CURRICULUM AND SYLLABI

M. TECH. IN GREEN ENERGY TECHNOLOGY

For 2011 Batch of M.TECH GET.

Centre for Green Energy Technology

PONDICHERRY UNIVERSITY

PUDUCHERRY – 605 014

2011

PONDICHERRY UNIVERSITY
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 modeling. 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 M.Sc in Material Science, Physical Sciences, Chemical Sciences, Biological Sciences or equivalent degree. B.E/B.Tech in Electronics, Electrical, Mechanical or equivalent degree, excepting M.Sc. IT and B.E/ B.Tech IT, with at least 55% marks or equivalent grade in qualifying examination 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, modeling 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. 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.

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.

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.

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M.Tech in Green Energy Technology

COURSE STRUCTURE

SEMESTER-I

Course Code	Course Title	Course Type*	L	T	P	C
Core Courses						
GETY511	Energy, Environment and Sustainable Development	C	3	0	0	3
GETY514	Renewable Energy Resources & Systems	C	3	0	0	3
GETY515	Modeling and Simulations	C	3	0	0	3
Soft-Core Courses (Any two to be taken)						
GETY512	Fuel & combustion Technology	S	3	0	0	3
GETY513	Thermal and Electrical Systems	S	3	0	0	3
Practical						
GETY516	Energy Laboratory –I	C	0	0	4	3
Bridge Courses						
GETY517	Fundamentals of Biochemistry	B	3	0	0	0
GETY518	Scientific Writing and Research Methodology	B	3	0	0	0

Total No. of Credits: 18

SEMESTER-II

Course Code	Course Title	Course Type*	L	T	P	C
Core Courses						
GETY522	Wind Energy & Small Hydropower Systems	C	3	0	0	3
GETY523	Solar Photovoltaic Energy Conversion	C	3	0	0	3
GETY525	Processing of Green Energy Materials	C	3	0	0	3
Soft-core courses (Any two to be taken)						
GETY521	Solar Thermal Energy Conversion	S	3	0	0	3
GETY524	Waste to Energy Conversion	S	3	0	0	3
GETY526	Green Management	S	3	0	0	3
GETY527	Environmental Risk Management	S	3	0	0	3
Practical						
GETY528	Energy Laboratory –II	C	0	0	4	3

Total No. of Credits: 18

SEMESTER-III

Course Code	Course Title	Course Type*	L	T	P	C
Core Courses						
GETY616	Bio Energy and Conversion systems	C	3	0	0	3
GETY618	Solar Photovoltaic Systems & Technology	C	3	0	0	3
Soft-core courses (Any two to be taken)						
GETY611	Green Chemistry	S	3	0	0	3
GETY612	Green Nanotechnology	S	3	0	0	3
GETY613	Green Concepts in Buildings	S	3	0	0	3
GETY614	Carbon Sequestration at Landscape Level	S	3	0	0	3
GETY615	Green Energy and Economics	S	3	0	0	3
GETY617	Smart materials: Application of nanomaterial for batteries, solar and fuel cells	S	3	0	0	3
GETY633	Nanotechnology for Energy Systems	S	3	0	0	3
GETY634	Industrial Management & Etrepreneurship	S	3	0	0	3
Practical						
GETY 631	Mini-Project: Proposal Writing and Defence	C	1	0	2	3
GETY619	Energy Laboratory – III (Virtual Instrumentation and case study on Sustainable Energy Systems)	C	0	0	4	3

Total No. of Credits: 18

SEMESTER-IV

GET 620 Green Technology Dissertations:
(Core Course)

Course Code	Course Title	Course Type*	C
GETY620	Green Energy Technology Dissertation		
	Dissertation	C	15
	Viva-voce		3

Total No. of Credits: 18

*** C – Core Course; S - Soft-core Course; B – Bridge Course.**

FIRST YEAR, FIRST SEMESTER COURSES

1. Energy, Environment and Sustainable Development:
   This paper exposes students to the renewable and non-renewable sources of energies and its effects on the environment. It teaches the uses of clean energy technologies and its importance in sustainable development.

2. Fuel & Combustion Technology:
   Objective of this course is to impart knowledge on the industrialization of technology, in particular, green energy technology. It is expected that M.Tech students will appreciate the existing market potential and opportunities in the technology business

3. Thermal and Electrical Systems:
   Introduces the concepts of heat, thermodynamics and electrical engineering that is fundamental to grasp the technology of generation and conversion of energies in various forms.

4. Renewable Energy Resources & Systems:
   The course is designed to give overview of different sources of renewable energies. It lays emphasis on basic understanding of energy sciences, its importance, utility and conversion into various forms.

5. Modeling and Simulation:
   The course aims to provide a good practical knowledge about the scientific programming for modeling devices and systems. Graphical programming, interfacing of devices, modeling of green energy devices and systems are discussed in detail.

6. Energy Laboratory – I
   Laboratory training is aimed at imparting the concepts of energy conversion, energy utlization methodology, characterization and application. Student will acquire hand on training in the use of various characterization/ energy conversion & utilization devices.

7. Fundamentals of Biochemistry:
   The course develops necessary understanding on the biochemistry of energy materials. It is specifically designed to empower non-biology background students with necessary knowledge and very important concepts of biochemistry. Student will acquire understanding at the molecule level as well as at the bulk material level.

8. Scientific Writing & Research Methodology:
   It is a structured instructional training of students on how to go about acquiring necessary skills in research article writing, learning basic principles of research methodology and ethical issues in the practice of science and publication of scientific material.

L	T	P	C	CH
3	0	0	3	45

GETY 511: **Energy, Environment and Sustainable Development**
(Core Course)

Unit I **[8]**

Energy sources: Introduction to nexus between Energy, Environment and Sustainable Development; Energy transformation from source to services; Energy sources, sun as the source of energy; biological processes; photosynthesis; food chains, classification of energy sources, quality and concentration of energy sources; fossil fuel reserves - estimates, duration; theory of renewability, renewable resources; overview of global/ India's energy scenario.

Unit II **[8]**

Ecological principles: Ecological principles, concept of ecosystems, ecosystem theories, energy resources and their inter-linkages, energy flow, the impacts of human activities on energy flow in major man-made ecosystems- agricultural, industrial and urban ecosystems.

Unit III **[9]**

Energy Systems and Environment: Environmental effects of energy extraction, conversion and use; sources of pollution from energy technologies (both renewable and non renewable); primary and secondary pollutants; consequence of pollution and population growth; air, water, soil, thermal, noise pollution -cause and effect; pollution control methods, sources and impacts; environmental laws on pollution control. Kyoto Protocol; Conference of Parties (COP); Clean Development Mechanism (CDM); Reducing Emissions from Deforestation and Degradation (REDD).

Unit IV **[10]**

Green innovation & sustainability: Criteria for choosing appropriate green energy technologies, life cycle cost; the emerging trends – process/product innovation-, technological/ environmental leap-frogging; Eco/green technologies for addressing the problems of Water, Energy, Health, Agriculture and Biodiversity- WEHAB (eco-restoration/ phyto-remediation, ecological sanitation, renewable energy technologies, industrial ecology, agro ecology and other appropriate green technologies); design for sustainability (D4S).

Unit V **[10]**

Green Energy and sustainable development: The inseparable linkages of life supporting systems, biodiversity and ecosystem services and their implications for sustainable development; global warming; greenhouse gas emissions, impacts, mitigation and adaptation ; future energy Systems- clean/green energy technologies; International agreements/conventions on energy and sustainability - United Nations Framework Convention on Climate Change (UNFCC); sustainable development;

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] E H Thorndike, Energy & Environment: A Primer for Scientists and Engineers, Addison-Wesley Publishing Company
[5] R Wilson & W J Jones, Energy, Ecology and the Environment, Academic Press Inc.
[6] 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.
[14] http://unfccc.int/
[15] http://cdm.unfccc.int/

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3	0	0	3	45

GETY 512: **Fuel & Combustion Technology**
(Soft-core Course)

Unit I [9]

Solid Fuels: 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

Unit II [9]

Liquid and Gaseous Fuels: 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.

Unit III [7]

Theory of Combustion Process: Ignition: Concept, auto ignition, ignition temperature; Burners: Stoichiometry and thermodynamics; Combustion stoichiometry: Methods of combustion - Combustion thermodynamics.

Unit IV [9]

Fuel stoichiometry and analysis: Fuel 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).

Unit V [11]

Burner Design and Furnaces: Fluidized bed combustion process; 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, Pergamon Press.

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3	0	0	3	45

GETY 513: **Thermal and Electrical Systems**
(Soft Core Course)

Unit I [12]

Thermodynamic systems and Cycles: First and second laws of thermodynamics and their applications – Thermodynamic processes - Irreversibility of energy – Entropy. Properties of steam and classification of steam engines. Carnot cycle - Rankine cycle. Reciprocating engines - Otto Cycle - Diesel Cycle - Stirling Cycle. Refrigeration systems - Vapour-Compression refrigeration cycle - Ammonia absorption refrigeration cycle - Air-standard refrigeration cycle. Non-reacting gas mixture - Mixture of air and water vapour – Psychrometric chart – Air-conditioning applications - Heating and cooling - Cooling with dehumidification - Heating with humidification - Adiabatic mixing.

Unit II [8]

Conductive and Radiative heat transfer: Steady state conduction in one and two dimension-thermal resistance - critical radius. Unsteady state conduction - Heat conduction with and without heat generation - heat conduction in extended surfaces - solution to 2D heat conduction equation - numerical methods and finite difference method. Heat exchange by radiation - shape factor - radiant heat exchange in different geometries.

Unit III [5]

Convective Heat Transfer: Fluid flow: Navier-Strokes equations - Laminar and turbulent flow - boundary layer concept - solution to boundary layer problem. Heat transfer by convection - Heat transfer in laminar and turbulent flow systems - heat flow across a cylinder. Heat exchangers. Boiling and Condensations: Types of boiling - Film and drop condensation - Condensation on vertical plate and horizontal tubes.

Unit IV [10]

Electrical Machines: Electromechanical energy conversion. D.C. generators - Types of windings – Series – Shunt –Compound. E.m.f. equation - Power losses & efficiency. Armature reaction – Commutation - parallelising and load sharing. D.C.Motors: Back e.m.f. - Voltage equation – Torque generation - Shaft torque - Armature torque. Induction motors: Principle and construction – production of rotating field – Slip – Torque.

Unit V [10]

Transformers and Alternators: Transformer classifications - E.m.f. equation - Transformer losses & load characteristics. Transformer tests. Alternators: 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. Introduction to Power Transmission and Distribution

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] Claus Borgnakke and Richard E. Sonntag, Fundamentals of Thermodynamics, Wiley India Pvt. Ltd., Seventh Edition, 2009.
[7] William Z. Black and James G. Hartley, Thermodynamics, Third Edition, Dorling Kindersley India Pvt. Ltd. 2010.
[8] A. L. Prasuhn, Fundamentals of Fluid Mechanics, Prentice Hall, 1980
[9] S. P. Sukhatme, A Text book on Heat Transfer, Orient Longman, 1979.
[10] N. Balbanian, T. A. Bickart, Electrical network theory, John Wiley, New York, 1969
[11] B. L. Theraja, A. K. Theraja, A Text-book of Electrical Technology, New Delhi, 1988
[12] J. P. Holman and P. R. S. White, Heat Transfer , 7th ed. McGraw-Hill, London, 1992
[13] Blokh A G, Heat Transfer in Steam Boiler Furnace, Hemisphere Pub. Corp.
[14] Carl Schields, Boilers - Type, Characteristics and Functions, McGraw Hill Publishers

L	T	P	C	CH
3	0	0	3	45

GETY 514: **Renewable Energy Resources & Systems**
(Core Course)

Unit I [6]

Introduction: 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 II [18]

Solar Energy: Solar radiation: 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 III [8]

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

Unit IV [5]

Ocean Energy: 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 V [8]

Other Sources: 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] D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.
[2] C. S. Solanki, "Solar Photovoltaics: Fundamental Applications and Technologies, Prentice Hall of India, 2009.
[3] L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
[4] D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.
[5] S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill (1984).

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GETY 515: **Modeling and Simulation**

(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: [9]

Introduction to mathematical modeling: - Good programming, debugging and testing, Numerical integration –Differentiation, Elementary computer graphics, monster curves, box counting. Computing strategy, propagator method.

Unit 2: [9]

Fundamentals of Programming: Introduction to computational softwares: Programming in computational software(with the help of a specific software e.g. MatLab, Mathematica, Femlab etc)- 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: [9]

Graphical Programming: Starting graphical programming (with the help of any one of graphical programming software, e.g.: Simulink, Femlab etc) t. Model Files, Basic Elements-: blocks and lines.-Running Simulation-Building Systems- Block Libraries.: Sources, Sinks, Discrete, Linear. Nonlinear, Connections- - Interaction With other programmes (e.g.: Simulink with MatLab)- Defining Block Parameters Using Matlab, Variables-Exchanging Signals With other programmes Extracting Models (e.g. :Simulink into MatLab)

Unit 4: [8]

Lab exercises to develop simple Scripts and models related to building energy systems involving applications of thermodynamics, economics, heat transfer, fluid flow and optimization

Unit 5: [10]

Course project, Modeling of solar cells, Modeling of PV Solar Array: Modeling of PEM Fuel Cell. Modeling Biodegradation Kinetics, Modeling of Wind Turbine/generator:

References:

[1] Modeling 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.

[7] A first course in computational Physics, second edition, P.L DeVries, J.E. Hasbun , ISBN-978-93-80108-94-0

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1	0	4	3	45

GETY 516: **Energy Laboratory – I**
(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, Building duelling solar cells
2. Radiometry: Luxmeter circuit designing, Pyranometer circuit designing
3. 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.
4. Fuels: Density, Viscosity, Flash-point, Fire-point Pour-point, ASTM distillation of liquid fuels.
5. Proximate and ultimate analysis, calorific value of solid fuels.
6. Storage: Programmable batteries

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.
[6]Experiments with renewable energy-sudents guide- ISBN 1-928982-22-0
[7]African journal of Biotechnology,vol 9(12), pp 1719 (2010)

L	T	P	C	CH
3	0	0	0	45

GETY 517 **Fundamentals of Biochemistry**
(Bridge Course)

Unit I [4]

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 II [10]

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 & Haemoglobin, Test for Proteins.

Unit III [12]

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 IV **[9]**

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 V **[10]**

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.

[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.

L	T	P	C	CH
3	0	0	0	45

GETY 518: **Scientific Writing and Research Methodology**
(Bridge Course)

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.

FIRST YEAR, SECOND SEMESTER COURSES

1. Solar Thermal Energy Conversion:
   The course aims to provide understanding of the solar thermal energy conversion processes, storage and the utilization of solar thermal energy. Student will acquire knowledge on the various types of collectors, concentrators, thermal power plants design and thermal energy storage concepts.

2. Wind Energy & Small Hydropower Systems:
   Student will get the understanding on the source of energy in the wind, its characterization and various methods of harnessing the same. Detail theoretical understanding on design and characterization of wind energy conversion system is emphasized. In the other part of the course, fundamentals of energy generation from hydro power and small hydro power plant concepts are discussed. Students will also get exposure in terms of case studies on wind and hydrothermal power plant.

3. Solar Photovoltaic Energy Conversion:
   The principle, material and device technology of photovoltaic devices will be taught along with characterization and its assembly for applications.

4. Waste to Energy Conversion:
   The waste to energy conversion is one of the most important solutions for integrated waste management. The course deals in detail with waste management techniques and various conversion technologies to generate energy from waste.

5. Processing of Green Energy Materials:
   Processing of Energy and Materials involves in developing sustainable materials for application in various renewable energy technologies in clean energy production.

6. Green Management:
   In this course issues related to green and sustainable development practices in management are taught. Emphasis is made on corporate responsibilities towards sustainable development. It also exposes the need for management practices to ‘go green’ that can tap existing and futuristic business potentials.

7. Environmental Risk Management:
   Various issues relating to environmental risk management and its mitigation are taught.

8. Energy Laboratory – II
   Laboratory training is intended to familiarize students with types of energy conversion, generation and utilization devices, and their characterization. Emphasis is on clean energy generation and utilization in various forms.

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GETY 521 **Solar Thermal Energy Conversion**
(Soft-Core Course)

Unit I [6]

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.

UNIT II [11]

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. Performances of solar collectors, Concentrating Collector Designs

UNIT III [10]

Classification & design: 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.

UNIT IV [8]

Solar Thermal Energy Storage : Sensible storage; Latent heat storage; Thermo-chemical storage.

Simulation & Modeling: 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;

UNIT V [10]

Industrial Processes & Systems

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 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.

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GETY 522**: Wind Energy & Small Hydropower Systems**
(Core Course)

Unit I [9]

Wind Resource: Wind characteristics: Meteorology of wind – wind speed distribution across the world – spatial and temporal factors – Eolian features - Biological indicators. Wind measurement: Anemometers – balloon trackers. Wind energy conversion systems (WECS) - classifications.

Unit II [8]

Wind Energy Conversion: Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and Strip theory; Maximum power coefficient; Prandlt's tip loss correction; Rotor design and characteristics; Power, torque and speed characteristics – Wind turbine performance measurement – Loading analysis.

Unit III [8]

WECSdesign considerations: Design of WECS components – Stall, pitch & yaw control mechanisms – Brake control mechanisms; Theoretical simulation of wind turbine characteristics; Test methods.

Unit IV [8]

Wind Energy Application: Wind pumps: Performance analysis, design concept and testing; Principle of Wind Energy Generators; Stand alone, grid connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India; Case studies.

Unit V [12]

Small Hydropower Systems: 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.

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GETY 523: **Solar Photovoltaic Energy Conversion**
(Core Course)

Unit-I [8]

Properties of Semiconductor: Semiconductors: Crystals structures, atomic bonding, energy band diagram – direct & indirect band gap- p & n doping and carrier concentration - Hall effect in semiconductors – Intrinsic & extrinsic semiconductor - compound semiconductors - diffusion and drift of carriers, continuity equation – optical absorption – carrier recombination -Effect of temperature.

Unit-II [9]

Semiconductors for Solar Cell: Silicon: preparation of metallurgical, electronic and solar grade Silicon - Production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) method – imperfections – carrier doping and lifetime - Germanium - compound semiconductors: growth & characterization - amorphous materials – Transparent conducting oxides-Anti-reflection principles and coatings – organic materials

Unit-III [10]

Device fabrication: Semiconductor junctions: Schottky barriers, MIS, P-N junction, p-i-n junction and its properties Homo & hetero junction solar cells, multijunction solar cells-Fabrication techniques: Diffusion, thin film technology- physical vapour deposition (PVD)- Electro-deposition- Molecular beam epitaxy (MBE)- Metal organic chemical vapour deposition (MOCVD)- Plasma enhanced chemical vapour deposition (PECVD)- Organic and Nano tech solar cells – contact & grid metalization

Unit-IV [10]

Characterization and analysis: Device isolation & analysis - Ideal cell under illumination-solar cell parameters short circuit current, open circuit voltage, fill factor, efficiency; optical losses; electrical losses, surface recombination velocity, quantum efficiency - measurements of solar cell parameters; I-V curve & L-I-V characteristics, internal Quantum yield measurements – Effects of series and parallel resistance and Temperature - Loss analysis.

Unit: V Solar cell module materials and assembly [8]

PV modules: Module and Circuit Design - Identical and Non-identical Cells - Module Structuring and assembly - Environmental Protection - Thermal Considerations - Electrical Considerations and output conditioning - assembly materials – interconnects – crystalline and thin film modules - issues with solar PV modules, bypass diode and blocking diode – module testing and analysis.

References:

1. Seminconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
2. Fundamentals of Solar Cells: PV Solar Energy Conversion, Alan L Fahrenbruch and Richard H Bube , Academic Press, New York , 1983
3. Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997.
4. Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York, 1995.
5. J. Nelson, The physics of solar cells, Imperial College Press, 2006.
6. Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998

7. Practical Photovoltaics: Electricity from Solar Cells, by Richard Komp, ISBN:9780937948118, Publisher:Aatec Publications, Publication Date:February 2002.
8. Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, ISBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.
9. Solar Cell Array Design Handbook, H S Rauschenbach, Van Nostrand Reinfold, 1997.

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GETY 524: **Waste to Energy Conversion**
(Soft-core course)

UNIT-1 **[9]**

Introduction to Waste & Waste processing: Definitions, sources, types and composition of various types of wastes; Characterisation of Municipal Solid Waste (MSW) , Industrial waste and Biomedical Waste (BMW), waste collection and transportation; waste processing-size reduction, separation; waste management hierarchy, waste minimization and recycling of MSW; Life Cycle Analysis (LCA), Material Recovery Facilities (MRF), recycling processes of solid waste;

UNIT-2 **[9]**

Waste Treatment and disposal: Aerobic composting, incineration, different type of incineration; medical and pharmaceutical waste incinerations- land fill classification, types, methods and sitting consideration, layout and preliminary design of landfills: composition, characteristics, generation, movement and control of landfill leachate and gases, environmental monitoring system for land fill gases

UNIT-3 **[9]**

Energy from waste-thermo chemical conversion: Sources of energy generation, incineration, pyrolysis, gasification of waste using gasifiers, briquetting, utilization and advantages of briquetting,- environmental and health impacts of incineration; strategies for reducing environmental impacts.

UNIT-4 **[9]**

Energy from waste- Bio-chemical Conversion: Anaerobic digestion of sewage and municipal wastes, direct combustion of MSW-refuse derived solid fuel, industrial waste, agro residues, anaerobic digestion-biogas production, land fill gas generation and utilization, present status of technologies for conversion of waste into energy, design of waste to energy plants for cities, small townships and villages.

UNIT-5 **[9]**

Environmental and health impacts-case studies: Environmental and health impacts of waste to energy conversion, case studies of commercial waste to energy plants, waste to energy- potentials and constraints in India, eco-technological alternatives for waste to energy conversions - Rules related to the handling, treatment and disposal of MSW and BMW in India.

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] Robert Green, From Waste to Energy, Cherry Lake Pub. ISBN: 1602795096, 2009.
[10] G. Evans, Biowaste and Biological Waste Treatment, 2005
[11]. Biogas from waste and renewable resources, by Dieter D. And Angelika S. Wiley-Vch Publication 2010.

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GETY 525: **Processing of Green Energy Materials**

(Core Course)

Unit-1 **[9]**

Silicon processing methods: Dry and wet chemical processes used to develop new materials and micro-engineered products. Principles for electrochemical power sources, photovoltaic and their relevance in current energy industry.

Unit-2 **[10]**

Fabrications: Gas-solid and liquid-solid reactions-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 **[9]**

Newer Energy Materials: Carbon nano-tubes (CNTs) and multiwall carbon nanotubes (MWCNTs) -methods of production, properties and its utility in energy devices. Polymers and composites -classification, methods of production, properties, fabrication methods, and its utility in making energy devices.

Unit-4 **[10]**

Sustainable energy: Dye-sensitized solar cells (DSSCs), polymer solar cells, hybrid polymer solar cells, polymer based light emitting diodes, fuel cell-proton exchange membranes – operating principles, fabrication/assembling, testing methods and its specific application.

Unit-5 **[7]**

Recent advances in new energy 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 Publishing, 2001.
[7] J Fiksel, Design for Environment, Mcgraw Hill, 1996.
[8] Ed K. Mulder, Sustainable Development for Engineering, Greenleaf Publishing, 2006.
[9] V. R. Gowarikar, N.S. Viswanathan, J. Sreedhar, Polymer science, sixth reprint 1993.
[10] G.S. Misra, Introductory Polymer Chemistry, 1993
[11] W. Billmeyer, Textbook of Polymer Chemistry, F1984.
[12]Charles E. Carraher, Introductory Polymer Chemistry, CRC press, 2010.
[13] F.L. Mathews F.L. Chapman and Hall, Composite materials: Engineering and science, 1994
[14] M.M. Schwartz, Composite Material Hand Book, Mcgrow Hill Book Co., 1984.
[15]Frederick C. Krebs, Polymer photovoltaics- A practical approach, SPIE Press, 2008.
[16] E. Chiellini, H. Gil, G. Braunegg, J. Buchert, P. Gatenholm, M. Van-der Zee, Bio-related polymers, sustainable polymer science and technology, 2001.
[17] M. Graziani and P. Fornasiero, Renewable resources and renewable energy- A global challenge, CRC-Taylor and Francis, 2007.

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GETY 526: **Green management**
(Soft-core course)

Unit I [9]
The concept of green management; evolution; nature, scope, importance and types; developing a theory; green management in India; relevance in twenty first century

Unit II [9]
Organizational environment; internal and external environment; Indian corporate structure and environment; how to go green; spreading the concept in organization; Environmental and sustainability issues for the production of high-tech components and materials, life cycle analysis of materials, sustainable production and its role in corporate social responsibility (CSR) and corporate environmental responsibility (CER).

Unit III [9]
Approaches from ecological economics; indicators of sustainability; ecosystem services and their sustainable use; bio-diversity; Indian perspective; alternate theories

Unit IV [9]
Environmental reporting and ISO 14001; climate change business and ISO 14064; green financing; financial initiative by UNEP; green energy management; green product management

Unit V [9]
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

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GETY 527: **Environmental Risk Management**
(Soft-core course)

Nature of environmental risks, risk management with integration, environmental Law and Management, Environmental Epidemiology, Environmental auditing, Environmental Modeling 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 management. 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.

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GETY 528: **Energy Laboratory – II**
(Core Course)

List of Experiments

1. Study of Energy systems: Conventional & Non-conventional.
2. Solar cell L-I-V curve and performance analysis
3. PV module design and output analysis
4. PV module: L-I-V characteristics
5. Fuel Cell operation and electrical power generation
6. Performance analysis of an Electrical Inverter
7. Power generator; Measurement of power factor and load characteristics
8. Air conditioning performance test
9. Refrigeration performance test & COP measurement
10. Wind Tunnel: Pressure distribution analysis
11. Solar insulation measurement using Optical pyranometer
12. Step-up and step-down Transformer Characteristics

SECOND YEAR THIRD SEMESTER COURSES

1. Green chemistry:
   Green chemistry teaches 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 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 nanomaterial for alternative energy and green technologies.

3. Green Concepts in Buildings:
   Green building encompasses bringing the eco friendly and energy conserving concepts in everything from the choice of building materials to where a building is located.

4. Carbon sequestration at landscape level:
   Global policy issues on carbon sequestration and trading, mechanism of its assessment and monitoring, and carbon landscaping for conservation and sustainable utilization for energy application.

5. Green Energy and Economics:
   Issues related to economy of sustainable development and green energy management are specifically addressed.

6. Bio-energy Conversion Systems:
   Bioenergy plays a vital role in balancing greenhouse gases in the atmosphere. Bio-energy and conversion systems deal with energy production and conversion through thermochemical, biological and chemical processes from biomass.

7. Smart Materials: Application of Nanotechnology for Batteries, Solar & Fuel cells

8. Solar Photovoltaic Systems & Technology:
   The course gives the concepts, development, installation and maintenance of SPV power systems. Student will acquire knowledge on power systems design, installation including economic aspects SPV power systems and their cost analysis techniques.

9. Nanotechnology for Energy Systems:
   The course introduces the concepts of nanotechnology, design and production of various nanomaterials, specifically for alternate and renewable energy application, their characterization. Students will develop skills in the utilization of newer ideas of nanotechnology to green energy.

10. Industrial Management & Entrepreneurship:

11. Mini-Project: Proposal Writing and Defence:

    The project work is to acquaint the student in the selection of research problem, its analysis, relevant literature survey and its resolution.

12. Energy Laboratory – III

    Virtual instrumentation constitute major part of teaching and research training in the programme. Various topics of curriculum requiring strengthening of class room learning and problems where hands on training could not imparted due to various practicality issues, will be addressed through virtual instrumentation based teaching methods. The course consists of detail teaching of virtual instrumentation method and practice followed by case studies in different fields of green energy technology.

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GETY 611: **Green Chemistry**
(Soft-core Course)
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 I [6]
Introduction to Organic Chemistry /Analytical Chemistry /Basic Chemical Engineering

Unit II [8]
Introduction to Green Chemistry: 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 III [8]
Introduction to Pharmaceutical Process Chemistry: Introduction to process chemistry, the difference between synthesis and process, Rote design, Route optimization, DOE,

Unit IV [8]
Role of Analytical Chemistry in Process Chemistry Role of Process Safety in Process Chemistry: TH classification, MSDS, Thermal Hazards, Waste segregation and disposal.

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

Practical chemistry (Mini project): [12]

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)

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GETY 612: **Green nanotechnology**
(Soft-core Course)

Unit I [9]

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

Unit II [9]

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

Unit III [15]

Nanomaterials for Alternative Energy: 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 Photovoltaic. Semiconductor Nanocrystals and Quantum Dots for Solar Energy Applications Nanoparticles for Conducting Heat Transfer

Unit IV [6]

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

Unit V [6]

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.

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GETY 613: **Green Concepts in Buildings**
(Soft-core Course)
(Pre-requisite - Undergraduate degree in civil engineering)

Unit I
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 II
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 III
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 IV
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 V
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.

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GETY 614: **Carbon sequestration at landscape level**
(Soft-core Course)

Unit I [6]

Climate change and International agreements: 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 II [12]

Primary productivity - Mechanisms & Assessment : 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 III [11]

Biogeochemistry: 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 IV [12]

Remote sensing and spatial analysis : 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 V [4]

Biomass as a major source of energy in India: 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/

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GETY 615: **Green Energy and Economics**
(Soft-core course)

Unit I

Principles of Economics: Scarcity, opportunity cost, Efficiency - Resource allocation through market mechanism - Market failure and role of state

Unit II

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 III

Economics of Non-renewable 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 IV

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

Unit V

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.

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GETY 616: **Bio-energy and Conversion Systems**
(Core Course)

Unit I [8]
Biomass: Biomass resources; classification and characteristics; Techniques for biomass assessment; Application of remote sensing in forest assessment; Biomass estimation.

Unit II [8]
Thermochemical Conversion: Different processes, direct combustion, incineration, pyrolysis, gasification and liquefaction; economics of thermochemical conversion.

Unit III [10]
Biological Conversion: Biodegradation and biodegradability of substrate; biochemistry and process parameters of biomethanation; chemical kinetics and mathematical modeling of biomethanation process, biogas digester types; digester design and biogas utilisation; 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.

Unit IV [9]
Chemical Conversion: Hydrolysis & hydrogenation; solvent extraction of hydrocarbons; solvolysis of wood; biocrude; biodiesel production via chemical process; catalytic distillation; transesterification methods; Fischer-Tropsch diesel: chemicals from biomass.

Unit V [10]
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 co-firing of biomass with coal. Biomass productivity: Energy plantation and power programme. Economical impacts; food security and environmental impacts of biomass conversion to energy- energy from waste.

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

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GETY 617: **Smart Materials: Application of Nanotechnology for Batteries, Solar & Fuel cells**
(Core Course)

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

Unit II
Smart Batteries: Nanomaterials for anodes; Nanomaterials for cathodes; Battery performance and cyclability; Nanomaterials synthesis

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

Unit IV
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.

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GETY 618: **Solar Photovoltaic Systems & Technology**
(Core Course)

Unit 1: Solar PV module [**12**]
Solar PV modules – selection criteria – Testing and evaluation – module interconnects – array design and assembly – array characteristics and output conditioning – DC-DC converters and maximum power point tracking (MPPT).

Unit 2: SPV systems & components **[9]**
Introduction to PV systems - system components: module and array – Charge controllers – inverters – Batteries – power conditioning and Regulation – Mechanical assemblies – Balance of System Components

Unit 3: SPV power systems **[10]**
Types of SPV power systems: MW general power systems – Grid connected power systems – Remote area power systems – Specific purpose Photovoltaic systems: Space – Marine – Telecommunication – water pumping – refrigeration etc.

Unit 4: Power system design and installation **[8]**
Power considerations and system design – Array integration: mechanical integration – electrical integration – utility integration – Inspection and commissioning - Distributed power generation & smart Grids - Hybrid systems.

Unit 5: Economics **[6]**
SPV power system maintenance: cleaning, shadowing, stability etc., and troubleshooting – Economics

Text books:

1. 1 Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, ISBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.
2. Photovoltaic Systems, 2nd Edition, by James P. Dunlop, ISBN:9780826913081, Publisher:American Technical Publishers, Inc. 2010
3. Photovoltaics: Design and Installation Manual, by Solar Energy International, ISBN: 9780865715202, Publisher: New Society Publishers, (2004).
4. Ben G. Streetman, Solid State electronic devices, , , Prentice-Hall of India Pvt. Ltd., New delhi 1995.
5. M. D. Archer, Clean electricity from photovoltaics, R. Hill, Imperial College Press, 2001.
6. Photovoltaic Systems Engineering, Roger Messenger and Jerry Vnetre, CRC Press, 2003.
7. C.L.Wadhwa, Generation Distribution and utilization of Electrical Energy, Wiley Eastern Ltd., India(1989)
8. Roger C.Dugan , Mark .F. Mc Granaghan, Surya Santaso, H.Wayne Beaty, "Electrical Power Systems Quality", Second Edition, Mc Graw Hill, 2002.

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GETY633: **Nanotechnology for Energy Systems**
(Soft-core Course)

Unit I **[**9]

Nanomaterials: Nanostructured materials: zero dimensional, one-dimensional and two dimensional nanostructures- clusters of metals and semiconductors, nanowires, nanostructured beams, and nanocomposites - artificial atomic clusters – quantum size effects – Electronic Structure of Nanoparticles- size dependent optical absorption and electron transport properties – porous materials – ionic materials - membranes – catalysts.

Unit II **[**9]

Nanomaterials for Energy conversion: Challenges in energy conversion – role of nanostructures & materials – nanomaterials in solar Photovoltaic Technology: Band gap engineering & optical engineering - Tandem structures - quantum well and quantum dot solar cells - photo-thermal cells – Organic solar cells.

Unit III **[**9]

Nanomaterials for Hydrogen production & storage: Introduction to Hydrogen engine – Hydrogen production methods – Nanomaterials for hydrogen purification & storage – Hydrogen Sponge - volumetric and gravimetric storage capacities –automotive applications

Unit IV [9]

Fuel cell Technology: Fuel cell Principles – types of fuel cells (Proton exchange, Alkaline Electrolyte, Phosphoric acid, Molten Carbonate, solid oxide and direct methanol fuel cells)- Principle and operation of Proton Exchange Membrane fuel cell- Materials and fabrication methods for fuel cell technology- micro fuel cell power sources

Unit V [9]

Energy Efficient Nanodevices: Energy efficient devices –fabrication and applications of LED as light device – OLED – Semiconductor laser – single electron & single photon devices – energy efficient electronic switches & devices – MEMS & NEMS and their energy efficiency – Nanorobotics.

[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.

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GETY634 : **Industrial Management & Entrepreneurship**
(Soft-core Course)

Unit I [9]

Product Design: Concept generation- Product Architecture- Industrial Design Process- Management of Industrial design Process and assessing the quality of Industrial Design - Establishing the product specification

Unit II [9]

Product Development: Criteria for selection of product- Product development process- Design for Manufacture - Estimate the manufacturing cost- Reduce the support cost- Prototyping- Economics of Product development projects - Elements of Economic analysis- financial models - Sensitive analysis and influence of the quantitative factors.

Unit III [9]

Management Techniques: Technology Management - Scientific Management - Development of management. Thought-Principles of Management- Functions of management-planning- organization-Directing, Staffing and Controlling- Management by objective- SWOT analysis-Enterprise Resource planning and supply chain management.

Unit IV [9]

Entrepreneurial Competence and Environment: Concept of Entrepreneurship- Entrepreneurship as a career- Personality Characteristic a successful Entrepreneur- Knowledge and skill required for an Entrepreneur- Business environment- Entrepreneurship Development Training - Centre and State government policies and Regulations - International Business.

Unit V [9]

Management of Small Business: Pre feasibility study - Ownership - budgeting - project profile preparation - Feasibility Report preparation - Evaluation Criteria- Market and channel selection- Product launching - Monitoring and Evaluation of Business- Effective Management of Small business, intellectual property right (IPR) : national and international.

References:

1. Karal, T.Ulrich Steven, D.Eppinger, "*Product Design and Development*", McGraw- Hill International, editions, 2003.
2. S.Rosenthal, "*Effective Product Design and Development*", Irwin, 1992.
3. H.Koontz and H.Weihrich, "*Essentials of management*", McGraw Hill Publishing company, Singapore international edition, 1980.
4. J.J.Massie, "*Essentials of Management*" Prentice Hall of India Pvt. Ltd., 1985.
5. Hisrich, "*Entrepreneurship*" Tata Mc Grew Hill, New Delhi, 2001

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GETY 631: **Mini-Project: Proposal Writing and Defence**
(Core Course)

Objective:
It is expected that the student will develop skills in Selection of research theme/problem, scientific approach, defining specific objectives, design of experiment, estimation of budget, estimation of time duration, execution and data collection, analysis and presentation.

Impact:
Student is expected to gain knowledge on the importance of research - research outcome - Contemporary technological approach - demand and supply - profitability, social impact etc.,

Outcome:
In the course, student will plan, and execute a research project in the field of green energy technology thereby learn the issues relating to research practice, formulation of problem, implementation work and also ethical considerations.

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GETY 619 Energy Laboratory – III
(Core Course)

Virtual instrumentation and case studies on Sustainable Energy Systems:
6 hours 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

Virtual Instrumentation basics: Front panel and block diagram- Dataflow programming model Modular Programming: Basics of modular programming with sub-VIs- 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, Gasifiers, 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. Modeling 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.

SECOND YEAR, FOURTH SEMESTER

GET 620 Green Technology Dissertations:
(Core Course)

Research Project and Dissertation specifically designed to give the student practical experience in technologies and principles appropriate to developing a green technology. Students under the supervision of Faculty Advisor, and with the due permission from the Chairperson / Coordinator will undertake a research based project for a duration of one full semester (four months) at Pondicherry University/ associated academic institution/ industrial partner/ any other industry /research organization outside Pondicherry University practicing green energy technologies. A thesis written for this project will be evaluated by an expert followed by viva-voce.

Green Energy Technology Dissertation : Duration – One full semester (four months)

Dissertation **15 Credits**

Viva-voce **3 Credits**

Total No. of Credits: 18

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