COURSE STRUCTURE

M. TECH. IN GREEN ENERGY TECHNOLOGY

PONDICHERRY UNIVERSITY

PONDICHERRY – 605 014

PUDUCHERRY

2010

PONDICHERRY UNIVERSITY
PONDICHERRY – 605 014 INDIA

M.TECH. PROGRAM IN GREEN ENERGY TECHNOLOGY

BACKGROUND PAPER

The field of Green Energy Technology (GET) encompasses a continuously evolving group of methods, materials and processes from environmentally benign techniques for generating energy to its minimal utilization for maximal production of end materials and utilization of waste products when generated. The goals of this rapidly growing highly interdisciplinary field include i) sustainability - meeting the needs of society in ways that without damaging or depleting natural resources, ii) innovation - developing alternatives to technologies to those that have been demonstrated to damage health and the environment and source reduction – and iii) reducing waste and pollution by changing patterns of production and consumption. Thus, Green Technology is a term used to describe production of knowledge-based products or provide services that improve operational performance, productivity or efficiency, while reducing costs, inputs, energy consumption, waste and pollution.

M.Tech. offered at Pondicherry University in Green Energy Technology is a cutting edge material based program designed to equip post-graduates with multi-disciplinary skills and knowledge in the areas of green energy generation, green processes in chemical and construction industries, applications of nanotechnolgy, waste management and environmental sustainability etc. The course will be taught by a team of specialists working in the fields of green energy technology, chemical science, biological science, project management, and environmental policy. This is program is designed for two years spread into four semesters. First two semesters are for hard and soft core courses, third semester is entirely for soft-core (optional) courses and final semester is for project. Many soft-core courses are stand alone, so, they can be taken at any time offered by the Department. In addition there will be some bridge courses. Most of the first semester courses will be on energy and modelling. In the second and third semester courses will be based on energy, environment, chemistry, management and other GET related fields. Students will select courses suiting background and interest. Each theory course will have a project component which will be either individual or group based. Students will be required to earn at least 72 credits to qualify for the M.Tech. degree. Students with B.E. B.Tech. / M.Sc. (Material Science, Physics, Computer Science, Chemistry and related subjects) are eligible to undergo this program.

Subject areas covered in M.Tech. Green Energy Technology program are:

1. Energy Courses on energy includes the development of alternative fuels, new means of generating energy, energy efficiency, storage and distribution, modelling and waste management.

2. Green chemistry the invention, design and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances.

3. Green nanotechnology Nanotechnology involves the manipulation of materials at the scale of the nanometer. Green nanotechnology is the application of green chemistry and green engineering principles to this field.

4. Green building concepts Green building encompasses everything from the choice of building materials to where a building is located.

5. Green Chemical Bioenergetics Chemical Bioenergetics involves energy transduction in biological systems, bio-nano interfaces, biomimetic and bio-inspired self-assembling systems, and bio-fuel cells and applications.

6. Global Environmental Change and its Political Consequences Anthropogenically driven global change, and the links to carbon dioxide level rise since the Industrial Revolution. The environmental consequences of this for societies and the political responses both national and international to these crises are then placed within this perspective.

7. Green Economics this subject involves the search for products whose contents and methods of production have the smallest possible impact on the environment.

8. Research and Business Skills, Project and Portfolio Management Development of research, communication and project management skills.

9. Research Project and Dissertation Specifically designed to give the student practical experience in technologies and principles appropriate to developing a green technology. The student will undertake a research based project at Pondicherry University or at an associated academic or industrial partner and thus receive practical training in chosen area from an expert.

In addition to above, courses will be added time to time based on developments in this fast emerging field.

Teaching and Learning Methods Lectures, tutorials and seminars form the main methods of course delivery enhanced by individual and group project work, laboratory work, computing workshops and industrial visits.

Assessment Methods Teaching and assessment will be by Choice Based Credit System (CBCS). Evaluation will be through session (laboratory reports, class tests, set assignments) or by continuous assessment (designing, computer practical, seminar papers, project reports etc.) and end-semester examinations.

Employment: It is envisaged that the M.Tech. graduates in Green Technology will gain employment in the Engineering Industry with many companies now seeking to exploit the benefits of Green Technology products and processes.

1st YEAR

1st Semester:

L T P Credits Approximate Numbers of Lectures

1. GET 511 Energy & Environment (Core Course) 3 0 0 3 45 L
2. GET 512 Fuel & Combustion Technology (Soft Core Course) 3 0 0 3 45 L
3. GET 513 Heat Power & Electricity (Soft Core Course) 3 0 0 3 45 L
4. GET 514 Renewable Energy Resources & Systems (Core Course) 3 0 0 3 45 L
5. GET 515 Modelling and Simulation (Core Course) 3 0 0 3 45 L
6. GET 516 Energy Laboratory – I (Core Course) 0 0 4 3 5 L
7. GET 517 Introduction to Biochemistry (Bridge Course) 3 0 0 0 45 L
8. GET 518 Scientific Writing and Research Methodology (Bridge Course) 3 0 0 0 45 L

18 credits

2nd Semester:

1. GET 521 Solar Thermal Energy Conversion (Soft core Course) 3 0 0 3 45 L
2. GET 522 Wind Energy & Small Hydropower Systems (Soft Core Course) 3 0 0 3 45 L
3. GET 523 Solar Photovoltaic Energy Conversion (soft core Course) 3 0 0 3 45 L
4. GET 524 Waste to Energy Conversion (Soft Core Course) 3 0 0 3 45 L
5. GET 525 Sustainable Processing Energy and Materials (Soft core Course) 3 0 0 3 45 L
6. GET 526 Green Management (Soft Core Course) 3 0 0 3 45 L
7. GET 527 Environmental Risk Management (Soft Core Course) 3 0 0 3 45 L
8. GET 528 Energy Laboratory – II (Core Course) 0 0 4 3, 5 L

18 Credits

2nd YEAR

3rd Semester:

1. GET 611 Green Chemistry	(Soft core Course)	3 0 0 3 45 L
2. GET 612 Green Nanotechnology	(Soft core Course)	3 0 0 3 45 L
3. GET 613 Green Building Concepts	(Soft core Course)	3 0 0 3 45 L
4. GET 614 Carbon sequestration at Landscape Level	(Soft core Course)	3 0 0 3 45 L
5. GET 615 Green Energy and Economics	(Soft core Course)	3 0 0 0 45 L
6. GET 616 Bio-energy and Conversion Systems	(Soft core Course)	3 0 0 3 45 L
7. GET 617 Smart Materials: Application of Nano-technology for Batteries, Solar and Fuel cells	(Soft core Course)	3 0 0 3 45 L
8. GET 618 Solar Photovoltaic Technology	(Soft Core Course)	3 0 0 3 45 L
9. GET 619 Lab: Sustainable Energy Systems: Virtual instrumentation and case studies	(Core Course)	1 0 0 3 5 L
10. GET 631: Proposal Writing and Defence	(Core Course)	1 0 0 3 0 L
		18 credits

4th Semester

GET 620 Green Technology Dissertations:

(15 credits for the dissertation and 3 credits for the performance in viva-voce)

To be carried out with due permission from the Chairperson / Coordinator for one semester (four months) in any industry or a research organization outside Pondicherry University and practicing green energy technologies

A thesis written for this project will be evaluated by an expert followed by viva-voce.

Minimum credit requirement = 72; All teaching, learning and evaluations will follow Choice Based Credit System (CBCS) which is in vogue in Pondicherry University. Bridge courses are no credit courses; All students are expected to clear these courses, however, exemption to do the bridge course can be obtained on the basis of recommendation of a committee of experts consisting of the faculty advisor, concerned teacher, Head, Dean, and VC’s nominee in the PC.

FIRST YEAR, FIRST SEMESTER COURSES

GET 511 Energy & Environment 3 0 0 45 L
(Core Course)

Earth Energy Systems [15]
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 [6]
Ecological principles of nature; Concept of ecosystems; Different types of ecosystems; ecosystem theories; energy flow in the ecosystems; biodiversity.

Energy Systems and Environment [10]
Environmental effects of energy extraction, conversion and use; Sources of pollution; primary and secondary pollutants; Consequence of pollution and population 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.

Sustainability [14]
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).

References:
[1] Energy and EnvironmentSet: Mathematics of Decision Making, Loulou, Richard; Waaub, Jean-Philippe; Zaccour, Georges (Eds.), 2005, XVIII, 282 p. ISBN: 978-0-387-25351-0
[2] Energy and the Environment, 2nd Edition, John Wiley, 2006, ISBN:9780471172482; Authors: Ristinen, Robert A. Kraushaar, Jack J. AKraushaar, Jack P. Ristinen, Robert A., Publisher: Wiley, Location: New York, 2006.
[3] Energy and the Challenge of Sustainability, World Energy assessment, UNDP, N York, 2000.
[4] Ravindranath N.H., Usha Rao K., Natarajan B., Monga P., Renewable Energy and
[5] E H Thorndike, Energy & Environment: A Primer for Scientists and Engineers, Addison-Wesley Publishing Company
[6] R Wilson & W J Jones, Energy, Ecology and the Environment, Academic Press Inc.
[5] D W Davis, Energy: Its Physical Impact on the Environment, John Wiley & Sons
[7] AKN Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997.
[8] Global Energy Perspectives : Edited by Nebojsa Nakicenovic, Arnulf Grubler and Alan McDonald, Cambridge University Press, 1998.
[9] Environment – A Policy Analysis for India, Tata McGraw Hill, 2000.Environmental Considerations in Energy Development, Asian Development Bank, Manila (1991).
[10] G. Masters (1991): Introduction to Environmental Engineering and Science, Prentice –Hall International Editions.
[11] Fowler, J.M., Energy and the Environment, 2nd Ed. ,McGraw Hill, New York, 1984.
[12] Energy: Science, Policy, and the Pursuit of Sustainability by Robert Bent, ISBN13: 9781559639118, ISBN10: 1559639113, 2002.
[13] New Approaches on Energy and the Environment: Policy Advice for the President, by Richard D. Morgenstern, ISBN13: 9781933115016, ISBN10: 1933115017, Publisher: Resources for the Future, Publication Date: February 2005.

GET 512 Fuel & Combustion Technology 3 0 0 3 42 L
(Soft Core Course)

Solid, Liquid and Gaseous Fuels [13]
General: Coal; Family, origin, classification of coal; Analysis and properties; Action of heat on coal; Gasification; Oxidation; Hydrogenation and liquefaction of coal; Efficient use of solid fuels; Manufactured fuels; Agro fuels; Solid fuel handling; Properties related to combustion, handling, and storage Origin and classification of petroleum; Refining; Properties & testing of petroleum products; Various petroleum products; Petroleum refining in India; Liquid fuels from other sources; Storage and handling of liquid fuels. Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG; Cleaning and purification of gaseous fuels.

Theory of Combustion Process [11]
Stoichiometry and thermodynamics; Combustion stoichiometry: Combustion thermodynamics, burners; Fluidized bed combustion process.

Stoichiometry [11]
Stoichiometry relations; Estimation of air required for complete combustion; Estimation of minimum amount of air required for a fuel of known composition; Estimation of dry flue gases for known fuel composition; Calculation of the composition of fuel & excess air supplied, from exhaust gas analysis; Dew point of products; Flue gas analysis (O_2, CO_2, CO, NOx, SOx).

Burner Design and Furnaces [10]
Ignition: Concept, auto ignition, ignition temperature; Burners: Propagation, various methods of flame stabilization; Basic features and design of burners for solid, liquid, and gaseous fuels; Furnaces: Industrial furnaces, process furnaces, batch & continuous furnaces; Advantages of ceramic coating; Heat source; Distributions of heat source in furnaces; Blast furnace; Open hearth furnace, Kilns; Pot & crucible furnaces; Waste heat recovery in furnaces: Recuperates and regenerators; Furnace insulation; Furnace heat balance computations; Efficiency considerations.

References:
[1] Liquid Fuels for Internal Combustion Engines: A Practical Treatise for Engineers & Chemists, by Harold Moore, ISBN: 9781146203067, Publisher: Nabu Press, 2008.
[2] Gas and Oil Engines, and Gas-Producers: A Treatise on the Modern Development of the Internal Combustion Motor and Efficient Methods of Fuel Economy, Lionel Simeon Marks, Nabu Press, 2007.
[3] Blokh A.G, Heat Transmission in Steam Boiler furnaces, Hemisphere Publishing Corpn., 1988.
[4] S.P. Sharma & Chander Mohan, Fuels & Combustion, Tata McGraw Hill Publishing Co.Ltd.,1984.
[5] J. D. Gilchrist , Fuels, Furnaces & Refractories, Pergamom Press.

GET 513 Heat Power & Electricity 3 0 0 3 45

(Soft Core Course)

Thermodynamics: [6]
First and second law and their applications; Irreversibility of energy; Basic power generation and refrigeration cycles; Dehumidification; Fluid mechanics: Stress-strain relations and viscosity, mass and momentum balance.

Heat Engines and Heat Pumps [4]

Heat Transfer: [4]
Conductive, convective and radiative heat transfer; Boiling and condensation; Two and three dimensional heat flow.

Electrical Power Equipment: [10]
Electrical Machines: Transformer, induction motors; Variable speed drives VSD; DC machines.

Introduction to Power Transmission and Distribution [5]

Introduction to Conventional Power Plants: [6]
Thermal, hydel, nuclear, gas, and diesel power plants.

Alternators [10]
Principles and characteristics; Stand-alone, parallel and grid-connected operation of alternators; Frequency control and voltage regulation; Peak load and base load operations; Active and reactive power transfer; Losses and efficiency; Stability criteria

References:
[1] Electrical Distribution of Heat, Light and Power, by Harold Pitney Brown, ISBN: 9781141026906, Publisher: Nabu Press, Publication Date: January 2010.
[2] Roger Fouquet, Heat, Power and Light: Revolutions in Energy Services. Cheltenham, UK: Edward Elgar, 2008, (hardcover), ISBN: 978-1-84542-660-6.
[3] C. L. Wadhwa, Generation Distribution and utilization of Electrical Energy, Wiley Eastern Ltd., India (1989)
[4] A .J. Wood and B.F. Wallenberg (1986): Power Generation, Operation and Control, 2nd Edition, John Wiley &Sons, New York
[5] M. W. Zemansky, Heat and Thermodynamics 4th Ed. McGraw Hill, 1968.
[6] A. L. Prasuhn, Fundamentals of Fluid Mechanics, Prentice Hall, 1980
[7] S. P. Sukhatme, A Text book on Heat Transfer, Orient Longman, 1979.
[8] N. Balbanian, T. A. Bickart, Electrical network theory, John Wiley, New York, 1969
[9] B. L. Theraja, A. K. Theraja, A Text-book of Electrical Technology, New Delhi, 1988
[10] J. P. Holman and P. R. S. White, Heat Transfer , 7th ed. McGraw-Hill, London, 1992
[11] Blokh A G, Heat Transfer in Steam Boiler Furnace, Hemisphere Pub. Corp.
[12] Carl Schields, Boilers - Type, Characteristics and Functions, McGraw Hill Publishers

GET 514 Renewable Energy Resources & Systems –I 3 0 0 3 45

(Core Course)

Unit 1: [6]

Current energy requirements, growth in future energy requirements, Review of conventional energy resources- Coal, gas and oil reserves and resources, Tar sands and Oil Shale, Nuclear energy Option.

Unit 2: Solar Energy [18]

Solar radiation, its measurements and prediction. Solar thermal collectors, flat plate collectors, concentrating collectors. Basic theory of flat plate collectors, solar heating of buildings, solar still, solar water heaters, solar driers; conversion of heat energy in to mechanical energy, solar thermal power generation systems.Solar Photovoltaic: Principle of photovoltaic conversion of solar energy, types of solar cells and fabrication. photovoltaic applications : battery charger, domestic lighting, street lighting, water pumping, power generation schemes.

Unit 3: Wind Energy [8]

Atmospheric circulations, classification, factors influencing wind, wind shear, turbulence, wind speed monitoring, Betz limit, WECS: classification, characteristics, applications.

Unit 4: Ocean Energy [5]

Ocean energy resources, ocean energy routes. Principles of ocean thermal energy conversion systems, ocean thermal power plants. Principles of ocean wave energy conversion and tidal energy conversion.

Unit 5: Other Sources: [8]

Hydropower, Nuclear fission and fusion; Geothermal energy: Origin, types of geothermal energy sites, site selection, geothermal power plants; Magneto-hydro-dynamic (MHD) energy conversion.

References:

[1] Energy for the 21st Century: A Comprehensive Guide to Conventional and Alternative Sources, by Roy L. Nerseisan, ISBN:9780765624123, Publisher: M.E. Sharpe, Publication Date: March 2010.

[2] S. P. Sukhatme and J. Nayak, , Solar Energy - Principles of thermal collection and storage, second edition, Tata McGraw-Hill, New Delhi, 2008.

[3] D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.

[4] D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, New York, 1987. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.

[5] C. S. Solanki, "Solar Photovoltaics: Fundamental Applications and Technologies, Prentice Hall of India, 2009.

[6] The Nanoscience and Technology of Renewable Biomaterials by Lucian A. Lucia Wiley 2009.

[7] Power from the Wind: Achieving Energy Independence, by Dan Chiras, ISBN:9780865716209, Publisher:New Society Publishers, Publication Date:April 2009

[8] J W Twidell & A D Weir, Renewable Energy Resources, ELBS

[9] L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.

[10] D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.

[11] S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill (1984).

[12] J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, John Wiley (1991).

[13] Renewable Energy, Bent Sorensen (2nd Ed), Academic press, New York, 2000

[14] World Meteorological Organisation, Meteorological Aspects of the Utilisation of Wind as an Energy Source, Tech. Note No. 175, 1981.

[15] J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, second edition, John Wiley, New York, 1991.

[16] F. Kreith and J. F. Kreider, Principles of Solar Engineering , McGraw-Hill, 1978.

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

[18] T.N. Veziroglu, Alternative Energy Sources, Vol 5 and 6, McGraw-Hill (1978).

GET 515: Modeling and Simulation I 3 0 0 3 45

(Core Course)

Modeling and simulation allow engineers to reason about the expected behavior of a system without having to physically implement it. Simulation pervades much of engineering to build models of individual devices, circuit simulation, networks, and physical systems for control purposes. The course is intentionally designed to have a strong practical focus, with extensive laboratory work serving to develop key skills with the aim to enable students to use Modeling and Simulation in the design and verification of Renewable and Green Energy systems.

Unit 1:
Mathematical modeling: - physical simulation - Approximations in Mathematical Model building- advantages and limitations - process control - concept of physical domain and computational domain - assumptions and limitations in numerical solutions – Numerical integration -Differentiation

Unit 2: Matlab:
Computing with Matlab: Programming in Matlab- Multidimensional Arrays Polynomial Operations Using Arrays- Mathematical Functions User Defined Functions- Advanced Function Programming- Working with Data Files Program Design and Development- Graphics plotting functions Special Plot types Interactive plotting- Function Discovery Regression, 3-D plots, GUI-design

Unit 3: Simulink:
Starting Simulink. Model Files, Basic Elements-: blocks and lines.-Running Simulation-Building Systems- Block Libraries.: Sources, Sinks, Discrete, Linear. Nonlinear, Connections-Simulink - Interaction With Matlab-Defining Block Parameters Using Matlab, Variables-Exchanging Signals With Matlab Extracting Models From Simulink into Matalb

Unit 4:
Lab exercises to develop simple Matlab Scripts and Simulink models related to building energy systems involving applications of thermodynamics, economics, heat transfer, fluid flow and optimization, Modeling Biodegradation Kinetics, Modeling of Wind Turbine/generator: Modeling of PV Solar Array: Modeling of PEM Fuel Cell.

Reference books

[1] Modelling and Simulation: Exploring Dynamic System Behaviour, by Louis G. Birta, ISBN:9781846286216, Publisher: Springer, 2007
[2] An Engineer's Guide to MATLAB: With Applications from Mechanical, Aerospace, Electrical, and Civil Engineering E. B. Magrab S. Azarm B. Balachandran J. H. DuncanbK. E. Herold G. C. Walsh Prentice Hall 2004
[3] PEM Fuel Cell Modeling and Simulation Using MATLAB by Colleen Spiegel, Academic Press 2007
[4] Energy Simulation in Building Design, J A Clarke, 2002 (2nd Edn)
[5] G.M.Masters, Renewable and Efficient Electric Power Systems, Wiley 2004.
[6] Introduction to Matlab 7 for Engineers, by William J. Palm III, McGraw Hill 2005.

GET 516 Energy Laboratory – I 1 0 5 3
(Core Course)

Course Outline:
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

1. Solar: Solar radiation analysis, Experimental study on thermal performance of solar water heater, solar dryers, solar PV cell characterization and its networking, solar cooker.
2. 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.
3. Fuels: Density, Viscosity, Flash-point, Fire-point Pour-point, ASTM distillation of liquid fuels.
4. Proximate and ultimate analysis, calorific value of solid fuels.

References:
[1] Garg H.P., Kandpal T.C., Laboratory Manual on Solar Thermal Experiments, Narora Publishing House, New Delhi, 1999.
[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] Polak, P. (1979) Systematic Errors in Engineering Experiments, Macmillan Press Ltd.
[5] Annual Book of ASTM standards, Section I – V, Vol. 05.01-05.05, 2002-2003.

GET 517 Introduction to Biochemistry
(Bridge Course) 3 0 0 3 45 L

Unit 1. Introduction to Biomolecules Overview - Basic principles of Organic Chemistry, Types of Biomolecules, Chemical nature, Biological role, Biological buffers, Water and its importance in Biochemistry.

Unit 2. Structures & Properties Of Carbohydrates, Proteins Carbohydrates (Mono, Di, Oligo)-forms of Isomerism, Physiological importance, Polysaccharides - Starch- glycogen- Cellulose and their derivatives- Chitin- Peptidoglycons- Glycoaminoglycons- Glycoconjugates, Test for Carbohydrates. Classification of Amino acids and Proteins, Structure of Proteins- Primary-Secondary- Tertiary and Quaternary - Myoglobin & Hemoglobin, Test for Proteins.

Unit 3. Structures & Properties Of Lipids, Nucleic Acids Lipid - Classification (Fatty acids, Glycerolipids, Phospholipids, Glycolipids, Sphingolipids, Steroids) - Physiological importance, Significance of Cholesterol Nucleic Acids - Structure of Purines - Pyrimidines - Nucleosides - Nucleotides - Ribonucleic acids - Deoxyribonucleic acids - Nucleoprotein complexes, Synthetic Nucleotide analogs, Functions of Nucleotides - Carrier of Chemical energy of cell- Enzyme Cofactor - Regulatory Molecules

Unit 4. Metabolism and Biocatalysis Metabolism of carbohydrates, Lipids, Proteins. Role of vitamins and minerals. Introduction to Biocatalysis by Enzymes and Pathways, Introduction to Biosynthesis and Breakdown of Carbohydrates- Lipids- Proteins and Nucleic Acids

Unit 5. Intermediary Metabolism & Bioenergetics TCA cycle - Glycolysis - Glyconeogenesis - Pentose phosphate shunt - Urea cycle - Interconnection of Pathways - Metabolic regulations. High energy compounds - Electronegative Potential of compounds, Respiratory Chains- ATP cycle- Calculation of ATP production during Glycolysis and TCA cycle, Regulation of levels of High energy compounds and reducing equivalents inside the cell.

Text Books

[1] Biochemistry 3rd edition (2005) by Reginald H. Garrett, Charles M. Grisham.
[2] Lehninger's Principles of Biochemistry by David L. Nelson and Michael M. Cox, Macmillan Worth publisher, 2009.
[3] Biochemistry 6th edition by Jeremy M Berg, Lubert Stryer, John L. Tymoczko, 2008.
[4] Murray, R.K., Granner, B.K., Mayes, P.A., Rodwell, V.W., Harper's Biochemistry Prentice Hall International, 2008.
[5] Voet and Voet's Biochemistry, D. Voet and J. Voet 3rd Edition, John Wiley and Sons Inc., 2005.
[6] Biochemistry, 5th Ed by Eric E Conn, Paul K Stumpf, George Bruening and Roy H Doi, 2009.

GET 518 Scientific Writing and Research Methodology (Bridge Course) 3 0 0 0 45 L

A scientific or research article published in a peer reviewed journal is a technical document that describes a significant experimental, theoretical or observational extension of current knowledge, or advances in the practical application of known principles. A research article should report on research findings that are not only verifiable, reproducible and previously unpublished and should add to new understanding of the concerned subject. Unlike a novel, newspaper article or an essay, a research article should adhere to a structure and style, which is internationally acceptable. It should have an introduction, methods used, results obtained and discussion on the results and conclusions drawn. However, a RA is not only a technically rigid document, but also a subjective intellectual product that unavoidably reflects personal opinions and beliefs. Therefore, it requires good skills in both structuring and phrasing the discoveries and thoughts. These skills are acquired through experience, but can also be taught though instructional course like the one proposed now. Thus, above bridge course offered by English Department will help students to learn how to write research articles to be published in a scientific journal. In addition to scientific article writing this course will also cover principles of research methodology and scientific ethics. All the students of the GET program are expected to take this course and pass. However, students with appropriate background may be exempted from taking this course provided enough evidence exists in the form of clearance of a screening test.

GET 521 Solar Thermal Energy Conversion 3 0 0 3 45

Earth & Sun Relation [6]
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 [6]
Effective energy losses; Thermal analysis; Heat capacity effect; Testing methods; Evacuated tubular collectors; Air flat-plate Collectors: types; Thermal analysis; Thermal drying.

Selective Surfaces [5]
Ideal coating characteristics; Types and applications; Anti-reflective coating; Preparation and characterization.

Concentrating Collector Designs [5]
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 [5]
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 [4]
Sensible storage; Latent heat storage; Thermo-chemical storage.

Performances of solar collectors [4]
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 [5]
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 [5]
Solar still; Solar cooker: Solar pond; Solar passive heating and cooling systems: Trombe wall; Greenhouse technology: Fundamentals, design, modeling and applications.

References:
[1] Solar Cell Device Physics, by Stephen Fonash, ISBN:9780123747747, Publisher: Academic Press, Publication Date: April 2010
[2] Sukhatme S P., A Text Book on Heat Transfer, University Press, 1996
[3] Renewable Energy Resources, John W Twidell and A D Weir, ELBS
[4] Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997
[5] Solar Energy, S P Sukhatme, Tata McGraw Hill
[6] Solar Energy Handbook, J F Kreider and Frank Kreith, McGraw Hill
[7] Principles of Solar Engineering, D Y Goswami, Frank Kreith and J F Kreider, Taylor & Francis.
[8] Solar Engineering of Thermal Processes, J A Duffie and W A Beckman, John Wiley and Sons, New York

[9] Tiwari G.N., Suneja S., Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997.
[10] Tiwari G.N., Goyal R.K., Greenhouse Technology: Fundamentals, Design Modeling and Application, Narosa Publishing House, 1998.
[11] Renewable Energy: Power for a sustainable future, Godfrey Boyle (Ed), The Open University, Oxford University Press.

GET 522 Wind Energy & Small Hydropower Systems 3 0 0 3 45

Wind Energy Conversion [9]
Wind energy conversion principles; General introduction; Types and classification of WECS; Power, torque and speed characteristics.

WECS Design [8]
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 [8]
Wind turbine design considerations; Methodology; Theoretical simulation of wind turbine characteristics; Test methods.

Wind Energy Application [8]
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.

Small Hydropower Systems [12]
Overview of micro, mini and small hydro systems; Hydrology; Elements of pumps and turbine; Selection and design criteria of pumps and 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 India.

References:

[1] Wind Energy Explained: Theory, Design and Application, by J. F. Manwell, ISBN:9780470015001, Publisher: John Wiley & Sons, Publication Date: February 2010
[2] Introduction to Wind Energy Systems: Basics, Technology and Operation (Green Energy and Technology), by Hermann-josef Wagner, ISBN: 9783642020223, Publisher: Springer, September 2009.
[3] Wind Energy (Fueling the Future), by Lola Schaefer, ISBN:9781432915728, Publisher:Heinemann Educational Books, 2008.
[4] Wind Turbines: Fundamentals, Technologies, Application and Economics, Erich Hau , Springer Verlag; (2000)
[5] Wind Energy Explained , J. F. Manwell, J. G. McGowan, A. L. Rogers, John Wiley & Sons; 1st edition (2002)
[6] Wind Energy Handbook , Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, John Wiley & Sons; 1st edition (2001)
[7] Wind and Solar Power Systems , Mukund R. Patel, CRC Press; (1999)
[8] Mini Hydropower , Tong Jiandong(et al.) , John Wiley, 1997
[9] Wind Energy Technology, John F. Walker and Nicholas Jenkins, John Wiley, 1997
[10] Small Hydro Power Potential in India, Central Electricity Authority, New Delhi, 1997.
[11] Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, David A. Spera, (Editor) American Society of Mechanical Engineers; (1994)
[12] Wind Energy Basics: A Guide to Small and Micro Wind Systems, Paul Gipe , Karen Perez, Chelsea Green Publishing Company; 1999.
[13] Wind Energy Systems, G L Johnson, Prentice Hall Inc, New Jersey, 1985.

GET 523 Solar Photovoltaic Energy Conversion 3 0 0 3 45

(Soft core course)

Properties of Semiconductor [8]

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.

Solar Cell Physics [8]

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.

Solar Cell Fabrication Technology [6]

Preparation of metallurgical, electronic and solar grade Silicon; Production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) method: Design of a complete silicon, GaAs, InP solar cell; High efficiency III-V, II-VI multijunction solar cell; Thin film solar cells; Dye-sensitized solar cells.

Solar Photovoltaic System Design [12]

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 [8]

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.

References:

[1] Photovoltaic Systems, 2nd Edition, by James P. Dunlop, ISBN:9780826913081, Publisher:American Technical Publishers, Inc. 2010

[2] Practical Photovoltaics: Electricity from Solar Cells, by Richard Komp, ISBN:9780937948118, Publisher:Aatec Publications, Publication Date:February 2002.

[3] Fundamentals of Solar Cells: PV Solar Energy Conversion, Alan L Fahrenbruch and Richard H Bube , Academic Press, New York , 1983

[3] Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York, 1995

[4] Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998

[5] Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, ISBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.

[6] Applied Photovoltaics, by Stuart R Wenham, ISBN:9781844074013, Publisher:Earthscan Publications, 2007.

[7] Nanotechnology for Photovoltaics, by Loucas Tsakalakos, ISBN:9781420076745, Publisher:CRC Press 2010

[11] Terrestrial Solar Photovoltaic, T Bhattacharya, Narosa Publishers Ltd, New Delhi, 2006.

[12] Solar Cell Array Design Handbook, H S Rauschenbach, Van Nostrand Reinfold, 1997.

[13] Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997.

[14] Photovoltaic Systems Engineering, Roger Messenger and Jerry Vnetre, CRC Press, 2003.

GET 524 Waste to Energy Conversion 3 0 0 3 45
(Soft core course)

Solid Waste [8]

Definitions: Sources, types, compositions; Properties of Solid Waste; Municipal Solid Waste: Physical, chemical and biological property; Collection, transfer stations; Waste minimization and recycling of municipal waste

Waste Treatment & Disposal [16]

Size Reduction: Aerobic composting, incineration; Furnace type & design; Medical / Pharmaceutical waste incineration; Environmental impacts; Measures of mitigate environmental effects due to incineration; Land Fill method of solid waste disposal; Land fill classification; Types, methods & siting consideration; Layout & preliminary design of land fills: Composition, characteristics, generation; Movement and control of landfill leachate & gases; Environmental monitoring system for land fill gases

Energy Generation Form Waste [18]

Types: Biochemical Conversion: Sources of energy generation, Industrial waste, agro residues; Anaerobic Digestion: Biogas production; Types of biogas plants; Thermochemical conversion: Sources of energy generation, Gasification; Types of gasifiers; Briquetting; Industrial applications of gasifiers; Utilization and advantages of briquetting; Environment benefits of biochemical and thermochemical conversion

References:

[1] Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons, by Gary C. Young, ISBN:9780470539675, Publisher: John Wiley & Sons, Publication Date: June 2010.

[2] Recovering Energy from Waste Various Aspects Editors: Velma I. Grover and Vaneeta Grover, ISBN 978-1-57808-200-1; 2002

[3] Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Prentice Hall, 2000.

[4] Rich, Gerald et.al., Hazardous Waste Management Technology, Podvan Publishers, 1987.

[5] Waste-to-Energy by Marc J. Rogoff, DEC-1987, Elsiever, ISBN-13: 978-0-8155-1132-8, ISBN-10: 0-8155-1132-9.

[6] Parker, Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985.

[7] Manoj Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997.

[8] Bhide A. D., Sundaresan B. B., Solid Waste Management in Developing Countries, INSDOC, New Delhi, 1983.

[9] From Waste to Energy, Robert Green, Cherry Lake Pub. ISBN: 1602795096, 2009.

GT 525 Sustainable Processing Energy and Materials 3 0 0 3 45

(Soft core course)
Unit 1:
Silicon processing methods, dry and wet chemical processes used to develop new materials and micro-engineered products.

Unit 2:
Gas-solid and liquid-solid reactions, and their role in micro engineering. Various reactors and methods of fabrication methods, such as physical and chemical vapour deposition techniques, photolithography, electroless and electrochemical deposition, etching, and through mask plating and common models to describe these processes.

Unit 3:

Principles for electrochemical power sources, photovoltaics and their relevance in current energy industry. Environmental and sustainability issues for the production of high-tech components and materials

References

[1] A First Course in Electrochemical Engineering, The Electrochemical Consultancy Arlesford Press.
[2] W. Menz, J. Mohr and O. Paul, Microsystems Technologies, VCH Verlag.
[3] R Kirkwood and A Longley, Clean Technology and the Environment, Blackie October 1994.
[4] P. White, I. Franke, P. Hindle, Integrated Solid Waste Management: A Lifecycle Inventory pub. Chapman & Hall 1994.
[5] A. Johansson, Clean Technology", Lewis 1992.
[6] M. Charter and U. Tischner, Sustainable Solutions, Greenleaf .
[7] J Fiksel, Design for Environment, Mcgraw Hill, 1996.
[8] Ed K. Mulder, Sustainable Development for Engineering, Greenleaf Publishing.

GET 526: **Green management** 3 0 0 3 45

(Soft core course)

Unit-1 (9 lectures)

The concept of green management; evolution; nature, scope, importance and types; developing a theory; green management in India; relevance in twenty first century

Unit-2 (9 lectures)

Organizational environment; internal and external environment; how to go green; spreading the concept in organization; CSR towards environment; Indian corporate structure and environment

Unit-3 (9 lectures)

Approaches from ecological economics; indicators of sustainability; ecosystem services and their sustainable use; bio-diversity; Indian perspective; alternate theories

Unit-4 (9 lectures)

Environmental reporting and ISO 14001; climate change business and ISO 14064; green financing; financial initiative by UNEP; green energy management; green product management

Unit-5 (9 lectures)

Definition; green techniques and methods; green tax incentives and rebates (to green projects and companies); green project management in action; business redesign; eco-commerce models

Books for Further References:

[1] Green Management and Green Technologies: Exploring the Causal Relationship by Jazmin Seijas Nogarida, 2008.
[2] Green Marketing and Management: A global Perspective by John F. Whaik, 2005
[3] The Green Energy Management Book by Leo A. Meyer
[4] Green Project Management by Richard Maltzman And David Shiden
[5] Green Marketing by Jacquelin Ottman
[6] Green and World by Andrew S. Winston

GT 527: Environmental Risk Management 3 0 0 3 45

Nature of environmental risks, risk management with integration, environmental Law and Management, Environmental Epidemiology, Environmental auditing, Environmental Modelling and Monitoring, Management of major industrial accidents, Process risk assessment and Integrated Pollution Control; Dangerous substances and risk assessment for new substances; Life Cycle Assessment; Environmental Impact Assessment and project planning; Environmental Management Systems (ISO 14001 & EMAS) and risk mangement. Cost-Benefit Analysis, Operations Strategies.

Reading List

[1] Environmental Risk Management By Paul Pritchard, Earth Scan Publications, 2001, ISBN:9781853835988,.

[2] Handbook of Environmental Risk Assessment and Management Peter P. Calow, Publisher: Wiley-Blackwell; 1998, ISBN-10: 0865427321, ISBN-13: 978-0865427327.

[3] J. Glasson, R. Therivel, and A. Chadwick, Introduction to Environmental Impact Assessment (Essential reading), UCL Press, 1994

[4] HMSO, Environmental Assessment , a guide to the procedures (Essential reading) 1989 , DOE , Welsh Office.

GET 528 Energy Laboratory – II 1 0 6 3

Core Course
Lectures

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

Laboratory:

- 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.

SECOND YEAR THIRD SEMESTER COURSES –

Any four courses (4 credits each) and one minor project (2 credits) in one of the elective courses

1. Green chemistry

The invention, design and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances.

2. Green nanotechnology

Nanotechnology involves the manipulation of materials at the scale of the nanometer. Green nanotechnology is the application of green chemistry and green engineering principles to this field.

3. Green building concepts

Green building encompasses everything from the choice of building materials to where a building is located.

4. Green Chemical Bioenergetics

Chemical Bioenergetics involves energy transduction in biological systems, bio-nano interfaces, biomimetic and bio-inspired self-assembling systems, and bio-fuel cells and applications.

5. Global Environmental Change and its Political Consequences

Anthropogenically driven global change, and the links to carbon dioxide level rise since the Biosolar cells Industrial Revolution. The environmental consequences of this for societies and the political responses both national and international to these crises are then placed within this perspective.

6. Environmentally preferred purchasing

This subject involves the search for products whose contents and methods of production have the smallest possible impact on the environment.

GET 611 Green Chemistry

(Soft core Course) 3 0 0 3 45 L

Green chemistry about chemical research and engineering that develops the design of chemicals and environmentally benign processes that minimize the use and generation of hazardous substances. In this course concepts of green chemistry will be exposed with real world applications in pharmaceutical industry and fine chemical industry. Apart from theory the course will have practical component where students are encouraged to do mini project involving principles of green chemistry.

Unit 1: Introduction to Organic Chemistry /Analytical Chemistry /Basic Chemical Engineering [8 h]

Unit 2: Introduction to Green Chemistry: [10 h]
Principles of Green Chemistry, Reasons for Green Chemistry (resource minimisation, waste minimisation, concepts), Green reactions solvent free reactions, Catalyzed (heterogeneous/homogeneous) reactions, MW/ Ultrasound mediated reactions, Bio catalysts etc

Unit 3: Introduction to Pharmaceutical Process Chemistry: [12 h]
Introduction to process chemistry, the difference between synthesis and process, Rote design, Route optimization, DOE,

Unit 4: Role of Analytical Chemistry in Process Chemistry Role of Process Safety in Process Chemistry: TH classification, MSDS, Thermal Hazards, Waste segregation and disposal.

Unit 5: Scale-up aspects including PE in Process Chemistry: Case Studies; New Initiatives : Micro reactors, Spinning Disc reactors [3 h]

Practical chemistry (Mini project): [24 h]

References:

[1] James H.Clarke & Duncan Maacquarrie, Handbook of Green Chemistry and Technology, Wiley-Blackwell; 1 edition (2002)
[2] Paul T.Anastas and John C. Warner, Green Chemistry: Theory and Practice, Oxford University Press, USA (2000)
[3] M.Lancaster, Green Chemistry (Paperback), Royal Society of Chemistry; 1 edition (2002)
[4] Stanley E.Manahan, Green Chemistry and the Ten Commandments of Sustainability, 2nd ed (Paperback), ChemChar Research Inc (2005)
[5] Albert Matlack, Introduction to Green Chemistry (Hardcover), CRC Press; 1 edition (2001)
[6] Kenneth M.Doxsee and James Hutchison Green Organic Chemistry: Strategies, Tools, and Laboratory Experiments (Paperback), Brooks Cole; 1 edition (May 7, 2003)
[7] Green Chemistry in the Pharmaceutical Industry, Peter Dunn (Editor), Andrew Wells (Editor), Michael T. Williams (Editor), Wiley-VCH (2010)
[8] Handbook of Green Chemistry – Green Solvents (Hardcover), Walter Leitner (Editor), Philip G. Jessop (Editor), Chao-Jun Li (Editor), Peter Wasserscheid (Editor), Annegret Stark (Editor), Paul T. Anastas, Wiley-VCH (2010)

GT 612 Green nanotechnology

(Soft core Course) 3 0 0 3 45 L

Nanotechnology plays significant role in meeting the challenges inherent in minimizing environmental impacts while maximizing energy resources. Nanotechnologies can improve structural engineering of energy sources, create novel methods of cooling, and inspire new approaches to water supply and treatment. This course aims to provide the fabrication principles, characterization and application of nanomaterials for alternative energy and green technologies.

Unit 1: Introduction to nanomaterials: 9 h
Nanoparticles preparation techniques, Greener Nanosynthesis: Greener Synthetic Methods for Functionalized Metal Nanoparticles, Greener Preparations of Semiconductor and Inorganic Oxide Nanoparticles, green synthesisi of Metal nanoparticles, Nanoparticle characterization methods,

Unit 2: Nanomaterials for "Green" Systems: 9 h
Green materials, including biomaterials, biopolymers, bioplastics, and composites Nanotech Materials for Truly Sustainable Construction: Windows, Skylights, and Lighting. Paints, Roofs, Walls, and Cooling.Multifunctional SensorsGas Sensors, Bio-mimetic Sensors, Optical Interference Sensors Thermo-, light-, and stimulus-responsive smart materials Nanomaterials

Unit 3: Nanomaterials for Alternative Energy: 15 h
Nanomaterials for Fuel Cells and Hydrogen Generation and storage, Nanostrcutures for efficient solar hydrogen production, Metal Nanoclusters in Hydrogen Storage Applications, Metal Nanoparticles as Electrocatalysts in Fuel Cells, Nanowires as Hydrogen Sensors, Ceramic nanocomposites for alternate energy and environment protection, Applications for Cobalt Nanoparticles and Graphite Carbon-Shells, Nanomaterials for Solar Thermal Energy and Photovoltaics. Semiconductor Nanocrystals and Quantum Dots for Solar Energy Applications Nanoparticles for Conducting Heat Transfer

Unit 4: Nanomaterials in Energy Storage Devices: 6 h
MWNT for Li Ion Batteries, Nanomaterials in Electrodes, Hybrid Nanotubes: Anode Material, Supercapacitor, Battery Electrodes

Unit 5: 6 h
Metal nanocluster catalysts for Coal Liquefaction. Nanomaterials for Desalination and Purification of Water

[1] Nanotechnology for Photovoltaics, by Loucas Tsakalakos, ISBN:9781420076745, Publisher: CRC Press, Publication Date: April 2010.
[2] Dahl, 1. A.; Maddux, B. L. S.; Hutchison, 1. E. Toward Greener Nanosynthesis. Chemical Reviews, 2007, 107, 2228-2269.
[2] Nanomaterials, nanotechnologies and design: an introduction for engineers By M. F. Ashby, Daniel L. Schodek, Paulo J. S. G. Ferr
[3] Nanoscale materials By Luis M. Liz-Marzán, Prashant V. Kamat
[4] Environmental applications of nanomaterials: synthesis, sorbents and sensors By Glen E. Fryxell, Guozhong Cao
[8]. Global roadmap for ceramics and glass technology By Mrityunjay Singh, Gary S. Fischman, Stephen Freiman, John Hellmann, Kathryn Logan, Tom Coyle, Wiley 2007
[9] On Solar Hydrogen and Nanotechnology By Lionel Vayssieres Wiley, 2009
[10] Green Nanotechnology: Solutions for Sustainability and Energy in the Built Environment
[11] Geoffrey B. Smith, University of Technology, Broadway, Australia; Claes-Goran S. Granqvist, Uppsala University, Sweden CRC Press ISBN: 9781420085327, Publication Date: August 31, 2010.

GT 613: **GREEN CONCEPTS IN BUILDINGS**
(Soft core Course) 3 0 0 3 45 L

Pre-requisite (undergraduate degree in civil engineering)

Unit1: Environmental implications of buildings energy, carbon emissions, water use, waste disposal; Building materials: sources, methods of production and environmental Implications. Embodied Energy in Building Materials: Transporation Energy for Building Materials; Maintenance Energy for Buildings.

Unit 2: Implications of Building Technologies Embodied Energy of Buildings: Framed Construction, Masonry Construction. Resources for Building Materials, Alternative concepts. Recycling of Industrial and Buildings Wastes. Biomass Resources for buildings.

Unit 3: Comforts in Building: Thermal Comfort in Buildings- Issues; Heat Transfer Characteristic of Building Materials and Building Techniques. Incidence of Solar Heat on Buildings-Implications of Geographical Locations.

Unit 4: Utility of Solar energy in buildings concepts of Solar Passive Cooling and Heating of Buildings. Low Energy Cooling. Case studies of Solar Passive Cooled and Heated Buildings.

Unit 5: Green Composites for buildings
Concepts of Green Composites. Water Utilisation in Buildings, Low Energy Approaches to Water Management. Management of Solid Wastes. Management of Sullage Water and Sewage. Urban Environment and Green Buildings. Green Cover and Built Environment.

TEXT BOOKS

[1] K.S.Jagadish, B. U. Venkataramareddy and K. S. Nanjundarao. Alternative Building Materials and Technologies. New Age International, 2007.
[2] Low Energy Cooling For Sustainable Buildings. John Wiley and Sons Ltd, 2009.
[3] Green My Home!: 10 Steps to Lowering Energy Costs and Reducing Your Carbon Footprint, by Dennis C. Brewer, ISBN:9781427798411, Publisher: Kaplan Publishing, Publication Date: October 2008.
4] B. Givoni, Man, Climate and Architecture Elsevier, 1969.
[5] T. A. Markus and E. N. Morris Buildings Climate and Energy. Pitman, London, 1980.
Arvind Kishan et al (Ed)
[6] Climate Responsive Architecture. TataMcGraw Hill, 2001.
[7] Sustainable Building Design Manual. Vol 1 and 2, Teri, New Delhi, 2004.
[8] O. H. Koenigs Berger, T. G. Ingersoll, Alan Mayhew and S. V. Szokolay. Manual of Tropical Housing and Building. Orient Long man, 1975.

REFERENCE BOOKS

[1] Osman Attmann Green Architecture Advanced Technologies and Materials. McGraw Hill, 2010.
[2] Michael F. Ashby Materials and the Environment, Elsevier, 2009.
[3] Jerry Yudelson Green building Through Integrated Design. McGraw Hill, 2009.
[4] Mili M. Ajumdar (Ed) Energy Efficient Building in India. Teri and Mnes, 2001/2002.
[5] T. N. Seshadri et al Climatological and Solar Data for India. CBRI and Sarita Prakashan, 1968.
[5] Fundamentals of Integrated Design for Sustainable Building By Marian Keeler, Bill Burke
[6] The New Solar Electric Home: The Photovoltaics How-To Handbook, by Joel Davidson, ISBN: 9780937948095, Publisher: Aatec Publications, Publication Date: July 1987.

GT 614 Carbon sequestration at landscape level

(Soft core Course) 3 0 0 3 45 L

UNIT 1. Climate change and International agreements - 6 hours

The green-house effect. The United Nations Framework Convention on Climate Change (UNFCCC). The Intergovernmental Panel on climate change (IPCC), the Kyoto Protocol, the Clean Development Mechanism (CDM). Afforestation and Reforestation projects, Reduced Emissions from Deforestation and Degradation (REDD). CDM projects, finance, project development. Conservation of natural carbon sinks.

UNIT 2. Primary productivity: mechanisms and assessment - 12 hours

Photosynthesis, absorption and yield. C3, C4 and CAM pathways. Laboratory measurement of primary productivity: cell, plant, ecosystem. Direct field measurements of biomass and primary productivity: allometric models, harvest methods for forests, grasslands and ocean. Indirect measurements of biomass and primary productivity: remote sensing and other methods. The CDM methodologies for measurement of stocks and fluxes.

UNIT 3. Biogeochemistry - 11 hours

Role of soil in the carbon balance: decomposition and sequestration in soils. The carbon cycle: plant, soil and atmosphere. Impact of soil degradation. Conditions for the formation of fossil stocks of carbon. Carbon balance of ecosystems: forests, grasslands and oceans. Impact on the global carbon balance.

UNIT 4. Remote sensing and spatial analysis - 12 hours

Sensors. Reflectance of vegetation. Measuring biomass with remotely sensed data. Measuring primary productivity with remotely sensed data. High resolution satellites, use and limitations to measure biomass and primary productivity. Low resolution satellites use and limitations to measure biomass and primary productivity. Regional and global assessments of biomass and primary productivity. Introduction to Geographic Information Systems (GIS). Land-use and land-use changes assessment. The Clean Development Mechanism (CDM) methodologies for measurement of stocks and fluxes at the landscape level.

UNIT 5. Biomass as a major source of energy in India - 4 hours

Fuel-wood use in rural households. Consequences for ecosystems. Future energy scenario in rural areas. Utilization of biomass in industrial and semi-industrial settings. Future utilization of biomass in India. Future of landscape management: optimal management.

Books and References

[1] Bhatta, B. 2009. Remote sensing and GIS. Oxford University Press.
[2] Monteith, J. L., and M. H. Unsworth. 1990. Principles of environmental physics, Second edition. Edward Arnold.
[3] Neteler, M., and H. Mitasova. 2008. Open Source GIS. A GRASS GIS approach, Third edition. Springer.
[4] Pachauri, S. and L. Jiang, 2008. The household energy transition in India and China. Interim Report, International Institute for Applied Systems Analysis.
[5] Walker, B. and W. Steffen (eds.) 1996. Global change and terrestrial ecosystems. International geosphere-biosphere programme book series. Cambridge University Press.

Websites for exhaustive documentation on: Afforestation / Reforestation, REDD, CDM, Kyoto Protocol, UNFCCC - http://unfccc.int/2860.php; IPCC - http://www.ipcc.ch/

GET 615 Green Energy and Economics
(Soft core course)

3 credits; 45 lectures

Unit 1. **Principles of Economics**
Scarcity, opportunity cost, Efficiency - Resource allocation through market mechanism - Market failure and role of state

Unit 2. **Energy Taxonomy**
Types of energy: oil (including the implications of OPEC), natural gas, coal, solar, wind), their merits and demerits, economic issues (effect of price controls, cost-benefit) and environmental perspectives - Renewable and non-renewable energy - Commercial and non-commercial energy - The McCkelvey classification of energy resources

Unit 3. **Economics of Nonrenewable Resource Extraction**
Hotelling rule - Baumol model of resource extraction - Allocation of depletable energy resources without substitute resource with constant and increasing marginal extraction cost - Allocation of depletable energy resources with substitute resource with constant and increasing marginal extraction cost

Unit 4. **Measuring Resource Scarcity**
The "mineralogical threshold" - Resource life time measure - Unit cost measures - Real prices as scarcity indicators - economic Rent as scarcity measure

Unit 5. **Policy Issues**
Energy Demand: Global and Indian trends - Determinants of energy demand; energy productivity" and management of energy demand - Policy toward Electricity in India: pricing, implications of state subsidies, case for and against privatization in electricity generation and distribution; relevance to India of California experience in privatization of electricity distribution - Potential for renewable energy use in India (solar and wind energy)

Text Books and References

1. Kanchan Chopra and Vikram Dayal (2009), "High Economic Growth, Equity and Sustainable Energy Devopment", In (ed) Oxford Handbook of Enviornmental Economics, Oxford University Press, New Delhi.
2. Parry C Field (2001), "Natural Resource Economics", Mcraw Hill. Chapters 10 & 11.
3. Nick Hanely, Jason F Shogren and Ben White (2001), "Introduction to Environmental Economics", Oxford University Press. Chapter 14.

GET 616 Bio-energy and Conversion Systems
(Soft core Course) 3 0 0 3 45

Biomass Formation [6]
Biomass resources: Classification and characteristics; Techniques for biomass assessment; Application of remote sensing in forest assessment; Biomass estimation.

Thermochemical Conversion [8]
Different processes: Direct combustion, incineration, pyrolysis, gasification and liquefaction; Economics of thermochemical conversion.

Biological Conversion [8]
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 [6]
Hydrolysis & hydrogenation; Solvent extraction of hydrocarbons; Solvolysis of wood; Biocrude and biodiesel; Chemicals from biomass.

Waste Conversion [7]
Anaerobic digestion of sewage and municipal wastes; Direct combustion of MSW-refuse derived solid fuel; Land fill gas generation and utilization

Power generation [10]
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.

References:
[1] Alternate Energy: Assessment & Implementation Reference Book, James J Winebrake, Springer January 2007.
[2] Biofuels - Securing the Planet's Future Energy Needs, Edited by A Demirbas Springer 2009.
[3] Biomass Assessment Handbook - Bioenergy for a sustainable environment Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
[4] Biomass Assessment Handbook - Bioenergy for a sustainable environment, Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
[5] Dictionary of Renewable Resources - 2nd Edition, Revised and Enlarged, Zoebelein, Hans, Wiley-VCH, 2001.
[6] Energy Technology and Directions for the Future, John R. Fanchi, Elsevier Science February 2004.
[7] Fundamentals of Renewable Energy Processes, Aldo da Rosa, Academic Press September 2005.
[8] Renewable Bioresources - Scope and Modification for Non-Food Applications Edited by Stevens, Christian and Verhe, Roland, Wiley June 2004
[9] Renewable Energy, Third Edition, Bent Sorensen, Academic Press August 2004
[10] Success & Visions for Bioenergy: Thermal processing of biomass for bioenergy, biofuels and bioproducts, Edited by A V Bridgwater, CPL Press September 2007.
[11] The Future for Renewable Energy 2, Edited by EUREC Agency, James & James (Science Publishers) Ltd March 2002.
[12] Anthony San Pietro, Biochemical and Photosynthetic aspects of Energy Production, Academic Press, New York, 1980
[13] David Boyles, Bio Energy Technology Thermodynamics and costs, Ellis Hoknood, Chichester, 1984
[14] R. C. Maheswari, Bio Energy for Rural Energisation , Concepts Publication, 1997
[15] EL - Halwagi M M, Biogas Technology : Transfer & Diffusion, Elsevier Applied SC, London 1986
[16] N. H. Ravindranath and D. O. Hall Biomass, Energy, and Environment: A Developing Country Perspective from India, Oxford University Press, 1995

GET 617: Smart Materials: Application of Nano-technology for Batteries, Solar and Fuel cells

(Soft core Course) 3 0 0 3 45

Unit 1: Nanotechnology

What is in the nanotechnology; Energy related application areas; Implications for philosophy, ethics and society.

Unit 2: Smart Batteries

Nanomaterials for anodes; Nanomaterials for cathodes; Battery perfromance and cyclability; Nanomaterials synthesis

Unit 3: Fuel cells

Role of nanochain, nanofibers, nanotubes in low temperature fuel cells; Application areas; Fabrication of electrodes and evaluation of performance with nanomaterials.

Unit 4: Solar Cells

Band gap and nanomaterials; Energy conversion efficiency; Performance and reliability of nanomaterials based solar cells

Textbook and Reference Materials

[1] Nanotechnology: assessment and perspectives, H. Brune et al., New York, Springer, 2006.

[2] Nano-hype: the truth behind the nanotechnology buzz, David M. Berube; Amherst, N.Y., Prometheus Books, 2006.

[3] Nanotechnology challenges: implications for philosophy, ethics and society, editors: Joachim Schummer, Davis Baird Hackensack, NJ: World Scientific Pub., 2006.

[4] Energy conversion and storage scientific journals.

GET 618: **Solar Photovoltaic Technology**
(Soft core Course) 3 0 0 3 45

Unit 1
Quantum mechanics, Crystals structures, atomic bonding, types of semiconductors, energy band diagram, p-type and n-type semiconductors, doping and carrier concentration, diffusion and drift of carriers, continuity equation, P-N junction and its properties, dark I-V equation of P-N junction, junction under illumination,

Unit 2
solar cell parameters, production of silicon, fabrication of solar cells, design of solar cells, optimization of process parameters, measurements of solar cell parameters; short circuit current, open circuit voltage, fill factor, efficiency; optical losses; electrical losses, surface recombination velocity, quantum efficiency, I-V curve; thin film solar cell technologies, amorphous Si solar cells, CdTe, CIGs solar cells, solar cells and solar PV modules, issues with solar PV modules, bypass diode and blocking diode,

Unit 3
applications of solar PV systems, electronic circuits in PV, design of solar PV systems; battery sizing, PV panel sizing, inverter sizing, solar lanterns, water pumping application, home lighting application, cathodic protection, remote lighting.

Text books:
[1] Photovoltaics: Design and Installation Manual, by Solar Energy International, ISBN: 9780865715202, Publisher: New Society Publishers, Publication Date: September 2004.
[2] C. S. Solanki, “Solar Photovoltaics: Fundamental Applications and Technologies, Prentice Hall of India, 2009.
[3] Solar Water Heating: A Comprehensive Guide to Solar Water and Space Heating Systems
by Bob Ramlow and Benjamin Nusz, ISBN:9780865715615, Publisher: New Society Publishers, Publication Date:June 2006.
[4] Seminconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
Ben G. Streetman, Solid State electronic devices, , , Prentice-Hall of India Pvt. Ltd., New delhi 1995.
[5] J. Nelson, The physics of solar cells, Imperial College Press, 2006.
[6] R. Brendel, Thin-film crystalline silicon solar cells: Physics and technology, , Wiley-VCH, Weinheim, 2003.
[7] M. D. Archer, Clean electricity from photovoltaics, R. Hill, Imperial College Press, 2001.
[8] M. A. Green, Solar cells: Operating principles, technology and system applications, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.

GET 619 Lab: Sustainable Energy Systems: (Core Course) 1 0 0 3 5 L
Virtual instrumentation and case studies 6 Hrs per week, 3 Credits

The trend engineering design today, is towards more digital prototyping and computer-based evaluation and testing before a time-consuming and expensive production of either scale models or full-size physical prototypes of components or systems. During this lab course, the student is expected to gain practical experience on case studies related to alternate and green technologies. Students will be given the opportunity to develop a detailed prototype interactive virtual instrumentation system for a sustainable energy project that they can use as the basis of their final industrial project, to be pursued at the fourth semester. Students are expected to give two seminars and submit a system document that must include sufficient technical content along with resource assessment, economic appraisal, development schedule and plan as well as environmental, economic and social impact assessment.

Course Contents

LabVIEW basics: Front panel and block diagram- Dataflow programming model Modular Programming: Basics of modular programming with subVIs- Creating an icon and connector pane Graphing with LabVIEW: Using waveform charts to display data, XY graphs to display data Strings and File I/O: Creating string controls and indicators, Using File I/O VIs

Data Acquisition: Plug-in DAQ devices, Performing analog I/O, Counters, Digital I/O, Instrument Control, .Sensors and Transducers, PC Based Measurement Data Acquisition & Signal Conditioning., Intelligent Instrumentation

LabVIEW for Data Acquisition (Paperback) Bruce Mihura Prentice Hall, 2001
LabVIEW for Electric Circuits, Machines, Drives, and Laboratories, by Nesimi Ertugrul, Prentice Hall 2002
LabView: Advanced Programming Techniques, SECOND EDITION Rick Bitter,
Taqi Mohiuddin, Matt Nawrocki CRC Press; 2 edition, 2006
LabVIEW for Everyone: Graphical Programming Made Easy and Fun (3rd Edition) (Hardcover)~ Jeffrey Travis,
Jim Kring Prentice Hall; 3 edition 6, 2006

The virtual instrumentation case studies investigated in this lab are expected to include Renewable /Non-Conventional Energy Systems- Solar, Wind, Small Hydro, Biofuels, Solar thermal & Solar PV systems. Types of Solar energy convertors, Wind Energy Conversion Systems, Wind data analysis, Grid connected systems, Mini/Micro/Pico hydel systems-Turbines, Grid connected and stand alone systems, Bio fuels- Biogas. Bio mass. Bio diesel, Gassifiers, Hybrid systems, Energy conservation and Energy Efficiency, Intelligent buildings

1. Study of Electrical Power Systems Using LabVIEW Virtual Instruments (VI) Modules Paper 137, Proceedings of The 2008 IAJC-IJME International Conference ISBN 978-1-60643-379-9
2. A LabView Based Instrumentation System for a Wind-Solar Hybrid Power Station Journal of Industrial Technology • Volume 20, 2004, 1-8
3. Modeling and Simulation of Crush Natural GasTurbo Engine JOURNAL OF COMPUTERS, VOL. 4, 2009, 1175-1181
4. Using LabVIEW in a Mini Power System Model Allowing Remote Access and New ImplementationsInternational Conference on Engineering Education – ICEE 2007, September 3 – 7, 2007
5. A Matlab-Based Modeling and Simulation Package for Electric and Hybrid Electric Vehicle Design IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 48, NO. 6, NOVEMBER 1999
6. Modelling and control of a Fuel Cell System and Storage Elements in transport applications, Journal of Process Control 15 (2005) 481–491
7. Transient Modeling and Simulation of Wind Turbine Generator and Storage Systems Paper 042, Conference on Power Systems, Canada , Montreal, Oct. 1-4 2006
8. Design and Simulation of an Automated System for Greenhouse using LabVIEW, American-Eurasian Journal and Environmental Science, 2008, vol 3, 279-284.

GET 631: Proposal Writing and Defence (Core Course) 1 0 0 3 0 L

Project overview: Title, Estimated budget, Estimated duration, Objectives, Abstract.
Problem and justification: Contemporary technological research, demand and supply, profitability, social impact, Objectives – general and specific, methodology, conceptual and theoretical framework, data collection, data analysis, ethical considerations, training needed, organizational matters.
Anticipated results and dissemination: Potential use; contribution to existing technical and scientific knowledge; policy formulation and implementation; development processes at the local, national, and regional levels
Needs of specific project, intellectual property; timetable and budget; schedule and duration travel, research expenses, mode of evaluation.
Appendices.

EXTRA BOOKS FOR GREEN ENERGY TECHNOLOGY COURSE

[1] Prof. Dr. Manfred Stiebler Wind Energy Systems for Electric Power Generation
ISBN: 978-3-540-68762-7 e-ISBN: 978-3-540-68765-8, Springer Series in Green Energy and Technology ISSN 1865-3529.
[2] Renewable Energy Technology, Economics and Environment, Kaltschmitt, Martin; Streicher, Wolfgang; Wiese, Andreas (Eds.), 2007, XXXII, 564 p. 270 illus., Hardcover, ISBN: 978-3-540-70947-3.
[3] Green Manufacturing, Fundamentals and Applications Series: Green Energy and Technology Dornfeld, David (Ed.) 1st Edition., 2010, 260 p., Hardcover, ISBN: 978-1-4419-6015-3 Due: June 28, 2010.
[4] Boyle, Godfrey. 2004. Renewable Energy (2nd edition). Oxford University Press, 450 pages (ISBN: 0-19-926178-4).
[5] Boyle, Godfrey, Bob Everett, and Janet Ramage (eds.) 2004. Energy Systems and Sustainability: Power for a Sustainable Future. Oxford University Press, 619 pages (ISBN: 0-19-926179-2)
[6] Renewable Energy: Its Physics, Engineering, Environmental Impacts, Economics & Planning. 2004. Bent Sørensen. 3rd edition. ELSEVIER Academic Press.
[7] Renewable and Efficient Electric Power Systems. 2004. Gilbert M. Masters. John Wiley & Sons, Inc. NJ.
[8] Kibert, C. (2005) Sustainable Construction: Green Building Design and Delivery (Hoboken, NJ: John Wiley
[9] G. J. Levermore. 2000. Building Energy Management Systems (2nd ed.), E & FN Spon
[10] Gasch, R., Twele, J.; 2001, "Wind Power Plants" James & James Science Publishers Ltd., UK / Solarpraxis AG, Germany. ISBN 1902916387 (UK) / 3934595235 (DE)
[11] Klass, D.; 1998 "Biomass Renewable Energy, Fuels, and Chemicals" Cloth. Academic P, UK. ISBN 0124109500
[12] Renewable Energy Resources (2nd Edition), John Twidell and Tony Weir, Taylor and Francis, 2006
[13] Fundamentals of Renewable Energy Processes, Aldo Da Rosa, Elsevier Academic Press, 2005
[14] Green Building Handbook Volume 1, A guide to building products and their impact on the environment Tom Woolley, Sam Kimmins, Paul Harrison and Rob Harrison
[15]. Lisa Wells and Jeferey Travis, LabVIEW for Everyone, Graphical Programming
Even Made Easier, Prentice Hall, NJ 07458, 1997.
[16]. Saadat, Hadi, Power Systems Analysis, Prentice Hall, NJ, 1999.
[17]. Stevenson, William D. Elements of Power System Analysis, McGraw-Hill, NY, 1982.
[18]. Ertugrul, Nesimi. LabVIEW for Electric Circuits, Machines, Drives, and
Laboratories, Prentice Hall, NJ, 2002.
[19]. Chugani, M., Samant, A., and Cerna, N. LabVIEW Signal Processing, Prentice Hall,
NJ 07458, 1998.
[20] Virtual Instrumentation Using Lab VIEW By Gupta, Joseph, John.
[21] Thermal Energy Storage: Basics, Design, Applications to Power Generation and Heat Supply (Topics in Energy) (Hardcover) G. Beckmann
[22] Biohydrogen: For Future Engine Fuel Demands Ayhan Demirbas Springer 2009 Designing with Solar Power - a sourcebook for building integrated photovoltaics - new edition Edited by Deo Prasad and Mark Snow Earthscaan May 2005
[23] Dictionary of Energy Edited by Cutler J. Cleveland and Christopher Morris Elsevier 2005
[24] Fuel Cells: The Sourcebook - New Edition 2004 Escovale 2004.
[25] Introduction to Wind Energy Systems Hermann-Josef Wagner and Jyotirmay Mathur Springer 2009.
[26] Next Generation Photovoltaics: High Efficiency through Full Spectrum Utilization
Edited by A Marti and A Luque, CRC Press 2003
[27] Ocean Wave Energy - Current Status and Future Prespectives Edited by J Cruz Springer 2008
[28] Organic Photovoltaics: Mechanisms, Materials, and Devices Edited by Sam-Shajing Sun and Niyazi Serdar Sariciftci CRC Press 2005
[29] Renewable Electricity and the Grid Godfrey Boyle Earthscan April 2009
[30] Solar Cells - Materials, Manufacture and Operation Tom Markvart and Luis Castaner
Elsevier December 2004.
[31] Sustainable Energy Production and Consumption - Benefits, Strategies and Environmental Costing Edited by Barbir, Frano; Ulgiati, Sergio, Springer June 2008.
[32] Wind Turbines - Fundamentals, Technologies, Application, Economics - 2nd edition E Hau, Springer 2006.