PONDICHERRY UNIVERSITY

P.G. DIPLOMA PROGRAM IN GREEN ENERGY TECHNOLOGY
(Regular, One Year Programme)

Granted by University Grants Commission, New Delhi

Under Innovative Programme

BACKGROUND

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 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 consumption, waste and pollution.

Post Graduate Diploma in Green Energy Technology offered at Pondicherry University is designed to equip students with multi-disciplinary skills and knowledge in the areas of green energy generation technologies, energy management with environmental concern. 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 one year duration, comprised of two semesters. First semester comprises hard and soft core theory courses together with laboratory practical to enrich understanding of students in the areas of Green Energy Technologies. Each theory course is designed to have a project component to explore the technical understanding and skill development. Second semester is entirely dedicated for project work and dissertation. The entire course of study requires earning at least 36 credits to qualify for the P.G.Dip. in Green Energy Technology (PGD-GET). B.E/B.Tech in Mechanical, Electrical, Civil, Electronics, Chemical or Biotechnology specialization, or M.Sc in Physics, Chemistry, Material Science, Nanoscience or Photonics with Mathematics at B.Sc level and having at least 55% marks or equivalent grade in the qualifying examination are eligible to undergo this program.

The scope of the proposed PG-Diploma in Green energy Technology is to develop professional with an understanding about the overall energy scenario worldwide, various sources of energy and their merits and demerits, importance of renewable energy sources, various aspects of energy resources including the environmental and ecological impact, Overall understanding about the

solar photovoltaic, solar thermal, bio-energy, wind, ocean, hydro and other new means of energy generation, energy efficiency, utilization, storage and distribution methodologies.

Project work and Dissertation is specifically designed to inculcate professional skills to the student with practical experience in Green Energy technologies. Project work is research based that can be carried out at Pondicherry University or at an associated academic or industrial partner and thus receive practical training in chosen area from an expert. Dissertation will be evaluated as per academic practice followed.

In addition to above, course curriculum and syllabi will be updated time to time based on the developments. Teaching and Learning Methods includes lectures, tutorials and seminars as main methods and in addition course delivery will be 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 P.G.D.GET holder will gain employment in the Engineering Industry with many companies now seeking to exploit the benefits of green energy technology products and processes.

Minimum credit requirement is fixed as 36. 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 bridge 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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P.G. Diploma in Green Energy Technology

COURSE STRUCTURE **

SEMESTER-I

Course Code	Course Title	Course Type*	L	T	P	C
CORE COURSES						
GETD511	Energy, Renewable Energy Resources and Sustainable Development	H	3	0	0	3
GETD512	Thermodynamics, Fuels & Combustion Technology	H	3	0	0	3
GETD513	Solar Photovoltaic Devices & Energy Conversion Systems	H	3	0	0	3
GETD514	Solar Thermal Technology & Energy Conversion Systems	H	3	0	0	3
GETD515	Biological Systems, Resources & Bioenergy Technologies	H	3	0	0	3
SOFT-CORE COURSES# (Any Two to be taken)						
GETD516	Wind Energy Technologies	S	3	0	0	3
GETD517	Biodiesel Feedstock & Production	S	3	0	0	3
GETD518	Battery and Fuel Cell Technologies	S	3	0	0	3
Practical						
GETD510	Energy Laboratory	H	0	0	4	3

Minimum No. of Credits: 21

SEMESTER II

GETD520	Green Energy Technology Dissertation Dissertation Viva-voce	H	 12 3			15

No. of Credits: 15

***H – Hard-core Course; S - Soft-core Course**

Relevant soft core courses offered to MTech (Green energy technology) in III Semester may also be taken (list given in Annexure I).

**to be approved.

PROFILE OF THE COURSES

1. **Renewable Energy Resources & Sustainable Development:**
   This course exposes students the energy scenario, overview about the various sources of energy, difference between renewable and non-renewable energy sources and its impacts on the environment. It teaches the uses of clean energy technologies and its importance in sustainable development.

2. **Thermodynamics, Fuel & Combustion Technology:**
   Objective of this course is to lay foundation on science of energy conversion, study of fuel materials for harnessing energy.

3. **Energy Laboratory:**
   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.

4. **Solar Photovoltaic Devices & Energy Conversion Systems**
   The principle, material and device technology of photovoltaic devices, characterization techniques, SPV power system components, design and installation will be taught along.

5. **Solar Thermal Technology & Energy Conversion Systems:**
   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.

6. **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 with particular reference to electrical machines & turbines 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.

7. **Bioenergy, Biodiesel Resource Development & Production**
   Bio-energy and conversion systems deal with biomass resource estimation and management, various energy conversion technologies and methods to generate energy from waste. Biodiesel from plants and algae represent renewable bioenergy resource. It has proven potential for large scale production, replacement biofeul and commercial exploitation. This course will cover various aspects of biodiesl resource development, production process and protocols & standards concerning its utilization in conventional energy sectors.

8. **Batteries and Fuel Cell Technologies:** From the basics to technologies on electrochemical energy conversion & storage will be taught which includes various types of batteries, supercapacitors and fuel cells.

9. **Project Work:** One full semester project work in Industrial and renewable energy technology development laboratories leading to dissertation.

L	T	P	C	CH
3	0	0	3	45

GETD 516 Energy, Renewable Energy Resources and Sustainable Development
(Hard Core course)

Unit I

[9]

Introduction: Introduction to nexus between energy, environment and sustainable development; Energy sources, sun as the source of energy; photosynthesis; classification of energy sources, fossil fuel reserves and resources - overview of global/ India's energy scenario.

Unit-II: **[**9**]**

Energy Ecology and Environment: concept and theories of ecosystems, - energy flow in major man-made ecosystems- agricultural, industrial and urban ecosystems - sources of pollution from energy technologies and its impact on atmosphere - air, water, soil, and environment - environmental laws on pollution control – innovation and sustainability: - eco-restoration/ phyto-remediation, renewable energy technologies, industrial ecology, agro ecology and other appropriate green technologies

Unit III [9]

Solar Energy: Solar radiation: measurements and prediction. Indian's solar energy potential and challenges, Solar thermal energy conversions systems: flat plate collectors, solar concentrators and other applications. Solar Photovoltaic: Principle of photovoltaic conversion of solar energy, types of solar cells and fabrication.

Unit IV [9]

Wind Energy: Wind Resource: Meteorology of wind, Indian's wind energy potential and challenges, distribution across the world, Eolian features, Biological indicators. Wind measurement systems: anemometers, wind velocity distributions, wind shear, turbulence, Betz limit and energy potentials. Wind Energy Conversion Systems: Classifications and applications.

Unit V [9]

Bioenergy: Biomass as energy resources; India's bio –energy potential and challenges- Classification and estimation of biomass; Source and characteristics of biofuels: Biodiesel, Bioethanol, Biogas. Types of biomass energy conversion systems waste to energy conversions.

Text Books

[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.

References

[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).
[6] 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
[7] 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.
[8] Energy and the Challenge of Sustainability, World Energy assessment, UNDP, N York, 2000.
[9] E H Thorndike, Energy & Environment: A Primer for Scientists and Engineers, Addison-Wesley Publishing Company
[10] R Wilson & W J Jones, Energy, Ecology and the Environment, Academic Press Inc.
[11] D W Davis, Energy: Its Physical Impact on the Environment, John Wiley & Sons
[12] AKN Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997.
[13] Global Energy Perspectives : Edited by Nebojsa Nakicenovic, Arnulf Grubler and Alan McDonald, CambridgeUniversity Press, 1998.
[14] Environment – A Policy Analysis for India, Tata McGraw Hill, 2000.Environmental Considerations in Energy Development, Asian Development Bank, Manila (1991).

GETD 511 Thermodynamics, Fuels & Combustion Technology
(Hard Core course)

Unit – I **[13]**

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]**

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 – III **[8]**

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 – IV **[8]**

Combustion Process: Ignition: Concept, auto ignition, ignition temperature; Burners: Stoichiometry and thermodynamics; Combustion stoichiometry: Methods of combustion - Combustion thermodynamics. Fuel stoichiometry relations and stimation of combustion - Dew point of products; Flue gas analysis (O_2, C_2, CO, NOx, SOx).

Unit – V **[8]**

Burners & Furnaces: Fluidized bed combustion process; Basic features and design of burners for solid, liquid, and gaseous fuels; Furnaces: Industrial furnaces, process furnaces, batch & continuous furnaces; 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.

Text Books

[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.

References

[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.

GETD 512 Solar Photovoltaic Devices & Energy Conversion Systems
(Hard Core Course)

Unit-I Properties of Semiconductor:
Semiconductors: direct & indirect band gap Intrinsic & extrinsic semiconductor- compound semiconductors - p & n doping and carrier concentration - - - diffusion and drift of carriers – optical absorption –temperature - Silicon: purification and crystallation - carrier doping - Germanium - compound semiconductors: InP & GaAs-crystallization and characterization - amorphous materials – Transparent conducting oxides-Anti-reflection principles and coatings – organic materials

Unit-II Device fabrication and Characterization:
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 metallization- characterization techniques: I-V, C-V and L-I-V.

Unit-III Solar cell module materials and assembly
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.

Unit-IV: Solar PV system components & system design
Introduction to PV systems - system components: module and array – Charge controllers – inverters – Batteries – power conditioning and Regulation – Mechanical assemblies – Balance of System Components MW general power systems – Grid connected power systems – Remote area power systems – Specific purpose Photovoltaic systems: Space – Marine – Telecommunication – water pumping – refrigeration etc.

Unit-V Advanced SPV technologies
Solar PV concentrators – Concentrator photovoltaic materials and devices – Hybrid SPV power systems – SPV power plant design tools and methodologies – SPV economics

Text Books

1. Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, ISBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.
2. Fundamentals of Solar Cells: PV Solar Energy Conversion, Alan L Fahrenbruch and Richard H Bube , Academic Press, New York , 1983

References

3. Photovoltaic Systems, 2nd Edition, by James P. Dunlop, ISBN:9780826913081, Publisher:American Technical Publishers, Inc. 2010
4. Photovoltaics: Design and Installation Manual, by Solar Energy International, ISBN: 9780865715202, Publisher: New Society Publishers, (2004).
5. Ben G. Streetman, Solid State electronic devices, , , Prentice-Hall of India Pvt. Ltd., New delhi 1995.
6. M. D. Archer, Clean electricity from photovoltaics, R. Hill, Imperial College Press, 2001.

GETD 513 Solar Thermal Technology & Energy Conversion Systems
(Hard Core Course)

Unit – I: [4]

Solar Radiation: Characteristics of solar radiation - Effect of earth atmosphere; Measurement & estimation on horizontal and tilted surfaces; Analysis of Indian solar radiation data and applications. Instruments for measuring solar radiation.

Unit – II: [12]

Heat Transfer: *Conductive and Radiative Heat Transfer:* Steady state conduction in one and two dimension- 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. *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 – III: [11]

Solar Thermal Energy Device:

Selective Surfaces: Ideal coating characteristics; Types and applications; Anti-reflective coating; Preparation and characterization. Performances of solar collectors. *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. *Concentrating Collector:* 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.

Unit – IV: Solar Cooling System: [8]

Liquid based solar heating system; Natural, forced and gravity flow, mathematical modeling, Vapour absorption refrigeration cycle; Water, ammonia & lithium bromide-water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling. Solar Thermal Energy Storage Systems: Sensible storage; Latent heat storage; Thermo-chemical storage.

Unit - IV: Design of Industrial Solar Systems: [10]

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; 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;

Text Books

[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

References:

[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.

L	T	P	C	CH
3	0	0	3	45

GETD 514: Biological Systems, Resources & Bioenergy Technologies
(Hard Core Course)

Unit I **[9]**

Introduction to Biomolecules:

Classification of amino acids, carbohydrates and nucleotides; Structure and properties of carbohydrate polymers, proteins and nucleic acids; Classification and utility of lipids and fatty acids; Functional roles of biomolecules – energy carriers, enzyme cofactors and biochemical regulation. Biosynthesis and Metabolism.

Unit II **[6]**

Biomass: Biomass resources; classification and characteristics; Techniques for biomass assessment; Application of remote sensing in forest assessment; Biomass estimation; Biomass to biofuel; Source and classification of biofuels and their characteristics.

Unit III **[9]**

Biochemical Conversions:

Biocatalysis by enzymes and pathways - Fermentation and bioprocess engineering – Chemical kinetics – Mathematical modelling of biochemical reactions – Bioreactor designs; Biodegradation and biodegradability of substrate; anaerobic digestion - Bioconversion of lignocellulosic feedstock to sugars - Bioconversion of sugars and starches to fuels - Difference of the technologies of starch ethanol and cellulosic ethanol.

Unit IV **[12]**

Thermochemical & Chemical Conversions:

Thermochemical Conversion: Direct combustion, incineration, pyrolysis, gasification and liquefaction; economics of thermochemical conversion. Biogasification: Biomethanation process, biogas digester types, biogas utilisation; Waste to energy.

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 **[9]**

Biofuels Standards & Power Generation: Physical and chemical characteristics of biofuels – Biomass, wood gas, biomethane; ethanol, biodisel, Wood oil; Bioblends - Indian and International standard specifications. Bioblends; Adaptation of biofuel in various applications – biomass integrated gasification/combined cycles systems - Sustainable co-firing of biomass with coal; Biofuel economy; Case studies.

Text Books

[1] Lehninger's Principles of Biochemistry by David L. Nelson and Michael M. Cox, Macmillan Worth publisher, 2009.
[2] Biochemistry 6th edition by Jeremy M Berg, Lubert Stryer, John L. Tymoczko, 2008.
[3] Voet and Voet's Biochemistry, D. Voet and J. Voet 3rd Edition, John Wiley and Sons Inc., 2005.

References:

[4] Biochemistry, 5th Ed by Eric E Conn, Paul K Stumpf, George Bruening and Roy H Doi, 2009.
[5] Biofuels - Securing the Planet's Future Energy Needs, Edited by A Demirbas Springer 2009.
[6] Biomass Assessment Handbook - Bioenergy for a sustainable environment Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
[7] Dictionary of Renewable Resources - 2nd Edition, Revised and Enlarged, Zoebelein, Hans, Wiley-VCH, 2001.

[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] Anthony San Pietro, Biochemical and Photosynthetic aspects of Energy Production, Academic Press, New York, 1980
[12] Fundamentals of Renewable Energy Processes, Aldo da Rosa, Academic Press September 2005.
[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
[17] Energy Technology and Directions for the Future, John R. Fanchi, Elsevier Science February 2004.

L	T	P	C	CH
1	0	4	3	45

GETD 510 Green Energy Laboratory
(Hard 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	3	45

GETD 515 Wind Energy Technologies
(Soft-core courses)

Unit I [8]
Wind Energy Potential: Wind Velocity Distribution – Estimation of wind resource – Wind Indian and Global scenario

Unit II [12]
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]
WECS design considerations: Design of WECS components – Stall, pitch & yaw control mechanisms – Brake control mechanisms; Theoretical simulation of wind turbine characteristics; Test methods & SCADA.

Unit V [9]
Wind Power Generation & Control: Wind electric generators – Fixed speed induction genrators – Voltage Source Converters – Double fed induction generators – Fully rated convertors. Power quality from wind turbines.

Unit V [8]
Wind Energy Application: Wind forms – Stand-alone and Grid-connected systems - Hyrbid systems.Wind pumps: Performance analysis, design concept and testing; Economics of wind energy utilization; Wind energy in India; Case studies.

Text Books

[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.

References

[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).

L	T	P	C	CH
2	0	0	2	30

GETD 516 Biodiesel: Feedstock Development & Fuel Production
(Soft Core courses)

Unit I 10 hours
Taxonomic variation of algae - sampling, culture and biomass estimation – Algae as bioindicators - phycoremidation. Macroalgae and microalgae – characteristics of microalgae for biofuel application. Algae feedstock for energy conversion - biomass and lipid optimization in algae – stress control and genetic engineering approaches.

Unit – II 7 hours
Characterization of photosystems in microalgae – energy conversion efficiencies - optical characteristics of photoactive proteins in algae – recent development in artificial leaves and biosolar cells – Algal genetics.

Unit – III 8 hours
Cultivation of Algae for biodiesel and high value chemicals: Laboratory culture, Open raceways ponds, closed photobioreactors, design and illumination concepts - continuous culture and biomass recovery – Process engineering.

Unit – IV 8 hours
Chemical synthesis of biodiesel: Liquefaction of algal cells by hexane extraction - catalytic distillation - transesterification - Fischer-Tropsch diesel. Large scale biomass production and lipid yield optimization. Biocrude from algae – biorefinery for fuel production.

Unit – V 12 hours
Conventional fuels versus biofuels – methods of physical characterization of algae biodiesel - ASTM standards for biofuel blends – enhancement of biofuel properties – challenges and limitation in the use of biofuel – socio-economic aspects of algae as alternate fuel – algal fuel technology in Indian scenario and Global trend.

Test Books

1. Algae by Linda E. Graham and Lee W. Wilcox, Printice Hall (2000)
2. Biofuels Engineering Process Technology by Caye M. Drapcho et al. Mc. Graw Hill (2008)
3. Fresh water Algae: Identification and use as bioindicator by Edward Bellinger and David Saigee; Wiley-Blackwell, 2010. ISBN 978-0-470-05814-5

References

4. Hand book of microalgae culture: Biotechnology and Applied Phycology, Edited by Amos Richmond, Blackwell Science, 2004.
   ISBN 0–632–05953–2
5. Algal Culturing Techniques, Edited by R. Andersen, Academic Press 2004.
   ISBN: 9780120884261
6. Algae Biofuel by S K Bhatnagar, Atul Saxena, Stefan Kraan; Studium Press (India) Pvt. Ltd. (2011)
7. Success & Visions for Bioenergy: Thermal processing of biomass for bioenergy, biofuels and bioproducts, Edited by A V Bridgwater, CPL Press September 2007.
8. Anthony San Pietro, Biochemical and Photosynthetic aspects of Energy Production, Academic Press, New York, 1980.
9. National Algal Biofuels Technology Roadmap, US DOE, Office of Energy Efficiency & Renewable Energy, Biomass Program (2010); www.biomass.energy.gov.

GET617: Battery and Fuel Cell Technologies **3 0 0 3 45L**
(Soft Core Course)

Unit I Lead acid Battery [9 h]
Advantages and disadvantages of lead acid batteries, electrochemical reactions, physical and chemical properties of active materials, characteristics and properties of sulphuric acid, constructional features, materials and manufacturing methods, SLI (Automotive) batteries, charge and discharge properties of lead acid batteries, sealed lead acid or maintenance free batteries fabrication technology and testing. Lead acid battery for PV and automotive applications.

Unit II Lithium-ion Battery [9 h]
Advanced anodes and cathodes – theoretical capacity – merits and demetris - Nanomaterials for anodes: carbon nanotubes, graphene, Sn, Al, Si, SnO_2, NiO, TiO_2 & $LiTiO_4$. Nanomaterials for cathodes: $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$, and doped cathodes. Fabrication of nanostructured $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$, Si, Sn and CNTs. Battery fabrication technology and testing, batteries for electric vehicles, hybrid vehicles and solar photovoltaic applications.

Unit III Metal-Air Batteries [9 h]
Lithium-Air, Sodium-Air, Zinc-Air batteries: Principle – components – anodes-cathodes, fabrication - evaluation – merits and demerits and applications.

Unit IV Fuel Cell Technology [9 h]
Membrane electrode assemblies, fabrication, catalyst layer, fuel cell supports, GDL, bipolar plates, fuel cell catalysts – precious and non-precious metal catalysts, bi-functional catalysts – nanomaterials for low temperature fuel cells – reversible fuel cells. Fuel cell stacks and systems - fuel cells for vehicles and grid connected applications.

Unit V Hybrid Energy Systems [9 h]
Concept of hybrid energy systems, development of battery and supercapacitors systems – Batteries and Fuel cells power systems – Recent developments and application areas.

Text Books

1. Subramanian Srinivasan, Fuel Cells from fundamentals to applications, Springer, 2006
2. Modern Batteries Colin A Vincent and Bruno Scrosati, 1997 Pub Arnold ISBN 0-340-66278-6
3. Electric Vehicle Battery Systems Sandeep Dhameja, October 2001, Pub Newnes ISBN 0750699167

References

4. T. R. Crompton, Battery Reference Book, SAE International, 1996.
5. Edition: 2EV/Hybrid Batteries & Battery Material Suppliers: An Automotive Market Review
6. David Linden, Hand Book of Batteries, McGraw-Hill, Inc, New York.
7. Linden D and Thomas B. Reddy, Hand book on batteries and fuel cell", McGraw Hill Book Co., New York, 3rd Edition, 2002.
8. Fuel Cell System Explained James Larminie and Andrew Dicks, 2003, Pub Wiley ISBN:0-470-84857-X
9. Energy conversion and storage scientific journals.

GETD 520 Green Technology Dissertations:
(Hard 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 **12 Credits**

Viva-voce **3 Credits**

Total No. of Credits: 15

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Annexure I

Course Code	Course Title	Course Type*	L	T	P	C
Soft-core Courses						
GETY614	Nanotechnology for Energy Systems	S	3	0	0	3
GETY615	Energy Audit and Management	S	3	0	0	3
GETY616	Algal Energy Technology	S	3	0	0	3
GETY528	Green Chemistry	S	3	0	0	3
GETY618	Carbon Sequestration at Landscape Level	S	3	0	0	3
GETY529	Green Building Concept	S	3	0	0	3

GETY615: Nanotechnology for Energy Systems **3 0 0 3 45L**
(Soft Core Course)

Unit.1 Nano-electronics [9 h]
Atom by Atom arrangements , band structure formation, concept of wave, phase group velocities, electron state in solids, uncertainty principle, operators, wave properties of particle, quantum mechanical postulates, Schrödinger's Wave Equation, free electron gas, spherical potential (hydrogen atom like problem), Hydrogen molecule like problem , electronic states of 2-D, 1-D, 0-D nanosystems.

Unit 2 Physical Properties of Nanosystems [9 h]
Absorption, refraction, self electro optic effect, QCSE and Pockel effect in nanosystem, transport properties of nanosystems, partition function and thermodynamics of nanosystems.

Unit.3 Nanotechnology for Photovoltaic Energy Conversion [9 h]
Challenges in energy conversion – role of nanostructures & materials – nanomaterials in solar Photovoltaic Technology: Bandgap engineering & optical engineering - Tandem structures - quantum well and quantum dot solar cells - Organic solar cells.

Unit.4 Nanotechnology for Photoelectrochemical and Photothermal Conversion Cells [9 h]
Concept of photo-electro chemical cell. Conversion of solar energy to hydrogen, technology for storage, photo-thermal cells, nanotechnology in thermal conversion, nanosystems for heat storage.

Unit.5 Energy Efficient Nanodevices [9 h]
Energy efficient devices –fabrication and applications of LED as light device – OLED – Semiconductor laser – single electron & single photon devices – energy efficient switches &modulator, amplifiers and lasers – MEMS & NEMS and their energy efficiency

Text books
[1] Physical principles of micro Micro-electronics, G.Yepifanov, Mir Publishers
[2] Semiconductor device-basic principles-Jasprit singh, Wiley

Reference
[3] Quantum Chemistry, Levine, Prentice Hall
[4] Statistical Mechanics and properties of matter, E.S.R Gopal,Ellis Horwood
[5] Introduction to solids, Azaroff, Tat Mc-Graw Hill

GETY 616: Energy Audit and Management **3 0 0 3 45L**
(Soft Core Course)

UNIT I Energy Auditing Techniques [9]
Energy Audit: Definition, need and objectives, types of Energy Audit, Energy audit strategies, Basic Components of Energy Audit, Energy Audit Instruments, Important survey items: Methodologies of conducting energy audit: Post audit analysis:

UNIT II Furnaces and Boilers [9]
Furnaces: Classification, general fuel economy measures in furnaces, excess air and heat distribution losses, temperature control, draft control, case studies.
Boilers: Types, analysis of losses, performance evaluation, feed water treatment, blow down, energy conservation opportunities, FBC boilers, case studies.

UNIT III Insulation and refractories [6]
Insulation type and application, economic thickness of insulation, heat savings and application criteria, refractory-types, selection and application of refractories, case studies.

UNIT IV Steam system, Cogeneration, Cooling tower and Waste heat recovery [12]
Steam system
Properties of steam, assessment of steam distribution losses, steam leakages, steam trapping, condensate and flash steam recovery systems, identifying opportunity for energy saving, case studies
Cogeneration
Need, applications, advantages, topping cycles, bottoming cycles, combined cycles, steam tracking mode, electricity tracking mode, saving potential, case studies.
Cooling Tower
Types and performance evaluation, efficient system operation, flow control strategies and energy saving opportunities, case studies
Waste heat recovery
Availability and reversibility, first and second law efficiency, classification, advantages and applications, commercially viable heat recovery devices, saving potential, case studies
HVAC and refrigeration system, vapour compression refrigeration cycle, refrigerants, factors affecting refrigeration and air conditioning system performance and savings potential.
Vapour absorption refrigeration system, working principle, types and comparison with vapour compression system, saving potential, distribution system for conditioned air.

UNIT V Energy Conservation (Electrical Systems) [9]
Electrical systems and bill analysis: Electricity billing, electrical load management, maximum demand control, Energy conservation opportunities in Lighting systems, Electric motors, Compressed air systems, HVAC & refrigeration system, Fans & blowers, Pumps, Cooling tower and DG system, case studies.

Text Books
1. GL Witte, Philips, S Scbmidt and Daid R Brown, Industrial energy management and utilization, Hemisphere publishing corporation, Washington.
2. Carig B, Saith, Energy Management Principles, applications, benefit and saving, Per n Presss, Newyork
3. F W Pyne, P gm Energy Conservation Manual, Fairmount Proem, INC. P.O. Box 14227 Atlanta, GA 30224

References
4. D Patrick and SW Fardo, Energy conservation, Prentice Hall, INC Engleweek Cliffs (NJ) 7632
5. Davida, Fuels of opportunity, characteristics and uses in combustion systems, Edition-2004, Publisher-Elsevier Ltd., UK
6. Efficient electrical use by CB Smith.

7. Savings electricity in utility systems of industrial plants by BG Desai, BS Vaidya, DP Patel and R Parman
8. Manual of variable speed drives by CII.
9. Electrical power distribution in industrial plants by MD Parmar
10. BR Gupta, Generation of electrical energy edition 2005, Eurasia Publishing house Ltd., Ram Nagar
11. Instructions to Energy Auditors, Vol. –I & Vol. –II- National Technical Information Services, US Dept of commerce, Springfield, VA 22161.
12 Energy Auditing, The Fairmont Press Inc. Published by Atlanta, Georgia.
13. Albert Thumann PE, CEM, Plant engineers & Managers guide to energy conservation-8th edition-2002, Published by the Fairmont Press, Inc 700 Indian Train Liburn, GA30047.
14. BEE Volume – Second edition 2005.
15. GG Ranjan, Optimizing energy efficiencies in industry, Edition-2003 McGraw Hill.

GETY613: Algal Energy Technology **3 0 0 3 45L**
(Soft Core Course)

Unit I 9 h

Taxonomic variation of algae - sampling, culture and biomass estimation – Algae as bioindicators - phycoremidation. Macroalgae and microalgae – characteristics of microalgae for biofuel application. Algae feedstock for energy conversion - biomass and lipid optimization in algae – stress control and genetic engineering approaches.

Unit II 9 h

Characterization of photosystems in microalgae – energy conversion efficiencies - optical characteristics of photoactive proteins in algae – recent development in artificial leaves and biosolar cells.

Unit III 9 h

Cultivation of Algae for biodiesel and high value chemicals: Laboratory culture, Open raceways ponds, closed photobioreactors, design and illumination concepts - continuous culture and biomass recovery – Process engineering.

Unit IV 9 h

Chemical synthesis of biodiesel: Liquefaction of algal cells by hexane extraction - catalytic distillation - transesterification - Fischer-Tropsch diesel. Large scale biomass production and lipid yield optimization. Biocrude from algae – biorefinery for fuel production.

Unit V 9 h

Conventional fuels versus biofuels – methods of physical characterization of algae biodiesel - ASTM standards for biofuel blends – enhancement of biofuel properties – challenges and limitation in the use of biofuel – socio-economic aspects of algae as alternate fuel – algal fuel technology in Indian scenario and Global trend.

Text Books

1. Freshwater Algae: Identification and Use as Bioindicators by Edward G. Bellinger and David C. Sigee, Wiley-Blackwell, John Wiley & Sons, 2010.
2. Resource Manual & Technical Manual, edited by S.Seshandri et al. A Bioresource Document compilation by Shri Murugappa Chettiyar Research Centre, Sponsored by National Bioresoruce Development Board, DBT, India.

References

3. Biodiesel Handling and Use Guide, Fourth Edition, an online document by National Renewable Energy Laboratory, USA. http://www.osti.gov/bridge
4. Algae by Linda E. Graham and Lee W. Wilcox, Prentice Hall, 2000.

GETY 528: **Green Chemistry**
(Soft-core Course) **3 0 0 3 45 L**

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

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

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

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

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

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

Practical chemistry (Mini project): [24 h]

Text Books

[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)

References

[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)

GETY 618: **Green Concepts in Buildings**
(Soft-core Course) **3 0 0 3 45 L**

Pre-requisite (undergraduate degree in civil engineering)

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

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

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

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

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

TEXT BOOKS

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

REFERENCES

[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.

GETY 619: **Carbon sequestration at landscape level**
(Soft-core Course) **3 0 0 3 45 L**

UNIT 1. Climate change and International agreements - 6 hours
The green-house effect. The United Nations Framework Convention on Climate Change (UNFCCC). The Intergovernmental Panel on climate change (IPCC), the Kyoto Protocol, the Clean Development Mechanism (CDM). Afforestation and Reforestation projects, Reduced Emissions from Deforestation and Degradation (REDD). CDM projects, finance, project development. Conservation of natural carbon sinks.

UNIT 2. Primary productivity: mechanisms and assessment - 12 hours
Photosynthesis, absorption and yield. C3, C4 and CAM pathways. Laboratory measurement of primary productivity: cell, plant, ecosystem. Direct field measurements of biomass and primary productivity: allometric models, harvest methods for forests, grasslands and ocean. Indirect measurements of biomass and primary productivity: remote sensing and other methods. The CDM methodologies for measurement of stocks and fluxes.

UNIT 3. Biogeochemistry - 11 hours
Role of soil in the carbon balance: decomposition and sequestration in soils. The carbon cycle: plant, soil and atmosphere. Impact of soil degradation. Conditions for the formation of fossil stocks of carbon. Carbon balance of ecosystems: forests, grasslands and oceans. Impact on the global carbon balance.

UNIT 4. Remote sensing and spatial analysis - 12 hours
Sensors. Reflectance of vegetation. Measuring biomass with remotely sensed data. Measuring primary productivity with remotely sensed data. High resolution satellites, use and limitations to measure biomass and primary productivity. Low resolution satellites use and limitations to measure biomass and primary productivity. Regional and global assessments of biomass and primary productivity. Introduction to Geographic Information Systems (GIS). Land-use and land-use changes assessment. The Clean Development Mechanism (CDM) methodologies for measurement of stocks and fluxes at the landscape level.

UNIT 5. Biomass as a major source of energy in India - 4 hours
Fuel-wood use in rural households. Consequences for ecosystems. Future energy scenario in rural areas. Utilization of biomass in industrial and semi-industrial settings. Future utilization of biomass in India. Future of landscape management: optimal management.

Text Books
[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.

References
[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.