIR Publishers, Moscow,
[7] Khan E.(1988):*Electrical Utility Planning and Regulation,* American Council for an Energy Efficient Economy, Washington D.C
[8] Soni, M.L., P.V. Gupta and V.S. A. Bhatnagar, (2000) ; *A Course in Electrical Power*, Dhanpat Rai & Sons, New Delhi

EN572	**Energy, Ecology and Environment**	**3-0-0**	**CR 3**

Origin of the earth; Earth's temperature and atmosphere; Sun as the source of energy
Biological processes; photosynthesis; food chains; Energy sources: classification of energy sources, quality and concentration of energy sources; Overview of world energy scenario;Fossil fuel reserves - estimates, duration, overview of India's energy scenario, energy and development linkage.
Ecological principles of nature, concept of ecosystems; different types of ecosystems; ecosystem theories; energy flow in the ecosystems; biodiversity.
Environmental effects of energy extraction, conversion and use; Sources of pollution; primary and secondary pollutants; Consequence of pollution growth; Air, water, soil, thermal, noise pollution- cause and effect; Causes of global, regional and local climate change; Pollution control methods; Environmental laws on pollution control.
Global warming; Green House Gas emissions, impacts, mitigation; Sustainability;
Externalities, Future energy systems; Clean energy technologies; United Nations Framework Convention on Climate Change (UNFCC); Sustainable development; Kyoto Protocol; Conference of Parties (COP); Clean Development Mechanism (CDM); Prototype Carbon Fund (PCF).

Text Books:

[1] Masters G. (1991): *Introduction to Environmental Engineering and Science*, Prentice – Hall International Editions.
[2] Ravindranath N.H., Usha Rao K., Natarajan B., Monga P. (2000); *Renewable Energy and Environment – A Policy Analysis for India*, Tata McGraw Hill,.
[3] Fowler, J.M., (1984); *Energy and the Environment*, 2nd Ed., McGraw Hill, New York,

References:

[1] Asian Development Bank (1991); Environmental Considerations in Energy Development, Manila

[2] Nakicenovic Nebojsa, , Grubler Arnulf and Alan ed (1998) ; Global Energy Perspectives : McDonald, Cambridge University Press

[3] *Shaheen Esber I., (1992); Technology of Environmental Pollution Control ,* PennWell Books

[4] Maheshwari A and Geeta Parmar, (2002); Textbook Of Energy Ecology Environment & Society, Anmol Publications Pvt Ltd

[5] Dave (2008); Textbook Of Environment & Ecology, Thomson Business Information

[6] Kaushika N.D. and Kaushik Kshitij (2004) ; Energy, Ecology and Environment: A Technological Approach. New Delhi, Capital Publishing Company,

[7] De A.K., (2005); Environmental Chemistry, New Age International Publishers

[8] Reddy AKN, RH Williams, TB Johansson, (1997) ; *Energy after Rio, Prospects and challenges*, UNDP, United Nations Publications, New York,.

EN573	Energy Management and Auditing	3-0-0	CR 3

Energy Management: Concept of energy management, energy demand and supply, economic analysis; Duties and responsibility of energy managers.

Energy Conservation: Basic concepts, Energy conservation in household, transportation, agricultural, service and industrial sectors, Lighting, HVAC systems

Energy Audit: Definition, need, and types of energy audit; Energy management (audit) approach: Understanding energy costs, bench marking, energy performance, matching energy use to requirement, maximizing system efficiencies, optimizing the input energy requirements; Fuel & energy substitution; Energy audit instruments; Energy Conservation Act; Duties and responsibilities of energy managers and auditors.

Material and Energy balance: Facility as an energy system; Methods for preparing process flow; material and energy balance diagrams.

Energy Action Planning : Key elements; Force field analysis; Energy policy purpose, perspective, contents, formulation, ratification; Organizing the management: location of energy management, top management support, managerial function, roles and responsibilities of energy manager, accountability; Motivation of employees: Information system-designing barriers, strategies; Marketing and communicating: Training and planning.

Monitoring and Targeting: Defining monitoring & targeting; Elements of monitoring & targeting; Data and information analysis; Techniques: energy consumption, production, cumulative sum of differences (CUSUM); Energy Service Companies; Energy management information systems; SCADA systems.

Electrical Energy Management: Supply side: Methods to minimize supply-demand gap, renovation and modernization of power plants, reactive power management, HVDC, and FACTS. Demand side: conservation in motors, pumps and fan systems; energy efficient motors.

Thermal energy Management: Energy conservation in boilers, steam turbines and industrial heating systems; Application of FBC; Cogeneration and waste heat recovery; Thermal insulation; Heat exchangers and heat pumps; Building Energy Management.

Text Books:

[1] Smith CB, (1981); *Energy Management Principles*, Pergamon Press, NewYork,
[2] Hamies, (1980); *Energy Auditing and Conservation; Methods, Measurements, Management &Case study*, Hemisphere, Washington

References:

[1] Krieder J. and Rabi A. (1994): *Heating and Cooling of Buildings: Design for Efficiency,* McGraw-Hill.
[2] Archie, W Culp (1991); *Principles of Energy Conservation*, McGraw Hill
[3] Gellings C.W. and J.H. Chamberlin (1993): Demand-Side Management Planning, Fairmont Press.
[4] Murphy, W.R and G. Mckay (1982) ; Energy Management, Elsevier
[5] Witte, Larry C, (1988); *Industrial Energy Management & Utilization*, Hemisphere Publishers, Washington
[6] Callaghan P. O' (1993); *Energy Management*, McGraw - Hill Book Company
[7] Bureau of Energy Efficiency (2003); Study material for Energy Managers and Auditors Examination: Paper I to IV.

EN574	Energy Economics & Planning	3-0-0	CR 3

Energy economics: Basic concepts.
National accounting framework. Criteria for economic growth. Economic theory of demand, production and cost market structure. Application of econometrics; input and output optimization and simulation methods to energy planning and forecasting problems. Dynamic models of the economy and simple theory of business fluctuation. Evaluation of National and Regional energy policies; oil import, energy conservation, rural energy economics. Conflict between energy consumption and environmental pollution, energy efficiency, cost-benefit risk analysis. Project planning and implementation.

Text Books:

[1] Ferdinand E. Banks, (2000) *Energy Economics: A Modern Introduction, (1st ed)*, Kluwer, London,
[2] Kandpal T.C., H. P. Garg (2003) *Financial Evaluation of Renewable Energy Technology*, Macmilan India Ltd. New Delhi,

References:

[1] Munasinghe M. and P. Meier (1993): *Energy Policy Analysis and Modeling*, Cambridge University Press.
[2] Samuelson P. A. and William D. Nordhaus (1992): *Economics, 14th edition*, McGraw-Hill, New York.
[3] Donnelly W. A. (1987): *The Econometrics of Energy Demand: A Survey of Applications*, Praeger, New York.
[4] Dixon, et al, (1994) ; *Economic Analysis of Environmental Impacts*, Earthscan Publications Ltd., London,

[5] Hackett Steven C., M.E. Sharpe, (1998) ; *Environmental and Natural Resources Economics*, New York,.
[6] Thuesen G. J, W. J. Fabrycky, (2001) ; *Engineering Economy, (Ninth Ed.),* Prentice-Hall of India Pvt. Ltd.
[7] White J. A., et. al., (1989) ; *Principles of Engineering of Economic Analysis*, John Wiley and Sons. Inc..
[8] Dasgupta Ajit K, D W Pearce, (1980): *Cost Benefit Analysis, Theory and Practice*, Macmilan
[9] United Nations, ed (1989); *Energy Issues and options for Developing Countries*, Taylor and Francis
[10] Hohmeyer, O., and R L Ottinger (ed 1992), *Social costs of energy: Present Status and Future Trends,* Springer Verlag
[11] Kaplan, Seymour1(983) ; *Energy Economics: Quantitative Methods for Energy and Environmental Decisions*, McGraw Hill
[12] Meyers Robert A (Ed.1986.) *Handbook of Energy Technology and Economics*, John Wiley and Sons.
[13] Robert L. Pirog and Stephen C. Stamos (1987) *Energy Economics: Theory and Policy*, Prentice-Hall New Jersey

EN593	**Basic Sciences & Engineering for Energy Study**	**3-0-0**	**CR 3**

Biology fundamentals: Plant cell, Biomass production, net primary productivity, Function of soil, net energy production by plants, wood structure, wood chemistry, Energy plant species and plantation, basic elements of biomass accumulation
Microorganism types, growth & nutrition, Ecological aspects of microbial degradation, degradation of Cellulose/hemicelluloses/lignin
Fermentation- Aerobic /Anaerobic-microorganism involved-mechanism
Waste degradation by microorganism, Chemical oxygen demand/Biological oxygen demand
Chemistry fundamentals: Chemical thermodynamics, Endo and exothermic recations, Laws of Thermodynamics, Internal Energy, Enthalpy;
Fundamentals of biochemistry-Carbohydrates-Cellulose/Hemicelluose/starch/Glucose; lipid- oil/fat, secondary plant products; lignin structure; amino acid/protein
Concepts of solution & P^H
Mechanical Engineering Fundamental: Fundamental of Internal combustion engine; Working principles and applications of Turbine, Compressor, Blower and Fan; Principles of power transmission devices (Gear, Belt, Chain) and their applications; Fluid coupling introduction applications and limitations; Principles of mechanical couplings (Universal joint, Flange coupling, Flexible coupling, Rigid coupling, Key coupling)**Electrical Engineering Fundamental:** Open circuit, short circuit, series parallel connection, single phase vs. three phase power; Basic concepts of electrostatic induction, flux, inductors, capacitors, resistors Primary, Secondary batteries, law of electrolysis; Fundamentals of AC and DC power and their applications, Y/Δ transformation, Kirchoff's laws, Norton Maxwells theorem; Fundamental of electrical motors & generators, their classifications and applications
Chemical Engineering Fundamental: Mass and Energy Balance: Steady state and unsteady states, Material and energy balances for physical process, Material and energy balances for chemical process;

Vapor-Liquid Equilibrium and Mass Transfer Operations: Vapor Pressure, Ideal Vapor-Liquid Equilibrium (Raoult's Law), Phase Diagram, Non-Ideal Vapor Liquid Equilibrium (Henry's Law), principles of distillation, extraction, humidification, drying etc.
Chemical Reaction Kinetics: Reaction Mechanism, Rate Laws, Order of Reaction and Effect of Temperature on Reaction Rates
Introduction to Modeling: thermodynamic principles of process systems and development of steady state and dynamic lumped and distributed parameter models based on, first principles. Introduction to solution strategies

Text Books:

[1] Theory of Machine, S. S. Rattan, Tata McGraw Hill, 2010.
[2] Chemical Engineering (Vol. I& II), J. M. Coulson & J. F. Richardson, Butterworth Heinemann, 4th Edition, 2002.
[3] General Microbiology by Hans G. Schlegel, Cambridge University Press

Reference Books:

[1] Theraja B.L. (2005) Textbook of Electrical Technology Volume I, S. Chand & Co Ltd.
[2] Uicker J. J., Gordon P. and Shigley Joseph Edward (2006) Theory of Machine and Mechanism, Oxford University Press,
[3] Frenk Kerith (2000) The CRC Hand Book of Thermal Engineering, CRC Publication
[4] Schonborn W. (ed) Biotechnology Vol.8. Vol. VCH publication

EN594	Fundamentals of Measuring Instruments for Energy Study	3-0-0	CR 3

Instrumentation and Measurement Systems: Introduction to instrumentation and control of energy systems, Principles of measurements; Static characteristics, accuracy, precision, repeatability, reproducibility, Resolution, sensitivity, linearity, drift, span, range, Dynamic characteristics-Transfer Function, Zero order instruments, First order instruments-step and ramp response of first order instruments, frequency response of first order instruments, second order instruments, step ramp response of second order instruments, dead time; Elements, errors types of errors, cross errors, systematic errors, random errors; Basic electronics and display instruments; Transducers, sensors, and actuators;
Measuring instruments/devices for temperature, pressure, velocity, speed, flow, torque and solar flux, current, voltage and power factor; Chromatography; Industrial instrumentation; Environmental pollution monitoring devices
Introductions to Microprocessors: μP 8085: Block diagram, pin out diagram, fetching and executing instructions; Programmed I/O; Restart; Interrupts; Circuits & instructions; Serial input & output; Extending the interrupt system; Direct memory access; Chip 8156; Port numbers of 8156; Programming the I/O ports; Data logger; Microcontroller
Introduction to Control Systems: Control systems: Feedback and non-feedback systems, reduction of parameter variations, block diagram of control system, regenerative feedback; Control systems and components

Text Books

[1] Raman, C.S., Sharma, G.R., Mani, V.S.V., (1983) Instrumentation Devices and systems, Tata McGraw Hill, New Delhi,.
[2] Doeblin, Measurements System (1978) Application and Design, McGraw Hill
[3] Morris. A.S, (1998) Principles of Measurements and Instrumentation, Prentice Hall of India,

Reference Books:

[1] Kalsi, H.S.; *Electronic Instrumentation* ; Tata McGraw Hill; 1995
[2] Eugene Xavier, S.P., Joseph Cyril Babu, J.; *Principles of Control Systems*: S Chand & Co., 1999
[3] W D Cooper and A D Helfrick, *Electronic Instrumentation and Measurement Techniques*, Prentice Hall of India, New Delhi, 1989.
[4] Patranabis D., *Principles of Industrial Instrumentation*, Tata McGraw Hill, New Delhi, 1999.
[5] Morris A S., *Principles of Measurements and Instrumentation*, Prentice Hall of India, 1998.
[6] Sawhney, A.K.; A Course in Electrical and Electronics Measurements & Instrumentation; Dhanpat Rai, 1998.

EN576	**Energy Laboratory-I**	**0-0-2**	**CR 2**

A. Lectures

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.
Data acquisition and processing: Data acquisition methods, data storage and display, examples of application in typical energy system.
Apparatus design and construction: Conceptual, substantive and detail designs of experiments; illustration of thermal energy equipment/devices and their accessories.
Experiment plan and execution: Preparatory work for carrying out experiments; range of experimental study, choice of measuring instruments, measurement system calibration, data sheets and log books, experimental procedure, etc; applications.
Technical Communication: Report preparation of experimental work, use of graphs, figures, tables, software and hardware aids for technical communication.

B. Laboratory

Renewable Energy Technologies
Solar: Solar radiation analysis, Experimental study on thermal performance of solar water heater, solar dryers, solar PV cell characterization and its networking, solar cooker.
Biomass: Experimental study on thermal performance and efficiency of biomass downdraft gasifier and sampling and analysis of air and flue gas from biomass energy systems i.e. gasifier, combustor and cook stoves using gas chromatography technique. Biogas production by anaerobic digestion and analysis.
Fuels: Density, Viscosity, Flash-point, Fire-point Pour-point, ASTM distillation of liquid fuels.

Proximate and Ultimate analysis, calorific value of solid fuels. Heat Transfer and Fluid Mechanics experiments

References:

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

EN577	Energy Laboratory-II	0-0-2	CR 2

A. Lectures
Construction, operating principle and use of the relevant instruments and equipment for conducting the experiments

B. Laboratory
Fuel Cell characteristics; Solar Photocatalysis; Hydrogen production and storage
Engines: Performance tests on I C Engine, Diesel engine test set-up; Duel-fuel engine
Performance tests on Microhydel power plant, Microhydel test-set-up
Performance tests on Wind energy generator
Thermal energy audit: Measurement of variables such as, temperature, pressure, air flow, etc in selected energy equipment and analysis
Building Energy Use and Phenomena
Measurement of basic parameters in electric power systems i.e. current, voltage, resistance, power factor, power and energy
Measurement and analysis of heat gain and air-conditioning load in a building;
Measurement and analysis of day lighting in a building: sky luminance, daylight from illumination from window and skylight, electric lighting integration.

N.B: In the course students will be required to do at least one innovative study in one of the listed/not listed experiments using the available facilities along with the regular experiments in consultation with a faculty.

Reference:

[1] Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV.

EN586	Solar Photovoltaic Energy	3-0-0	CR 3

Solar Cell Basics and Materials : Properties of Semiconductor: Intrinsic, extrinsic and compound semiconductor; Energy levels; Electrical conductivity; Determination of 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. Introduction to organic Solar Cells.

Solar Cell Physics: p-n junction: homo and hetro junctions, Metal-semiconductor interface; Dark and illumination characteristics; Figure of merits of solar cell; Efficiency limits; Variation of efficiency with band-gap and temperature; Efficiency measurements; High efficiency cells, Tandem structure. Junctions in Organic Solar Cells; Working and Efficiency limits.

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

Solar Photovoltaic System Design: Solar cell array system analysis and performance prediction; Shadow analysis: Reliability; Solar cell array design concepts; PV system design; Design process and optimization; Detailed array design; Storage autonomy; Voltage regulation; Maximum tracking; Use of computers in array design; Quick sizing method; Array protection and trouble shooting.

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

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

Text Books:

[1] Sukhatme S. P., (2000) ; Solar Energy : Principles of Thermal Collection and Storage, Tata McGraw-Hill

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

[3] Green M. A (2005) : Third Generation Photovoltics: Advanced Solar Energy, Springer

[4] Tiwari, G.N (2002); Solar Energy, Fundamentals design, modeling and Applications, Narosa, New Delhi

[5] Goswami, D. Yogi, Frank Kreith, and Jan F. Kreider (1999) Principles of Solar Engineering, Taylor and Francis, USA.

References:

[1] Kreith F. and Kreider J. F., (1978) ; Principles of Solar Engineering, McGraw-Hill

[2] Kreider J. F. and Kreith F., (1981) ; Solar Energy Handbook, McGraw-Hill

[3] Garg H.P, Prakash J, (1997); Solar Energy : Fundamentals & Applications, Tata McGraw-Hill, New Delhi

[4] Goswami, D. Yogi (1995) Engineering of solar photocatalytic detoxification and disinfction process, Advances in solar energy, 13, 208.

[5] Ollis, D. F., E. Pelizzetti, and N. Serpone (1989) Photocatalysis Fundamentals and Applications, Wiley-Interscience, NY, USA.

EN598	Energy and Society	3-0-0	CR 3

History of development of life in Earth, earth temperature and atmosphere, geochemical cycles, ecological principles of nature
Global energy scenario, Fuel & energy substitution
Earth resources, energy extraction, conversion and utilization- Solar, biomass, hydro power, wind and other sources of energy. Power generation from different energy sources
Energy demand across space and time; Economics importance of utilization of different energy sources Energy conservation and management-basic concepts, Energy conservation opportunities in household, transport, lighting etc. Energy Conservation Act Global warming; Green House Gas emissions, impacts, mitigation; Sustainability; Externalities, Clean energy technologies; United Nations Framework Convention on Climate Change (UNFCCC); Sustainable development; Kyoto Protocol; Conference of Parties (COP); Clean Development Mechanism (CDM); Prototype Carbon Fund (PCF) Uncertainties and social cost-benefit analysis of renewable energy systems; conflicts between energy and food security. factors that impact selection of energy technologies and policy instruments

Text Books

[1] Hodge B. K. Alternative Energy Systems, Publisher: Wiley; New Edition
[2] Hinrichs & Kleinbach. Energy: Its Use and the Environment, Fourth edition, Thompson Learning, 2005

References

[1] S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill
[2] Johansson Thomas B. ed (1993); Renewable energy: sources for fuels and electricity, Earthscan
[3] Craig R. Humphrey, Tammy L. Lewis, and Frederick H. Buttel Belmont. Environment, Energy, and Society: A New Synthesis. CA: Wadsworth Group, 2002.
[4] Pietro Anthony San, (1980); Biochemical and Photosynthetic aspects of Energy Production, Academic Press, New York
[5] Nag P K.(2006); Power Plant Engineering; Steam & Nuclear, Tata McGrawHill, N Delhi
[6] Johnson G L, (1985) ; Wind Energy Systems, Prentice Hall Inc, New Jersey
[7] Kandpal T.C., H. P. Garg (2003) ; Financial Evaluation of Renewable Energy Technology, Macmilan India Ltd. New Delhi
[8] Berman, ER Geothermal Energy, Noyes Data Corporation, New Jersey
[9] Kaushika N.D. and Kaushik Kshitij (2004) ; Energy, Ecology and Environment : A Technological Approach. New Delhi, Capital Publishing Company.

EN597	Alternative fuels for IC Engines	3-0-0	CR 3

IC engine: classification, operating principles and their applications.
Ideal and actual cycles of IC engine operations. Assessment of engine performance: efficiencies, bsfc, exhaust emission. Systems and their components (CI, SI, 2-stroke and 4-stroke): fuel supply, lubrication cooling, intake and exhaust, combustion and power transmission. Introduction to fuel characterization and Standards. 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 & pollution, corrosion. Alternate fuels for electrical power generation: technological issues in connection with handling and storage, delivery, combustion, emission & pollution, corrosion

Text Books

[1] Heywood, J., Internal Combustion Engine Fundamentals, McGraw Hill Publication
[2] J. G. Speight, Synthetic Fuels Handbook: Properties, Process, and Performance, McGraw-Hill, 2008
[3] Ayhan Demirbas, Biodiesel: A Realistic Fuel Alternative for Diesel Engines, Springer, 2010

Reference:

[1] Ferguseaon, Internal Combustion Engines, John Wiley & Sons, 1986.
[2] Ganesan, V., Internal Combustion Engines, Tata McGraw Hill, New Delhi, 2001.
[3] James G. Speight, Sudarshan K. Loyalka , Handbook of Alternative Fuel Technologies, CRC Press, 2007
[4] ASTM and EN standards for Alternate Fuel Characteristics, 2007
[5] Journal papers including SAE papers

EN584	Advanced Bioenergy	3-0-0	CR 3

Biomass Formation: Biomass resources: Classification and characteristics; Techniques for biomass assessment; Application of remote sensing in forest assessment; Biomass estimation.
Thermochemical Conversion: Different processes: Direct combustion, incineration, pyrolysis, gasification and liquefaction;Economics of thermochemical conversion.
Biological Conversion: Biodegradation and biodegradability of substrate; Biochemistry and process parameters of biomethanation; Biogas digester types; Digester design and biogas utilisation; Chemical kinetics and mathematical modeling of biomethanation process; Economics of biogas plant with their environmental and social impacts; Bioconversion of substrates into alcohol: Methanol & ethanol Production, organic acids, solvents, amino acids, antibiotics etc.
Chemical Conversion: Hydrolysis & hydrogenation; Solvent extraction of hydrocarbons; Solvolysis of wood; Biocrude and biodiesel; Chemicals from biomass.
Waste Conversion : Anaerobic digestion of sewage and municipal wastes; Direct combustion of MSW-refuse derived solid fuel; Land fill gas generation and utilization
Power generation: Utilisation of gasifier for electricity generation; Operation of spark ignition and compression ignition engine with wood gas, methanol, ethanol & biogas; Biomass integrated gasification/combined cycles systems. Sustainable cofiring of biomass with coal. Biomass productivity: Energy plantation and power programme.

Text Books:

[1] Anthony San Pietro (1980); *Biochemical and Photosynthetic aspects of Energy Production*, Academic Press, New York,
[2] Maheswari R. C. (1997) ; *Bio Energy for Rural Energisation* , Concepts Publication

[3] Ravindranath N. H. and D. O. Hall (1995); *Biomass, Energy, and Environment: A Developing Country Perspective from India*, Oxford University Press

References:

[1] Boyles David (1984), *Bio Energy Technology Thermodynamics and costs*, Ellis Hoknood, Chichester,
[2] EL - Halwagi M M (1986); *Biogas Technology : Transfer & Diffusio*n, Elsevier Applied SC, London
[3] Ralph Sims(2006) ;Brilliance of Bioenergy, James & James publication
[4] Wyman Charles, Taylor & Francis, (2007) ; Handbook on bioethanol : production and utilization , Applied Energy Technology Series
[5] Reed Tom and Bryant Becky (1979) ; Densified biomass: a new form of solid fuel , Biomass energy Foundation
[6] Milne T., Abatzoglou N., & Evans R. J.. NREL, 1998 ; Biomass gasifier "tars": their nature, formation, and conversion
[7] Higman and Burgt (2003); Gasification, Elsevier,
[8] Muzumdar B., (1999); A Text Book of Energy Technology: Both Conventional & Renewable Source of Energy
[9] Reed T. and Das A. (1988); Biomass downdraft gasifier engine systems handbook by Biomass energy Foundation
[10] Estill Lyle (2005) ; Biodiesel Power : The Passion, the People, and the Politics of the Next Renewable Fuel , New Society Publishers,

EN585	Advanced Solar Thermal Energy	3-0-0	CR 3

Earth & Sun Relation: Solar angles, day length, angle of incidence on tilted surface; Sunpath diagrams; Shadow determination; Extraterrestrial characteristics; Effect of earth atmosphere; Measurement & estimation on horizontal and tilted surfaces; Analysis of Indian solar radiation data and applications.
Flat-plate Collectors: Effective energy losses; Thermal analysis; Heat capacity effect; Testing methods; Evacuated tubular collectors; Air flat-plate Collectors: types; Thermal analysis; Thermal drying.
Selective Surfaces: Ideal coating characteristics; Types and applications; Anti-reflective coating; Preparation and characterization.
Concentrating Collector Designs: Classification, design and performance parameters; Tracking systems; Compound parabolic concentrators; Parabolic trough concentrators; Concentrators with point focus; Heliostats; Comparison of various designs: Central receiver systems, parabolic trough systems; Solar power plant; Solar furnaces.
Solar Heating & Cooling System: Liquid based solar heating system; Natural, forced and gravity flow, mathematical modeling, Vapour absorption refrigeration cycle; Water, ammonia & lithium bromide-water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling.
Solar Thermal Energy Storage: Sensible storage; Latent heat storage; Thermo-chemical storage.
Performances of solar collectors: ASHRAE code; Modeling of solar thermal system components and simulation; Design and sizing of solar heating systems: f – chart method and utilizability methods of solar thermal system evaluation; Development of computer package for solar heating and cooling applications;

Solar Energy for Industrial Process Heat: Industrial process heat: Temperature requirements, consumption pattern; Applications of solar flat plate water heater & air heater for industrial process heat; Designing thermal storage; Transport of energy.
Solar Thermal Energy Systems: Solar still; Solar cooker: Solar pond; Solar passive heating and cooling systems: Trombe wall; Greenhouse technology: Fundamentals, design, modeling and applications.

Text Books:

[1] Goswami D Y, Kreith Frank and Kreider J F, Taylor & Francis (1999); Principles of Solar Engineering, Taylor & Francis, USA
[2] Tiwari, G.N (2002); Solar Energy, Fundamentals design, modeling and Apllications, Narosa, New Delhi
[3] Duffie J. A. and W. A. Beckman, (2006); Solar Engineering of Thermal Processes, Johnn Wiley

References:

[1] Garg H P.et al,(1985) ; *Solar Thermal Energy storage, D Reidel Publishing Co*
[2] Alexiades, V & A.D. Solomon, (1993) ; Mathematical Modeling of Melting and Freezing process, Hemisphere publishing corporation, Washington
[3] Narayan R., B. Viswanathan, (1998) ; Chemical and Electrochemical Energy System, Universities Press
[4] Ter-Gazarian A., (1994) ; Energy Storage for Power Systems, Peter Peregrinus Ltd. London
[5] Kilkis B. and S. Kakac (Ed 1989) ; Energy Energy Storage Systems, KAP, London
[6] Norton, B(1992); Solar Thermal Energy Technology, Springer-Verlag, U.K

EN587	Petroleum Refining	3-0-0	CR 3

Origin: Origin of oil and gas; Physical properties and chemical composition Classification of Crude Oil.
Preparation of Crude Oil for Refining: Dehydration, demulsification, and desalting
Production: Atmospheric and vacuum distillation; Production of straight run fuels.
Refining: Stabilization, adsorption, and solvent extraction processes in petroleum refining
Cracking and Other Processes: Thermal cracking; Catalytic cracking; Isomerization; Alkylation; Polymerization; Coking; All types of hydroprocessing, hydrocracking and hydrotreating.
Various Treating Processes for Products Improvement.
Manufacturing of Other Products.
Lubricating oil, white oil, wax, bitumen etc.
Petroleum Product's Tests and Their Significance.
Pollution Control in Petroleum Industries.

Text Books:

[1] Speight James G., ed (1998), *Petroleum Chemistry and Refining*, Taylor & Francis, Washington.
[2] Speight James G, (1999) ; *The Chemistry and Technology pf Petroleum*, 3rd Edition, Marcel Dekker, Inc, New York,.

[3] Bhaskara Rao B K, (1997) ; *Modern Petroleum Refining Processes*, Oxford and IBH Publishing Co. Pvt. Ltd.

References:

[1] Mian M. A., (1992); *Petroleum Engineering: Handbook of practicing engineer,1st ed.* Penn Well Tulsa,
[2] Sehramn L L ed (2000), *Surfactants: Fundamentals and Applications in Petroleum Industry*, Cambridge University Press.

EN588	Petroleum Exploration, Drilling & Production	3-0-0	CR 3

Introduction: Origin, migration, and accumulation of oil and gas fields.
Methods of Petroleum Exploration: Geological, geophysical, geochemical, and hydrogeological surveys.
Classification of Traps: Structural, stratigraphic, and combination traps.
Drilling of Oil-gas Wells: Different methods, directional and horizontal drilling, offshore drilling, drilling complications, formation evaluation.
Drilling Fluids: Composition; Properties and types; Well completion methods
Reservoir Engineering: Consideration of different reservoir parameters for exploration, development, and exploitation of petroleum; Reservoir fluid characteristics; Gas reservoir.
Driving Mechanisms : Depletion drive, gas cap drive, water drive, combination drive; Gravity drainage.
Secondary Recovery of Oil and Enhanced Oil Recovery Methods.
Gathering, Processing and Transportation: Surface gathering systems; Gas processing; Liquid processing; Transportation of oil and gas.

Text Books:

[1] Mian, M. A., (1st ed., 1992); *Petroleum Engineering Handbook of Practicing Engineer,* Pennwell.
[2] Speight James G., ed (1998), *Petroleum Chemistry and Refining*, Taylor & Francis, Washington
[3] Mitra, A K, (1987); *Drilling Operation Manual,* Institute of Drilling Technology, ONGC

References:

[1] Devel, Lloyd E. , and George H. Holliday, (1990) ; *Soil Remediation for Petroleum ExtractionIndustry,* Pennwell,).
[2] Berger, Bill D. and Kenneth E. Anderson, (3rd ed., 1992); *Modern Petroleum a Basic Primer of Industry,* Pennwell,
[3] Sehramn L L ed (2000), *Surfactants: Fundamentals and Applications in Petroleum Industry*, Cambridge University Press
[4] Hyne, Norman J, (1995) ; *Non-technical Guide to Petroleum Geology, Exploration, Drilling and Production,* Pennwell Publishing Co

EN589	Wind Energy Utilization	3-0-0	CR 3

Wind Energy Conversion: Wind energy conversion principles; General introduction; Types and classification of WECS; Power, torque and speed characteristics.
Wind data analysis.

WECS Design: Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and combine theory; Rotor characteristics; Maximum power coefficient; Prandlt's tip loss correction.
Design of Wind Turbine: Wind turbine design considerations; Methodology; Theoretical simulation of wind turbine characteristics; Test methods.
Wind Energy Application: Wind pumps: Performance analysis, design concept and testing; Principle of WEG; Stand alone, grid connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India; Case studies.

Text Books:

[1] Johnson G L, (1985) ; *Wind Energy Systems*, Prentice Hall Inc, New Jersey,
[2] Spera David A., (Editor1994) *Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering,*American Society of Mechanical Engineers
[3] Paul Gipe , Karen Perez, (1999); *Wind Energy Basics: A Guide to Small and Micro Wind Systems*, Chelsea Green Publishing Company

References:

[1] Hau Erich (2000) ; *Wind Turbines: Fundamentals, Technologies, Application and Economics* : Springer Verlag
[2] Manwell J. F., McGowan J. G., Rogers A. L., (1st edition 2002); *Wind Energy Explained* , John Wiley & Sons
[3] Burton Tony, Sharpe David, Jenkins Nick, Bossanyi Ervin, John Wiley & Sons; 1st edition (2001); *Wind Energy Handbook* , John Wiley & Sons
[4] Patel Mukund R. (1999)*; Wind and Solar Power Systems* ,CRC Press

EN590	Hydrogen Energy & Fuel Cell	3-0-0	CR 3

Hydrogen Economy: Hydrogen and fuel cell; Suitability of Hydrogen as a fuel and Fuel-cell as energy conversion device.
Fuel Cell: Principle of working, Basic thermodynamics, Reaction kinetics, Charge and mass transport. Modeling a Fuel Cell.
Fuel Cell Characterization: System and components' characterization
Fuel Cell Technology: Types of Fuel Cells, Fuel Cell systems and sub-systems, system and sub-system integration; Power management, Thermal management; Pinch analysis.
Hydrogen Production: fossil fuels, electrolysis, thermal decomposition, photochemical, photocatalytic, hybrid; Storage: Metal hydrides, Metallic alloy hydrides, Carbon nano-tubes; Sea as the source of Deuterium, methane hydrate.; Hydrogen Transport.

Text Books:

[1] Wolf, Edmond L. (2004) *Nanoparticles and nanotechnology: An introduction to modern concepts of nanoscience*, John Wiley and sons, Canada.

[2] O'Hayre R., Cha S., Colella W., Prinz F B(2006) Fuel Cell Fundamentals, John Wiley and Sons, New York.
[3] Sorensen, B. (2005) Hydrogen and Fuel Cells, Elsevier Academic Press, USA

References:

[1] Narayan R, and B Viswanathan(1998) *Chemical and Electrochemical Energy Systems*, University Press(India) Ltd.
[2] Sarangpani, S. J. A. Kosek and A. B. LaConti(1995) Handbook of Solid State Batteries and Capacitors, World Scientific Publications, NJ, USA.
[3] Newman, J. (1991) Electrochemical systems, Prentice Hall, Engelwood Cliffs, NJ, USA.
[4] Gileadi, E. (1993) Electrode Kinetics for Chemists, Chemical Engineers and Material Scientist, VCH Publications, NY, USA.
[5] Harris, Peter J. F. (1999) Carbon Nanotubes and Related Structures-New Materials for the Twenty-first Century, Cambridge University Press, UK.
[6] Reich, Stefan, C. Thomsen, and J. Maultzsch(2004) *Carbon nanotubes – BasicConcepts and Physical Properties*, John Wiley and sons, Canada.
[7] Yurum, Yuda (ed.1994); Hydrogen Energy Systems, NATO ASI Series, London
[8] Baker, B.S., (1965), Hydrocarbon Fuel Cell Technology Academic Press, New works

EN592	**Energy, Climate Change and Carbon Trade**	**3-0-0**	**CR 3**

Energy and Climate Change: Global Consensus, evidence and predictions and impacts, Clean Energy Technologies, Energy economy, Role of Renewable Energy; Risk and opportunities; GHGs: GHGs emission and energy activities; Dealing with Climate change Consequences: Emission targets; Measures to reduce GHGs; Climate Change Act; International responses, Kyoto Protocol and CDM, CDM activities in Industries; Emission benchmarks; Governments policies for mitigation and adaptation: Price-based mechanisms such as cap-and-trade and carbon taxes, complementary non-price policies, and concepts of justice that frame the political negotiations; Carbon Market; Commerce of Carbon Market, Environmental Transformation Fund; Technology Perspective: Strategies for technology innovation and transformation.

Text Books:

[1] Stern, N.(2007). The Economics of Climate Change. The Stern Review. Cambridge University Press, New York.
[2] Barrett,S.(2007). Why Cooperate? The Incentive to Supply Global Public Goods. Oxford University Press, Oxford.
[3] Capoor, K., Ambrosi, P.(2008). State and Trends Of The Carbon Market (2008). The World Bank, Washington D.C.,May 2008. Available at: /http://siteresources. worldbank.org/ NEWS /Resources /State &Trends formatted 06 May10pm.pdf
[4] IPCC (Intergovernmental for Climate Change),(2007). Climate Change (2007): Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, NewYork.

References:

[1] Australia Prime Ministerial Task Group on Emissions Trading, (2007). Report of the task group on emissions trading.

[2] Baron, R.,Ellis, J.(2006). Sectoral crediting mechanisms for green house gas mitigation: institutional and operational issues. OECD/IEA.Available at: / http://www.iea.org/ textbase/ papers/2006/ greenhouse.pdf

[3] California Market Advisory Committee, (2007). Recommendations for designing a greenhouse cap-and-trade system for California. Recommendations of the market advisory committee to the California air resources board. June30,2007. Available at: / http:/ /www.climatechange.ca.gov/events/2007-06-12_mac_ meeting/2007-06-01_MAC_DRAFT_REPORT.

[4] Edenhofer O., Flachsland, C., Marschinski,R. (2007).Towards a global CO_2 market. Expertise for the Policy Planning Staff in the Federal Foreign Office. Potsdam Institute for Climate Impact Research,May2007.Available at:/ http: // www.pik-potsdam.de/ members / flachs / publikationen / towards-a-global- co2-markets.

[5] Edenhofer C. O.,Jakob, M.,Steckel, J.(2008). Developing the International Carbon Market. Linking Options for the EUETS. Report to the Policy Planning Staff in the Federal Foreign Office. Available at: / http: // www. pik-potsdam.de/members/edenh/ publications-1 / carbon-market - 08S.