PONDICHERRY UNIVERSITY
PONDICHERRY – 605 014 INDIA

CENTRE FOR GREEN ENERGY TECHNOLOGY

MADANJEET SCHOOL OF GREEN ENERGY TECHNOLOGIES

Syllabus

M.TECH. (Green Energy Technology)

2019

CENTRE FOR GREEN ENERGY TECHNOLOGY

PONDICHERRY UNIVERSITY, PONDICHERRY – 605 014, INDIA

M.TECH. IN GREEN ENERGY TECHNOLOGY

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 nanotechnology, waste management and environmental sustainability etc. The course will be taught by a team of specialists working in the fields of green energy technology, chemical science, biological science, project management, and environmental policy. This is program is designed for two years spread into four semesters. First two semesters are for hard and soft core courses, third semester is entirely for soft-core (optional) courses and final semester is for project. Many soft-core courses are stand alone, so, they can be taken at any time offered by the Department. In addition there will be some bridge courses. Most of the first semester courses will be on energy and modelling. In the second and third semester courses will be based on energy, environment, chemistry, management and other GET related fields. Students will select courses suiting background and interest. Each theory course will have a project component which will be either individual or group based. **Students will be required to earn at least 72 credits to qualify for the M.Tech. degree.** Students with 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.

The following are the thrust areas of our center currently focused for teaching and conducting research.

- Solar Thermal Energy Technology
- Solar Photovoltaic Technology
- Bio-energy Technology
- Energy Material Development
- Electrochemical Energy Conversion and Storage Technology
- Advanced Combustion Technology

<u>Subject areas covered in M.Tech. Green Energy Technology program are:</u>

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

2. **Energy, Environment, renewable energy and sustainable development:** This course focus on the fundamentals of energy, environment, renewable energy and sustainable development. This course will give overview of the energy scenario in national and global level.

3. **Modelling 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 Modelling and Simulation in the design and verification of Renewable and Green Energy systems. Green Economics this subject involves the search for products whose contents and methods of production have the smallest possible impact on the environment.

4. **Processing energy harvesting materials** is an essential part of Green Energy Technology. Course indents to introduce the material selection criteria and material processing techniques to the M.Tech students.

5. **Solar Thermal Technology & Energy Conversion Systems** 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. **Bio-energy and conversion systems** deal with biomass resource estimation and management, various energy conversion technologies and methods to generate energy from waste.

8. **Photovoltaic energy conversion** principles, required materials and device structures **-** characterization techniques and quality analysis. Installation and maintenance of SPV power systems – Knowledge on power systems components and economic aspects SPV power systems.

9. **Nanotechnology for energy harvesting** starts with the basic nano-electronics and elaborates to the size and shape depended properties of nanomaterial. Then it focuses towards the energy harvesting with nanomaterials and also explains how the nanomaterial properties can be tuned for energy storage and energy efficiency. Theoretical, computational and project based activities are included in the course.

10. **Electrochemical Energy Conversion and Storage:** From the basics to technologies on electrochemical energy conversion & storage will be taught which includes various types of batteries, supercapacitors and fuel cells.

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

12. **Energy Laboratories:** Students will be taught green energy experiments which involve estimation of calorific values of a fuel, studying solar radiation, assembling solar still, and solar water hear, fuel cell performance and simulation/ modelling of few energy devices, etc. In semester I, II & III, energy laboratory course will be offered.

13. **Mini-project and Proposal Writing:** All students will do a mini-project which involves taking up a small green energy project within campus or outside and learning about how to communicate the data to scientific journals.

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

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

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

Assessment Methods Teaching and assessment will be by Choice Based Credit System (CBCS). Evaluation will be through session (laboratory reports, class tests, set assignments) or by continuous assessment (designing, computer practical, seminar papers, project reports etc.) and end-semester examinations. The pattern of end-semester examination shall be broadly as per the following:

End Semester Theory Examination (Total Marks = 60)
Part A: Answer All the Questions. Five questions of 2 marks each (5 x 2 = 10).

Part B: Answer Any 5 questions out of 6. Each question carry 4 marks (5 x 4 = 20).

Part C: Descriptive. Answer any 5 questions out of 8. Each question carry 6 marks (5x6=30).
Each question may contain sub-divisions a, b, c etc.

End Semester-Practical Examination (Total Marls = 60)

Evaluation pattern:
Experiment / Demo 20 Marks. Procedure / Result   20 Marks. Viva 20 Marks.

Internal Examinations: Examinations are conducted in a semester for 40 Marks. Written Examination 30 Marks and Assignment /Seminar 10 Marks.

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.

M.Tech. Green Energy Technology - Program Specific Outcome:

1. Trained man powers in the area of major renewable and clean energy technologies
2. Acquiring specialization on the chosen field of renewable energy through industrial training and/or research work.
3. Acquire knowledge on energy generation including design, fabrication, testing and modelling of process
4. Gaining specific understanding on fabrication and evaluation of solar cells, battery, supercapacitors and fuel cells.
5. Gaining specific understanding on design and installation of PV power plant, solar thermal devices.
6. Specific understanding on biodiesel, bioethanol and biogas production
7. Specific understanding on conversion of waste to energy and harnessing energy from the wind
8. Gained knowledge on energy audit and management
9. Trained man powers on building sustainability on society and environment
10. Gained knowledge on art of scientific writing, publishing and presenting

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M.Tech (Green Energy Technology)
Course Curriculum Effective from academic year: 2019-20

SEMESTER-I

Course Code	Course Title	Course*	L	T	P	C
Hard-Core Course						
GETY511	Energy, Environment and Renewable Energy Technologies	H	3	1	0	3
GETY512	Modeling and Simulations	H	3	1	0	3
GETY513	Bio-energy & Conversion Systems	H	3	1	0	3
GETY514	Fuels & Combustion Technology	H	3	1	0	3
Soft-Core Courses						
GETY515	Nanomaterials: Properties, Synthesis, Characterization and Applications	S	3	0	0	3
GETY516	Heat Transfer and Electrical Power - Generation, Transmission and Distribution	S	3	0	0	3
GETY519	Biomass Feedstock and Solid Biofuel Production	S	3	0	0	3
Practical						
GETY510	Energy Laboratory –I	H	0	2	4	3

SEMESTER-II

Course Code	Course Title	Course Type*	L	T	P	C
Hard-core Course						
GETY522	Solar Thermal Energy: Fundamentals, Devices and Systems	H	3	1	0	3
GETY523	Solar Photovoltaic Energy Conversion	H	3	1	0	3
GETY525	Electrochemical Energy Conversion and Storage	H	3	1	0	3
Soft-core courses						
GETY524	Processing of Green Energy Materials	S	3	0	0	3
GETY526	Waste to Energy Conversion	S	3	0	0	3
GETY541	Polymer and Composite Materials for Renewable Energy	S	3	0	0	3
GETY616	Algal Energy Technology	S	3	0	0	3
Practical						
GETY520	Energy Laboratory –II	H	0	2	4	3

SEMESTER-III

Course Code	Course Title	Course Type*	L	T	P	C
Hard-core Course						
GETY611	Project (Phase I): Research Methodology, Proposal Writing and Defense	H	0	2	4	3
GETY612	Solar Photovoltaic Power Systems	H	3	1	0	3
GETY631	Wind Energy and Small Hydro Power Systems	H	3	1	0	3
Soft-core Courses						
GETY613	Advanced Battery and Fuel Cell Technologies	S	3	0	0	3
GETY614	Nanotechnology for Energy Systems	S	3	0	0	3
GETY615	Energy Audit and Management	S	3	0	0	3
GETY619	Biorefineries	S	3	0	0	3
Practical						
GETY610	Energy Laboratory – III (Virtual Instrumentation and Case Study on Sustainable Energy Systems)	H	0	2	4	3

Minimum No. of Credits: 18

SEMESTER-IV

Course Code	Course Title	Course Type*	L	T	P	C
GETY620	Project (Phase II) Green Energy Technology					
	Dissertation	H				11
	Viva-Voce					1
Total No. of Credits						**12**

H – Hard-core Course; S - Soft-core Course
L – Lecture; T – tutorial; P – Practical; C – No. of Credits

Evaluation:
All theory, practical and dissertation courses have Internal Assessment of 40 Marks and External Assessment of 60 Marks.

OTHER SOFT-CORE COURSES

These courses will be offered in any of first three semesters depending on the availability of the resource faculty.

Course Code	Course Title	Course Type*	L	T	P	C
GETY517	Scientific Writing and Research Methodology	S	3	0	0	0
GETY518	Environmental Risk Management	S	3	0	0	3
GETY527	Green Management	S	3	0	0	3
GETY528	Green Chemistry	S	3	0	0	3
GETY529	Green Building Concept	S	3	0	0	3
GETY531	Advance Heat Transfer for Energy Engineering	S	3	0	0	3
GETY532	Electrical Power Generation and Power System Analysis	S	3	0	0	3
GETY618	Carbon Sequestration at Landscape Level	S	3	0	0	3

GETY 511 - Energy, Environment and Renewable Energy Technologies

(Hard-core Course) **L T P C**
3 1 0 3 45L

Course Outcome:

- Understand the nexus between energy, environment and sustainable development
- Appreciate energy ecosystems and its impact on environment
- Learn basics of various types of renewable and clean energy technologies
- Serve as bridge to advanced courses in renewable energy

Unit I. Energy [8]

Introduction to the nexus between energy, environment and sustainable development, Energy sources over view and classification, sun as the source of energy, fossil fuel reserves and resources - overview of global/ India's energy scenario. Energy consumption models – Specific Energy Consumption

Unit II. Ecology and Environment [9]

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, The environmental protection act :Effluent standards and ambient air quality, innovation and sustainability, eco-restoration: phyto-remediation.

Unit III. Renewable Sources of Energy [10]

Solar Energy: Solar radiation: measurements and prediction. Indian's solar energy potential and challenges, solar energy conversion principles and technologies: Photosynthesis, Photovoltaic conversion and Photo thermal energy conversion. **Wind Energy**: Atmospheric circulations, atmospheric boundary layers, classification, factors influencing wind, wind shear, turbulence, wind energy basics and power Content, wind speed monitoring, Betz limit, wind energy conversion system: classification, characteristics and applications. **Ocean Energy**: Ocean energy resources-ocean energy conversion principles and technologies: ocean thermal, ocean wave & ocean tide

Unit IV. Bioenergy [9]

Biomass as energy resources; 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 conversion technologies.

Unit V. Other Energy Sources and Systems [9]

Hydropower, Nuclear fission and fusion-Geothermal energy: Origin, types of geothermal energy sites, site selection, geothermal power plants; hydrogen energy, Magneto-hydro-dynamic (MHD) energy conversion – Radioisotope Thermoelectric Generator (RTG), Bio-solar cells, battery & super capacitor, energy transmission and conversions.

References

1. Energy and EnvironmentSet: Mathematics of Decision Making, Loulou, Richard; Waaub, Jean- Philippe; Zaccour, Georges (Eds.), 2005.
2. Energy and the Environment, Ristinen, Robert A. Kraushaar, Jack J. AKraushaar, Jack P. Ristinen, Robert A., 2nd Edition, John Wiley, 2006,
3. Energy and the Challenge of Sustainability, World Energy assessment, UNDP, N York, 2000.
4. Solar Energy: principles of Thermal Collection and Storage, S.P. Sukhatme, Tata McGraw-Hill (1984).
5. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.
6. Wind Energy Conversion Systems, L.L. Freris, Prentice Hal 1990.
7. Geothermal Energy: From Theoretical Models to Exploration and Development by Ingrid Sober and Kurt Bucher, Springer, 2013.
8. Ocean Energy: Tide and Tidal Power by R. H. Charlier and Charles W. Finkl, Springer 2010
9. Introduction to Electrodynamics (3rd Edition), David J. Griffiths, Prentice Hall, 2009

GETY 512: Modelling and Simulations

(Hard-core Course) **L T P C**

3 1 0 3 45L

Course Outcome:

- Mathematical understanding of green energy systems
- Numerical calculations with advanced scientific software
- Programming skill development in research and engineering software

Unit I. [9]

Introduction to mathematical modelling: -Numerical integration –Differentiation, Elementary computer graphics, data analysis, -Physical and mathematical models, Solar simulator, computer simulation of solar radiation.

Unit II. [9]

Fundamentals of Programming: Introduction to computational softwares: Programming in computational software (with the help of a specific software eg. 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, optimization techniques.

Unit III. [9]

Graphical Programming: Starting graphical programming (with the help of any one of graphical programming software, eg: 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 (eg: Simulink with MatLab)-Defining Block Parameters Using Matlab, Variables-Exchanging Signals With other programmes Extracting Models (eg: Simulink into Matalb).

Unit IV. [9]

Lab exercises to develop simple Scripts and models related to building energy systems involving applications of data analysis, optimization, advanced graphics, diode model and simulation, simple photovoltaic models and simulation, DSSC model and simulation, FPC optimization model.

Unit V. [9]

Hybrid system modelling, PVT model, Wind Turbine/generator: Modelling of PV Solar Array: simulation of power output of PV systems, Modelling of PEM Fuel Cell.

Reference Books

1. Modelling and Simulation: Exploring Dynamic System Behaviour, by Louis G. Birta 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. Solar Photovoltaics, Fundamentals, Technologies and Applications, C.S. Solanki, Eastern Economy Edition, Third Edition, 2016, Academic Press 2007
4. G.M.Masters, Renewable and Efficient Electric Power Systems, Wiley, first edition, 2004.
5. Modeling of photovoltaic system using MATLAB: simplified Green Codes, Tamer Khatib, Wilfried Elmenreich, First Edition, Wiley, 2016

GETY 513: Bioenergy and Conversion Systems

(Hard-core Course) **L T P C**

3 1 0 3 45L

Course Outcome:

- Learn fundamentals of biochemistry and biological systems for energy application
- Realization of global bioenergy potential, and scenario of bioenergy in India.
- Understand various biofuel types and characteristics
- Understanding of various types of bioenergy conversion systems in practice
- Acquire basic knowledge on algal culture, biomass harvest and biofuel production
- Know the national and international biofuel Standards.

Unit I. Biological Systems [10]

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 breakdown of carbohydrates- Lipids-proteins and nucleic acids TCA cycle - Glycolysis - Gluconeogenesis - Pentose phosphate shunt - Urea cycle - Interconnection of Pathways - Metabolic regulations.

Unit II. Biochemical Conversions [10]

Bio catalysis 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 III. Thermochemical & Chemical Conversions [9]

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

Chemical Conversion: Hydrolysis & hydrogenation; solvent extraction of hydrocarbons; solvolysis of wood, bio crude, biodiesel production via chemical process; catalytic distillation; transesterification methods; Fischer-Tropsch diesel: chemicals from biomass.

Unit IV. Algae for Biofuel application [9]

Introduction to algal biomass; large scale culture and harvest methodologies - Open Raceway ponds & photo bioreactors; Biomass and Lipid optimization strategies; Algal biodiesel and bioethanol production process engineering – Concepts of Integrated bioprocess & bio refineries; Social and economic impact of algae as replacement petro fuel.

Unit V. Biofuels Standards & Power Generation [9]

Physical and chemical characteristics of biofuels – Biomass, wood gas, bio methane; ethanol, biodiesel, Wood oil; Bio blends - Indian and International standard specifications. Bio blends; Adaptation of biofuel in various applications – biomass integrated gasification/combined cycles systems - Sustainable co-firing of biomass with coal; Biofuel economy; Biofuel roadmap of India - policy issues, regulatory issues and economic impact; Entrepreneurship in biofuel - Prospects & Challenges, Case studies.

References:

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.
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.

GETY 514: Fuels & Combustion Technology

(Hard-core Course) **L T P C**

3 1 0 3 45L

Course Outcome:

- Acquire knowledge on fundamentals of solid, liquid and gases fuels.
- Acquire insight about combustion stoichiometry theory and enable them to assess the environmental impact of conventional fuels.
- Develop understanding on burner design, industrial furnaces and its applications.
- Learn the concept of industrial waste energy recovery & combustion energy efficiency process.

Unit I. Solid Fuels [9]

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. Liquid and Gaseous Fuels [9]

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. Theory of Combustion Process [9]

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

Unit IV. Fuel stoichiometry and analysis [9]

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. Burner Design and Furnaces [9]

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, Pergamom Press.

GETY515: Nanomaterials: Properties, Synthesis, Characterization and Applications

	L T P C
(Soft Core Course)	**3 0 0 3 45L**

Course Outcome:

The aim of this course is to expose the students to nanomaterial's basics, synthesis, characterization and broad application of them. Knowledge of the societal impact of nanomaterial will also be taught.

Unit I. Properties at Nanoscale [9]

Comparison of properties at bulk and Nano - Nanomaterials – nanostructures, chemical and physical properties-surface-to-volume ratio, density of states - Quantum confinement and Bohr exciton radius - Quantum size effects, electrical, optical & magnetic properties. Origin of Surface Plasmon resonance in metallic nanoparticles – Absorption and emission properties of semiconductor nanocrystals. Carbon-based nanomaterials.

Unit II. Nanomaterials by Physical and Chemical Methods [9]

Top-down and bottom up approaches - Physical methods: Inert gas condensation - Arc discharge-sputtering - Laser ablation. Chemical methods: reduction-precipitation – hydrothermal-solvothermal processes - sol-gel, micelle and micro emulsions – thermolysis - chemical vapor deposition methods - electrochemical synthesis - chemical modification of nanomaterials – functionalization.

Unit III. Green Synthesis of Nanomaterials [9]

General approach for green synthesis – principles - Green synthesis of metals and alloys – use of natural resources and biosynthesis of nanomaterials. Microwave synthesis of nanomaterials.

Unit IV. Structural and Morphological Characterization [9]

Powder XRD and crystallite size–light scattering and particle size – surface area and porosity – UV and IR studies. Microscopy techniques - Scanning Electron Microscopy (SEM) - Transmission Electron Microscopy (TEM) – Scanning Tunneling Microscopy (STM) - Atomic Force Microscopy (AFM) – Principle and analysis.

Unit V. Applications of Nanomaterials and Societal Implications [9]

Nanomaterials and Nanotechnology General Applications – green technology and green energy applications - Industrial manufacturing, materials and products, medicine and clean environment - implications for philosophy, ethics and society.

References:

1. Guozhong Cao, Nanostructures and Nanomaterials, Imperial College Press, 2004, London.
2. Charles P. Poole, Frank J. Owens, Introduction to Nanotechnology, A John Wiley & Sons, inc.
3. Pradeep T., Nano:The Essentials: Understanding Nanoscience and Nanotechnology, Tata McGraw-Hill Publishing Company Limited, New Delhi,2008.
4. Rao C.N.R, Müller, Cheetham, The Chemistry of Nanomaterials, Vol 1 and 2, Wiley-VCH VerlagGmBH& Co., Weinheim, 2004.
5. Nanotechnology: assessment and perspectives, H. Brune et al., New York, Springer, 2006.
6. Nano-hype: the truth behind the nanotechnology buzz, David M. Berube; Amherst, N.Y., Prometheus Books, 2006.
7. Edelstin A.S. and CammarataR.C..Nanomaterials: Synthesis, Properties and applications, Institute of Physics Publishing 1996.
8. M.C. Roco and W.S Bainbridge, Nanotechnology: Societal Implications II – individual Perspectives, Springer publishers, sponsored by National Science Foundation, Netherlands.

GETY516: Heat Transfer and Electrical Power -Generation, Transmission and Distribution

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- Learn various modes of heat and mass transfer analysis of applied to different thermal systems.
- Learn in detail generation, transmission and distribution aspects of electric power.
- Carry out cost analysis of electrical power and comprehend parameters associated with electric power generation and load management.

Unit I. [9]

Laws of Thermodynamics, Sterling Engine: Principle, working and efficiency, Basic Heat Transfer Concept and Terminology**:** Basic concepts terminology; Heat transfer coefficients; Thermal resistance; Overall heat transfer coefficient.

Conduction: Conduction equation; Steady state conduction in simple geometries; Thermal contact Resistance; Critical thickness of insulation; Multidimensional steady state heat conduction (Shaper Factor); Extended surfaces; Types of fins; Effectiveness and efficiencies of fins; Transient heat conduction; Lumped heat capacity analysis; Hailer's charts for semi-Infinite medium; Slab cylinder and sphere; Periodic heat conductions.

Unit II. Convection [9]

Principle of similarity; Mechanism of convection; Concept of velocity boundary layer; Concept of thermal boundary layer; Evaluation of dimensionless parameters; Forced flow convection (Laminar, Turbulent &Mixed); Boundary layer thickness; Convective heat transfer coefficient; Drag coefficient for flat plate, Inside tube , cylinder, sphere and banks of tubes, Free convection

(Laminar, Turbulent &Mixed) on horizontal, vertical and Inclined plates, cylinder and sphere; forced convection inside tubes and ducts; Forced convection over exterior surfaces.

Unit III. Radiation [9]

Blackbody radiation; View factor algebra; Enclosures with black surfaces and grey surfaces; Radiosity; Heat exchangers and its types; Effectiveness, LMTD and NTU methods.

Unit IV. Electrical System [9]

Introduction to electric power supply systems: Power generation plant, Transmission and distribution lines, Cascade efficiency; Electrical billing; Electrical load management and maximum demand control; Power factor improvement and benefits; Transformers; Distribution losses in industrial system; Assessment of Transmission and Distribution (T&D) losses in power systems; Estimation of technical losses in distribution system; Demand side management; Harmonics.

Unit V. Material and Energy Balance [9]

Energy intensity on purchasing power parity (PPP); Energy pricing in India; Energy units and conversation; Purpose of material and energy balance; Components of material and Energy balance; Basic principles of material and energy balance; Classification of processes: steady-state process, unsteady state process; Material balance: levels of material balance; Material balance procedure; Energy balance; Efficiency and losses; Facility as an energy system; Energy balance in power plant cycle; Energy analysis; Energy action planning.

References:

1. Heat Transfer - A Basic Approach, M.N. Oziesik, McGraw Hill Book Co, First edition, 1979.
2. Heat Transfer: A Modem Approach, M.Becter, Springer, First edition, 1986.
3. Heat Transfer, S.P. Shukatme, Universities Press, Fourth edition, 2005.
4. Principles of Engineering Heat Transfer, W.H. Giedt, D.Van Norstand Company,First edition 1961.
5. Heat and Mass Transfer in Buildings, Kieth. J. Moss, Routledge, First edition, 2015.

GETY519 Biomass Feedstock and Processing of Solid Biofuel

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- Student shall able to assess regional biomass potential for energy conversion.
- Learn the processes and technology to develop solid biofuel from available biomass
- Learn various solid biofuel processing processes and their commercial potential.

Unit I. Biomass Resources: [9]

Biomass Resources: Agricultural produce and waste biomass, Biomass from forest produce and energy plantation. Biomass yield, availability, energy potential. Industrial biomass, Biomass from urban and municipal wastes.

Unit II. Resource Assessment of Biomass: [9]

Interaction of biomass with electromagnetic spectrum –Principle of remote sensing and its application to biomass quantification - Vegetation indices - Analysis of satellite imageries for biomass quantification. Biomass feedstock potential in India - Regional biomass availability - Case studies.

Unit III. Processing of Biomass: [9]

Physical properties of biomass: Moisture, bulk density, size, grindability, crushability. Chemical composition of biomass- estimation of volatile matter, cellulose and lignin content. Properties of municipal solid waste – MSW management principle – Segregation of waste biomass – refuse derived fuels. Pelleting and briquetting of solid biomass – Process flow – factors influencing heat values. Pretreatment of biomass for energy enhancement – Torrefaction

.

Unit IV. Solid Biofuel Production Processes: [9]

Fuel characteristics of solid biofuels - co-firing in thermal power plants – application in industrial units, Industrial production of pellets and briquettes – Integrated process flow - feedstock and product portfolios – Seasonal biomass feedstock – Securing feedstock supply chain.

Unit V. Energy Economy of solid biofuel: [9]

Roll of biomass energy in energy security - energy economy of solid biofuel - regional biomass utilization-Entrepreneurships potential- International and national energy policies on solid biofuel – Integrated economy model in Solid Biofuel Production – Case studies.

Reference:

1. Industrial briquetting: fundamentals and methods, Vol.13. Studies in Mechanical Engineering by ZygmuntDrzymała, Elsevier, 1993.
2. Biomass Briquetting: Technology and Practices by P.D.Grover&S.K.Mishra, published by FAO Regional Wood Energy Development Programme in Asia,Bangkok, Thailand
3. Chakraverthy A, "*Biotechnology and Alternative Technologies for Utilization of Biomass OrAgricultural Wastes"*, Oxford & IBH publishing Co, 1989.
4. VenkataRamana P and Srinivas S.N, "*Biomass Energy Systems*", Tata Energy Research Institute, 1996.
5. Application and Problems of Biomass Briquetting Densification Fuel(BBDF) Technology in China by Wang Xutao and Zhang Bailiang, Springer Berlin Heidelberg
6. David Boyles, Bio Energy Technology Thermodynamics and Costs, Ellis Hoknood Chichester, 1984.
7. Mahaeswari, R.C. Bio Energy for Rural Energisation, Concepts Publication,1997
8. Best Practises Manual for Biomass Briquetting, I R E D A, 1997
9. Eriksson S. and M. Prior, The briquetting of Agricultural wastes for fuel, FAO Energy and Environment paper, 1990

GETY 510: ENERGY LABORATORY – I

(Hard-core Course) **L T P C**
0 2 4 3 90L

A. Course Outline:

- 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:

S. No.	List of Experiments
1.	Solar irradiation measurement using Optical Pyranometer
2.	To study the IV curves and calculate efficiency, fill factor, Pmax of solar cell at varied irradiance
3.	Study of SPV module assembly process
4.	Installation of Solar Panel and study of influencing parameters
5.	Structure, Electrical and Optical characterization of energy materials
6.	Determination of the viscosity, flash point, fire point and pour point of liquid fuels
7.	Experimental study of down draft gasifier and analysis of flue gas
8.	Biogas production by anaerobic digestion and analysis
9.	Synthesis of gold nanoparticles–green synthesis
10.	Characterization of Phase Change materials
11.	Proximate and ultimate analysis and calorific value solid fuels
12.	Biomass Briquetting and their Characterization
13.	Extraction and characterization of photosystem complex

Manuals

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,

References:

1. Polak, P. (1979) Systematic Errors in Engineering Experiments, Macmillan Press Ltd.
2. Annual Book of ASTM standards, Section I – V, Vol. 05.01-05.05, 2002-2003.
3. Experiments with renewable energy-students guide- ISBN 1-928982-22-0
4. African journal of Biotechnology,vol 9(12), pp 1719 (2010)

SEMESTER-II

GETY522: Solar Thermal Energy: Fundamentals, Devices and Systems

	L T P C
(Hard Core Course)	**3 1 0 3 45L**

Course Outcome:

This paper aims to impart knowledge on design and development of various types of solar thermal collectors. Students shall be trained to quantify the solar radiation received on the collector, carry out detailed thermal analysis of different types of solar collectors, decide on material selection for various components such as absorber plate, glazing, insulation, etc. Get thorough understanding on the working principle of various types of solar gadgets like solar water heater, solar air heater, solar still, solar drier, solar air conditioning system, solar thermal power generation, etc. Also, carry out techno-economic analysis of solar thermal projects.

Unit I. Solar Radiation Geometry [9]

Solar angles; the earth and solar constant; day length; angle of incidence on tilted surface; variation of extraterrestrial radiation; solar radiation at the earth's surface; solar radiation data; sunrise, sunset and day length; local apparent time; instruments for measuring solar radiation and sunshine; solar radiation on tilted surfaces; analysis of Indian solar radiation data and applications.

Unit II. Solar Collectors: Thermal Analysis [9]

Flat plate collectors: Effective energy losses; thermal analysis; heat capacity effect; overall loss coefficient; collector efficiency factor; collector heat removal factor; efficiency of flat plate collectors; testing methods. Evacuated tube collectors: Types; thermal analysis; testing methods. Concentrating collectors: Designing and types; acceptance angle; geometric concentration ratio; optical efficiency; thermal efficiency; testing methods. Selective surfaces.

Unit III. Solar Thermal Energy Storage [9]

Low, Medium and High temperature thermal energy storage. Sensible heat storage: Types of sensible heat storage; energy analysis in a liquid stratified tank; design aspects; materials for latent heat storage.

Latent heat storage: Phase change material (PCM) for latent heat storage; inorganic and organic PCM's; calculation of quantity of material required for latent heat thermal energy storage; design of a solar thermal device with the provision of thermal storage. Thermo-chemical storage: Materials; merits and demerits of thermo-chemical storage; potential of thermo-chemical storage materials for high temperature applications.

Unit IV. Solar thermal energy systems [9]

Solar water heating systems: Materials and components; Natural flow; Forced flow; applications Solar air heating systems: Description and classifications; porous and non-porous type; testing of solar air heater, applications. Solar concentrating systems: Materials for concentrators; types of concentrators, single axis and two axis tracking. Solar drying: Working principle; open sun drying; direct solar drying; indirect solar drying; Designing of solar drier; psychrometric chart; energy balance equation. Solar distillation: Working principle; thermal efficiency; various designs of solar still. Solar pond: Description; Non-convective solar pond; operational problems; other solar ponds. Solar cookers: Types of solar cookers; first figure of merit and second figure of merit. Solar energy for industrial process heat: Hot water, hot air and steam based industrial process heat systems; Solar refrigeration and air conditioning: Principle of absorption cooling; basics of absorption cooling; lithium bromide-water absorption system; vapor compression refrigeration Solar thermal power generation: Principles of solar engines; solar thermal power plants: parabolic trough, central receiver, parabolic dish, compact Fresnel linear reflector technology.

Unit V. Economic analysis for solar thermal engineering projects [9]

Annualized cost method: annualized cost; annualized capital cost; salvage value; capital recovery factor; salvage fund factor; annualized maintenance cost; Life cycle savings: savings per day; present worth of annual savings; present worth of cumulative savings. Payback period.

Text Books

1. Solar Thermal Engineering Process, Duffle and Beckman, John Wiley & Sons, Fourth edition, 2013.
2. Solar Energy, J.S. Hsieh, Prentice Hall Inc, first edition, 1986.
3. Applied Solar Energy, A.B. Meinel and M.B. Meinel, Addison – Wiley, Second edition, 1977.
4. Solar Energy: Fundamentals & Applications, Garg H P., Prakash J, Tata McGraw Hill, First edition, 1997.
5. Solar Energy, S.P. Sukhatme, Tata McGraw-Hill, Third edition, 2008.

GETY 523: Solar Photovoltaic Energy Conversion

L T P C

(Hard Core Course) **3 1 0 3 45L**

Course Objective: This course highlights about the solar energy, solar energy conversion principles, fundamentals about semiconductors and their application for solar cell fabrication and solar characterization

Expected Outcome: Students will have complete understanding about the solar energy and their conversion principles – solar cell fundamentals – solar cell fabrication and characterization techniques.

Unit I. Properties of Semiconductor [9]

Semiconductors **-** crystals structures, atomic bonding, energy band diagram – direct & indirect bandgap- 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. Semiconductors for Solar Cell [9]

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. Device fabrication [9]

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. Characterization and Analysis [9]

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. Thermo-photovoltaics [9]

Thermo photovoltaic principles - thermophotovoltaic materials and device fabrication – thermophotovoltaic device characterization and analysis – Thermophotovoltaic power systems

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. Bauer, Thomas, “Thermophotovoltaics: Basic Principles and Critical Aspects of System Design” Springer (2012).
9. Solar Cell Array Design Handbook, H S Rauschenbach, Van Nostrand Reinfold, 1997.

GETY 524: Processing of Green Energy Materials

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- Practical knowledge of materials embodied energy emission and toxicity
- Survey and analysis skill
- Hands on experience in making materials

Unit I. [9]

Selection criteria of light harvesting materials. Characterization of photo-absorbing and photo-conducting materials. TCO materials selection criteria, anti reflection coating material selection criteria. Selection criteria for photo-thermal conversion materials. Characterization of photo-thermal conversion materials.

Unit II. [9]

Silicon processing , source material, refining, Czochralski method, Float Zone method, wafer processing, diffusion, screen printing, buried contacts, rear contacts. Cell characterization and modelling.

Unit III. [9]

Thin-film fabrication techniques: vacuum technology, sputter coating technique, Epitaxial technology-Molecular Beam Epitaxy, Chemical beam Epitaxy, MOCVD, GaAs & CdTe material properties and processing. Electrochemical fabrication of thin film materials.

Unit IV. [9]

Green Building materials, Energy and Co_2 advantage of sustainable building, material selection criteria, Resource efficiency, Indoor air quality, energy efficiency, water conservation. Wind turbine materials. New materials for wind turbine. Standards policies and regulations of biofuel materials.

Unit V. [9]

Energy Efficient devices and material processing: material selection criteria for LEDs, OLEDS, Dye-sensitized solar cells (DSSCs), polymer solar cells, fabrication/assembling, testing methods and its specific application.

Text Books

[1] Solar photovoltaics, Fundamentals, Technologies and applications, C.S. Solanki, Eastern Economy Edition, Third edition, 2016

[2] Materials concepts for solar cells (Energy Future), Thomas Dittrich, Imperial College Press, First Edition 2014.

[3] Understanding Green Building Materials, T.R. Rider, S. Glass and J. McNaughton, W.W. Norton & Company, first editon 2011

[4] Semiconductor Materials for Solar Photovoltaic cells, P. Parathaman, W. Wong-Ng, Springer, first edition, 2015.

[5] Organic Solar cells: theory, Experiment and device simulation, W. Tress, Springer, First edition 2014

GET525: Electrochemical Energy Conversion and Storage

L T P C

(Hard Core Course) **3 1 0 3 45L**

Course Outcome:

- Enrich knowledge on basics of energy conversion & storage
- Gain know-how battery and fuel cell functioning
- Gain knowledge on fabrication technology of battery and fuel cells
- Aware about the storage of renewable energy using battery

The aim of this course is to give a broad view of electrochemical energy conversion and storage devices. The basics of these devices and their merits and demerits will be taught. At the end of this course, the students will have a thorough knowledge on what are primary and secondary batteries, important of supercacitors and fuel cells.

Unit I. Introduction [9]

Electrochemical cell, electro motive force, free energy changes and emf, concentration of the reactants on EMF, effect of cell temperature, derivation of number of electrons involved in a cell reactions, thermodynamic calculations, electrochemical series-equilibrium potential, Nernst equation-Battery types – primary and secondary batteries and examples - theoretical voltage, capacity, energy & specific energy, power & specific power.

Unit II. Primary batteries [9]

Dry cells-zinc/carbon battery, alkaline primary batteries, Zn/air, Lithium batteries, reserve batteries: principle, components, construction, characteristics, applications, and problems associated with the systems.

Unit III. Secondary Batteries [9]

Principle, construction, components, merits and demerits of lead acid, nickel-cadmium, nickel-metal hydride, lithium-ion batteries-Possible applications.

Unit IV. Supercapacitors [9]

Introduction to supercapacitors, types of supercapacitors, Reagone plot, similarities and differences between supercapacitors and batteries, electrode interface & double layer capacitors-redox capacitors-construction and performance evaluation, materials for supercapacitors and technology development – typical examples.

Unit V. Fuel Cells [9]

Introduction to fuel cells, merits and demerits, comparison to batteries & internal engines, types of fuel cells, EMF of fuel cells, Nernst equation, efficiency, current versus potential issues, fuel cell reaction kinetics, ORR, MOR, selection of fuel, electrode, electrolyte and membranes-fuel cell charge transport, fuel cell mass transport, fuel cell characterization, fuel cell losses, hydrogen - oxygen fuel cell, PEMFCs, DMFCs, PAFCs, molten carbonatate fuel cells,SOFCs and Biofuel cells.

Text Books

1. Barak, Electrochemical Power sources, I.E.E. series Peter Peregrinus Ltd. Steverage, U.K 1980 reprint 1997.
2. J.O.M. Bockris& A.K.N. Reddy, Modern Electrochemistry, Plenum Press, 1996.

References

1. A.J. Bard & L.R. Faulkner, Electrochemical Methods Fundamentals and Applications, John Wiley & Sons. 2nd Edition, 2001.
2. B.E. Conway, Electrochemical supercapacitors: scientific fundamentals and technological applications, Kluwer Academic / Plenum publishers, New York, 1999.
3. T.R. Crompton, Batteries reference book, Newners, 3rd Edition, 2002.

GETY 526: Waste to Energy Conversion

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

1. Learn fundamentals of solid waste generation and its management techniques.
2. Acquire knowledge on various waste treatments and disposal processes.
3. Student shall learn to appreciate importance of waste-to-energy and waste management hierarchy for all kinds of wastes materials.
4. Learn to assess environmental and health impacts of various waste-to-energy conversion technologies with case studies.

Unit I. [9]

Introduction to Waste & Waste processing: Definitions, sources, types and composition of various types of wastes; Characterization 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 II. Waste treatment and disposal [9]

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 III. Energy from waste-thermo chemical conversion [9]

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 IV. Energy from waste- Bio-chemical conversion [9]

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 V. Environmental and health impacts-case studies [9]

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, 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. Waste-to-Energy by Marc J. Rogoff, DEC-1987, Elsiever, ISBN-13: 978-0-8155-1132-8, ISBN-10: 0-8155-1132-9.
5. Manoj Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997.
6. Parker, Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985.
7. Bhide A. D., Sundaresan B. B., Solid Waste Management in Developing Countries, INSDOC, New Delhi, 1983.
8. Biogas from waste and renewable resources, by Dieter D. And Angelika S. Wiley-Vch Publication 2010.

GETY541: Polymer and Composite Materials for Renewable Energy Systems

(Soft Core Course) **L T P C** **3 0 0 3 45L**

Course Outcome:

- Acquire understanding on the basics of polymers and composites synthesis, analysis, and testing its properties.
- Develop ability to synthesis various types of polymeric and composite materials for specific applications such as solar PV, solar thermal, wind turbines, batteries, fuel cells, and related renewable energy technologies.
- Acquire state of the art in polymeric and hybrid composite materials in the field of renewable energy.

Unit I. Fundamentals of Polymers and Composites **[9]**

Basics, classification, structures, nomenclature, polymer synthesis, properties– polymer length, molecular weight, amorphous and crystalline. Organic semiconductors- conjugated polymers, charge transport in organic semiconductors. Introduction to composites-polymer matrix composites, polymer membranes, and carbon nanocomposites, types, preparation and processing of composites, properties of composites.

Unit II. Polymers and Composites for Solar Energy **[10]**

Organic photovoltaics; Introduction- principles of organic, polymer and hybrid photovoltaics, Donor and acceptor organic molecules, and bulk heterojunction devices with focus on organic/polymeric materials-fullerenes photoactive layer. Organic photoactive material synthesis-low bandgap conducting polymers. Processing and printed plastic solar cells and hybrid tandem cells. Stability and lifetime of organic polymer and metal oxide–polymer bulk heterojunction solar cells. Organic versus inorganic solar cells, Polymers and composites as solar thermal materials for solar thermal -polymeric solar absorbers and polymer solar reflector.

Unit III. Polymers and Composites for Wind and Biomass Energy **[10]**

Composite material synthesis for wind energy- glass, carbon, resins, aramid fibre-reinforced polymeric composites, natural fiber reinforced polymers- biocomposites, and nanocomposites for wind turbine blades. Composite manufacturing processes- Spary lay-up, press-forming, vacuum bagging and autoclave, resin infusion-vacuum process, reactive resin transfer molding and others. Testing- thermal analysis, tensile test, compression test, shear testing, rhelogy, fatigue, and recycling strategy for sustainability. Hybrid composites catalysis in biochemical/thermochemical biomass conversion to biofuels: hydrolysis, hydrotreating, reforming, deoxygenation, hydrothermal liquefaction, gasification, pyrolysis, Fischer–Tropsch synthesis, steam reforming/cracking, and transesterification. Polymeric sorbents for biogas cleaning and separation.

Unit IV. Polymers and Composites for Fuel Cells **[8]**

Polymer electrolyte membrane synthesis and characterization for fuel cells: Structure–property relationships, membrane electrode, organic-inorganic membranes-composites for bipolar plates. Design and development of proton exchange membranes fuel cell (PEMFC) based on Nafion, sulfonated poly(ether-ether ketone)s, sulfonated poly(aryl ether) for PEMFC and direct methanol fuel cell (DMFCs). Polymer composite membrane role (cation/aninon/proton-exchange membranes) in bioelectrochemical systems (MFCs) –construction and performance of MFCs.

Unit V. Polymers and Composites for Miscellaneous Renewable Energy Systems **[8]**

Polymer electrolytes in battery, lithium polymer composite and carbon based composites in batteries. Flexible organic light-emitting diodes: introduction, roll-to-roll printing and characteristics of OLEDS. Polymer/composite-based thermoelectric materials synthesis and fabrication. Natural materials for sustainable energy systems.

References:

1. Gowariker and Viswanathan, Polymer Science, Wiley Eastern, 1986.
2. Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, 1994.
3. Composite Materials, Author by Deborah D.L.Chung, Springer, 2002.
4. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley, 2010.
5. Organic Photovoltaics, CRC press-Taylor & Francis, Edited by Sam-Shajing Sun, Niyazi Serdar Sariciftci, 2005.
6. WOLEDs and organic Photovoltaics, Springer, Edited by Vivian W. W. Yam, 2010.
7. Wind energy –Hand book (2nd Edition), John Wiley & Sons, Authors-Tony Burton, Nick Jenkins, David Sharpe, Ervin Bossanyi, 2011.
8. New and future development in catalysis, Elsevier Publication, edited by Steven L. Suib, 2013.

9. Catalytic for renewables, Wiley-VCH Verlag GmbH & Co. KGaA, Edited by Gabriele Centi and Rutger A. van Santen 2007.
10. Fuel cells- Hand book, Seventh Edition, Author by Nigel Sammes, 2004.
11. PEM fuel cells- theory and practice, Elsevier Publication, Author by Frano Barbir, 2005.
12. PEM fuel cells- Material properties and performance, CRC press-Taylor & Francis, Editors: Hui Li, Shanna Knights, Zheng Shi, John W. Van Zee, Jiujun Zhang, 2010.

GETY616: Algal Energy Technology

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

Student will be in a position to assess the energy potential from culture of algae. Basic understanding on growth, characterization and lipid extraction for biofuel production shall be arrived. Various methodologies and instrumentation for large scale algal biomass production and fuel conversion will be learned. Will be become familiar with various standards of biodiesel and bioethanol.

Unit I. **[**9]

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]

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]

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]

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]

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.

References:

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.
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 520: ENERGY LABORATORY – II

L T P C

(Hard Core Course) **0 2 2 3 90L**

List of Experiments

1. Micro-controller based solar tracking system (simulation)
2. Micro-controller based solar tracking system (fabrication)
3. Impedance analysis of solar cell
4. Simulation of multi crystalline and amorphous solar modules
5. Solar panel installation
6. Fabrication of DSSC
7. I-V Characterization of DSSC
8. Thermal Performance evaluation of solar still without load
9. Performance evaluation of solar still with load
10. Solar air heater-Performance evaluation by natural convection
11. Solar air heater-performance evaluation by forced convection
12. Solar drier-Thermal performance evaluation by natural flow
13. Solar drier-Forced circulation analysis with different flow rates
14. Solar drier-evaluation of drying curve
15. Determination of thermal efficiency and heat loss factor of **FPC** based solar water heater
16. Determination of thermal efficiency and heat loss factor of **ETC** based solar water heater
17. Thermal testing of box type solar cooker: Determination of first and second figure of merits
18. To study the thermal performance of a paraboloid concentrating solar cooker
19. Performance evaluation of a single basin solar still
20. Solar air heater-Performance evaluation by natural convection
21. Solar air heater-performance evaluation by forced convection
22. Thermal performance and drying characteristic study on solar drier

Manuals

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,

References

1. Polak, P. (1979) Systematic Errors in Engineering Experiments, Macmillan Press Ltd.
2. Annual Book of ASTM standards, Section I – V, Vol. 05.01-05.05, 2002-2003.
3. Experiments with renewable energy-students guide- ISBN 1-928982-22-0, African Journal of Biotechnology, Vol. 9 (12), pp 1719 (2010).

SEMESTER – III

GETY611: Project (Phase I): Research Methodology, Proposal Writing and Defense

(Hard Core Course) **L T P C**
0 2 4 3 90L

Course Outcome:

Through this course project work student shall get acquaintance in the selection of research problem, its analysis, carrying out relevant literature survey and reviewing. Also, they will learn how to analyse data and write a technical report.

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.

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.

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

Expectation: Ethical considerations – respect of policy, formulation and implementation

References:

1. Scifinder,
2. Scopus
3. Scirus.com
4. ISI web of science

GET 612: Solar Photovoltaic Power Systems

(Hard-core Course) **L T P C** **3 0 0 3 45L**

Course Objective: This course teaches about the solar photovoltaic power system from module assembly process to establishment and commissioning of solar photovoltaic power plant

Expected Outcome: Students are expected to understand the technologies involved in the establishment and maintenance of solar photovoltaic power plant

Unit I. Solar PV Module [**9**]

Introduction: modue and circuit design - identical and non-identical cells - module structuring and assembly - assembly materials – environmental protection – interconnect: types and assembly process – crystalline and thin film modules - issues with solar PV modules, bypass diode and blocking diode – module testing and analysis- thermal considerations - electrical considerations and output conditioning - mechanical protection & module testing and evaluation.

Unit II. 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 III. SPV Power Pystems **[9]**

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., Concentrator solar cells and systems. Space quality solar cells and satellite power systems.

Unit IV. Power System Design and Installation **[9]**

Power considerations and system design – Array integration: mechanical integration – electrical integration – utility integration – Inspection and commissioning - SPV power system maintenance: cleaning, shadowing, stability etc., and troubleshooting – Economics

Unit V. Space Power Systems **[9]**

Solar Photovoltaic Power systems – Thermophotovoltaic power systems - Deep space power systems: Nuclear fusion systems, Radio-isotope Thermoelectric Generator power systems - Stirling Radioisotope Generator (SRG).

References

1. Solid State electronic devices by Ben G. Streetman, Prentice-Hall of India Pvt. Ltd., New delhi 1995.
2. Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial College Press, 2001.
3. Photovoltaic Systems Engineering, Roger Messenger and Jerry Vnetre, CRC Press, 2003.
4. Generation Distribution and utilization of Electrical Energy, C.L.Wadhwa, Wiley Eastern Ltd., India(1989)
5. Electrical Power Systems Quality by Roger C.Dugan , Mark .F. Mc Granaghan, Surya Santaso, H.Wayne Beaty, Second Edition, Mc Graw Hill, 2002

6. Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, ISBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.
7. Photovoltaic Systems, 2nd Edition, by James P. Dunlop, ISBN:9780826913081, Publisher:American Technical Publishers, Inc. 2010
8. Photovoltaics: Design and Installation Manual, by Solar Energy International, ISBN: 9780865715202, Publisher: New Society Publishers, (2004).

GETY 631: Wind Energy & Small Hydropower Systems

	L T P C
(Hard-core Course)	**3 1 0 3 45L**

Course Outcome:

Student will learn to asses the wind energy potential of a place, understand the various component of wind energy conversion system, get introduced to design and engineering aspects of wind turbine and control systems. Familiarize with different type of wind electric power generators. Lean basics of costing wind power generation. Also get know basics of small hydropower plant classification, installation detail and its impact on clean energy generation.

Unit I. Wind Energy Potential [9]

Wind Velocity Distribution – Estimation of wind resource – Wind Indian and Global scenario.

Unit II. Wind Energy Conversion [9]

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. WECS Design Considerations [9]

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

Unit IV. Wind Energy Application [9]

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. Small Hydropower Systems [9]

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
8. Small Hydro Power Potential in India, Central Electricity Authority, New Delhi, 1997.

GET613: Advanced Battery and Fuel Cell Technologies

(Soft Core Course)

L	T	P	C	
3	0	0	3	45L

Course Outcome:

- Gain knowledge on lead-acid and lithium-ion batteries components
- Acquired know-how about fabrication and evaluation of lithium-ion battery
- Get awareness about the market for electric vehicle in India and elsewhere
- Gain knowledge on hybrid energy systems
- Acquire knowledge on fabrication and evaluation of PEMFC fuel cell

Unit I. Lead Acid Battery [9]

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]

Advanced anodes and cathodes – theoretical capacity – merits and demerits - 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]

Lithium-Air, Sodium-Air, Sodium-Sulphur and Redox flow batteries: Principle – components – anodes-cathodes, fabrication-evaluation – merits and demerits and applications.

Unit IV. Fuel Cell Technology [9]

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]

Concept of hybrid energy systems, development of battery and supercapacitors systems – Batteries and Fuel cells power systems – Recent developments and application areas.

References

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
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.

GETY614: Nanotechnology for Energy Systems

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- Computational skill (nanomaterial properties)
- Practical skill in making nanomaterials and characterizing it

Unit I. Nano-electronics [9]

Concept of wave-matter duality, phase and group velocities, electron state in solids, uncertainty principle, operators, quantum mechanical postulates, Schrödinger's Wave Equation, free electron gas, spherical, electron in spherical potential (hydrogen atom), Hydrogen molecule, Atom by Atom arrangements , band structure formation, E-k diagram, electronic states of 2-D, 1-D, 0-D nanosystems.

Unit II. Physical Properties of Nanosystems [9]

Light absorption in Nano systems, size dependence and material dependence of absorption, band gap engineering, Fermi-level, ballistic and diffusive transport in nanosystems, coulomb blockade, resonant tunnelling, carrier separation techniques

Unit III. Nanotechnology for Solar Energy Conversion [9]

Challenges in energy conversion – role of nanostructures & materials – nanomaterials in solar Photovoltaic Technology: quantum well solar cell, quantum wire solar cell, quantum dot solar cell – quantum dot sensitized solar cell, photo-current calculation. Tandem structures –nanotechnology for solar thermal fuels, nanotubes for solar energy harvesting, Concept of photo-electro chemical cell.

Unit IV. Nanotechnology for Energy Storage [9]

Nanostructured electrodes fabrication, nanotubes for energy storage, nanotechnology for electrochemical storage, Nanotechnology for conversion of solar energy to hydrogen

Unit V. Nanotechnology for Energy Efficient Devices [9]

Energy efficient devices –fabrication and applications of quantum well LED as light device, –optical amplifiers, quantum well lasers, optical switch, Quantum dot luminescence materials.

Reference

1. Quantum Chemistry, Levine, Prentice Hall
2. Statistical Mechanics and properties of matter, E.S.R Gopal,Ellis Horwood
3. Introduction to solids, Azaroff, Tat Mc-Graw Hill.
4. Physical principles of micro Micro-electronics, G.Yepifanov, Mir Publishers, 1974, 1st Edition
5. Semiconductor device- An Introduction-Jasprit singh, Mc Graw Hill, International Edition, 1994
6. Nanoelectronics, B.Premlet, Phasor books, first edition 2012
7. Nanostructures and Nanomaterials, Synthesis, Properties and Applications,G. Gao, Imperial College Press, first edition, 2004

GETY 615: Energy Audit and Management

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

Course is designed to impart necessary knowledge on energy conservation and its management. Students shall learn energy conservation act (ECA), role of State and Central government in implementing ECA, role of Bureau of Energy Efficiency (BEE), various types of energy audits, techno-economic analysis of various energy conservation measures. Student shall be in a position to carryout material and energy balance calculation for various energy intensive systems.

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, vapor compression refrigeration cycle, refrigerants, factors affecting refrigeration and air conditioning system performance and savings potential.

Vapor absorption refrigeration system, working principle, types and comparison with vapor 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. Industrial energy management and utilization, Larry Witte, CRC Press, First edition, 1987.
2. Energy Management Principles, applications, benefit and saving, Craig B. Smith, Kelly E. Parmenter, Pergamon, First edition, 2013.
3. Energy Conservation Manual, Wulfinghoff, Donald, Energy Institute Press,First edition, 1999.
4. Industrial Energy Conservation, Reay D.A, Pergamon Press, First edition, 1977.
5. Energy Efficiency for Engineers and Technologists, T.D. Eastop, D.R. Croft, Logman Scientific & Technical. First edition, 1990.

GETY619: BIOREFINERIES

(Soft Core Course)

L T P C
3 0 0 3 45L

Course Outcome:

Learn various methodologies to convert biomass to biocurude. Acquire knowledge on conversion of biomass feedstock to complex and value added biomolecules. Specifically gain understanding on developing end-to-end solution for biofuel production and commercially sustaining the process in algae based biofuel conversion process.

Unit I. [6]

Liquefaction of Biomass: Biomass Feedstock -Thermochemical Conversion of Biomass – Liquefaction by Pyrolysis - Hydrothermal Liquefaction. Gasification -Biochemical Conversion-Pretreatment-Enzymatic Hydrolysis Fermentation.

Unit II. [9]

Biochemical Conversion & Metabolites: Introduction -Primary Metabolites -Saccharides -Lignin -Amino Acids, Peptides, and Proteins - Fatty Acids, Lipids -Organic Acids -Secondary Metabolites -Simple Phenols and Phenolic Acids -Polyphenols -Terpenes -Alkaloids - Stability of Isolated Compounds.

Unit III. [12]

Bio-separation Processes: Conventional Separation Approaches-Steam Distillation-Conventional Solid–Liquid Extraction -Ultrasound-Assisted Extraction -Microwave-Assisted Extraction -Pressurized Subcritical Liquid Extraction -Supercritical Fluid Extraction -Separation and Purification of Phytochemicals from Plant Extracts and Dilute Solution in Biorefineries -Liquid–Liquid Extraction -Membrane Separation-Molecular Distillation

Unit IV. Bio-refinery Concepts [9]

Classification of Biorefineries – Whole crop, Oleochemical and Lignocellulosic Feedstock Biorefineries – Adoptability of Biorefineries in Petrochemical Refineries. Case studies: Specific Feedstock Based Biorefinery Process Development.

Unit V. Algal Bio-refinery [9]

Micro algae and Macro algae -Microalgae Biomass Production –Directed Algae Production Techniques -Down Stream Processing –Integrated Bioprocess in Algae - Value Added Chemicals from Biomass - Algal Phytochemicals, Biodiesel, Proteins, Polyunsaturated Fatty Acids, Vitamins, Carotenoids - Industrial products: Phycobiliproteins, Phycocolloids and Phycosupplements.

Text Books:

1. Biofuels Engineering Process Technology by Caye M. Drapcho, Nghiem PhuNhuan, & Terry H. Walker, McGraw Hill Publishers.
2. *Bioprocess Engineering Principles*; Pauline M Dorass, Academic Press.
3. Ladisch, M.R., (2001), Bioseparation Engineering: Principles, Practice and Economics, Wiley, Interscience.
4. Biochemical Engineering Fundamentals; James E. Bailey and David F.Ollis, Mc Graw Hill book company.
5. Pauline M. Doran. Bioprocess engineering principles. Academic press. 1995

6. Biofuels from Plant Oils published by ASEAN Foundation (2010).
7. Industrial Biorefineries and White Biotechnology, Ashok Pandy et al (Editors), Elsevier 2015, ISBN :9780444634535

GETY 610: ENERGY LABORATORY – III
(Virtual Instrumentation and Case Studies on Sustainable Energy Systems)

	L T P C
(Hard Core Course)	**3 2 4 3 90L**

Course Outcome:

- Gain simulation and modeling skill.
- Apply computational and programming skill set to solve renewable energy technology related problem.
- Acquire basic concept of virtual instrument based programming and interfacing.
- Learn the programing skill to control and interact with devices in real-time.

Virtual Instrumentation and Case Studies

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 subVIs- Creating an icon and connector pane Graphing with LabVIEW: Using waveform charts to display data, XY graphs to display data Strings and File I/O: Creating string controls and indicators, Using File I/O VIs
Data Acquisition: Plug-in DAQ devices, Performing analog I/O, Counters, Digital I/O, Instrument Control, .Sensors and Transducers, PC Based Measurement Data Acquisition & Signal Conditioning., Intelligent Instrumentation.

Manuals & References:

1. LabVIEW for Data Acquisition (Paperback) Bruce Mihura Prentice Hall, 2001
2. LabVIEW for Electric Circuits, Machines, Drives, and Laboratories, by Nesimi Ertugrul, Prentice Hall 2002
3. LabView: Advanced Programming Techniques, SECOND EDITION Rick Bitter,
4. Taqi Mohiuddin, Matt Nawrocki CRC Press; 2 edition, 2006

5. LabVIEW for Everyone: Graphical Programming Made Easy and Fun (3rd Edition) (Hardcover)~ Jeffrey Travis,
6. 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.

Manuals & References:

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. Design and Simulation of an Automated System for Greenhouse using LabVIEW, American- Eurasian Journal and Environmental Science, 2008, vol 3, 279-284.
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

SEMESTER - IV

GET 620 Green Technology Dissertations:

(Hard Core Course) Full-time Dissertation work

Course Outcome:

1. Student shall specialize through industrial training and/or research work in the renewable energy field of their choice & basic degree specialization
2. Learn to identify a research problem or industrial problem, devise a methodology to solve the same.
3. Trained on design, fabrication and testing of energy products
4. Learn the entrepreneurship potential in renewable energy technologies.

Course Code	Course Title	Course Type*	L	T	P	C
GETY620	Green Energy Technology Dissertation Viva-voce	H	-	-	-	11 1
	Total No. of Credits					**12**

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

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

Minimum credit requirement = 72; All teaching, learning and evaluations will follow Choice Based Credit System (CBCS) which is in vogue in Pondicherry University.

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OTHER SOFT-CORE COURSES

These courses will be offered in any of first three semesters depending on the availability of the resource faculty.

	L T P C
(Bridge Course)	**3 0 0 3 45L**

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.

GETY 518: Environmental Risk Management

	L T P C
(Soft Core Course)	**3 0 0 3 45L**

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

References

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.

GETY 527: Green management

(Soft Core Course) **L T P C** **3 0 0 3 45L**

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

1. **References**

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

GETY 528: GREEN CHEMISTRY

(Soft Core Course)

	L	T	P	C	
	2	0	4	3	53L

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. **[8]**
Introduction to Organic Chemistry/ Analytical Chemistry /Basic Chemical Engineering

Unit II. **[9]**
Introduction to Green Chemistry: Principles of Green Chemistry, Reasons for Green Chemistry (resource minimization, waste minimization, 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. **[6]**
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. Scale-up aspects including PE in Process Chemistry: Case Studies; New Initiatives: Micro reactors, Spinning Disc reactors **[6]**

Practical chemistry (Mini project): [16]

References

1. James H.Clarke & Duncan Maacquarrie, Handbook of Green Chemistry and Technology, Wiley- lackwell; 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)a

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 531 Advanced Heat Transfer for Energy Engineering

L T P C

(Soft Core Course) **3 0 0 3 45L**

Unit I. Basic Concepts [6]

Introduction, Heat transfer in engineering, Mechanism of heat transfer, Temperature field and temperature gradient, Conduction, Thermal Conductivity, Thermal insulation, Contact resistance, Convection, Thermal radiation, Concept of driving potential, Combined mechanism of heat transfer.

Unit II. Conduction [11]

Conduction equation; Steady state conduction in simple geometries: Thermal contact resistance; Critical thickness of insulation; Multidimensional steady state heat conduction, Conduction in other shapes, Shape factor, Steady state heat conduction in solid/hollow cylinders with uniform heat generation, Transient heat conduction; Lumped heat capacity analysis; Heiler's charts for semi-Infinite medium; Slab cylinder and sphere.

Unit III. Heat Transfer with Extended Surfaces (Fins) [8]

Introduction, Fin model, Temperature calculation, Heat flow calculation, Fin performance: Fin effectiveness, Fin efficiency, Overall surface efficiency or Total efficiency, Circumferential fins and plate fins of varying sections, Optimization, Fin with radiation surrounding. Application of fins in enhanced heat transfer.

Unit IV. Convection & Radiation [11]

Principle of similarity, Mechanism of convection, Convective heat transfer coefficient, Free convection (Laminar, Turbulent &Mixed) on horizontal, vertical and Inclined plates, cylinder and sphere, forced convection inside tubes and ducts, Forced convection over exterior surfaces, Blackbody radiation, View factor algebra, Enclosures with black surfaces and grey surfaces, Radiosity, Heat exchangers and its types.

Unit V. Heat Exchangers [9]

Introduction, Overall heat transfer coefficient, Classification of heat exchangers, Log mean temperature difference, Heat exchanger performance: Effectiveness, Pressure drop and pumping power, Special cases, Effectiveness-NTU chart, Storage type heat exchangers, Compact heat exchangers.

References

1. The Dynamics of Heat: A Unified Approach to Thermodynamics and Heat Transfer, Fuch, Hans U, Springer Publications, 2010
2. Fundamentals of Heat and Mass Transfer, Frank P.Incroperal, David P.DeWitt, , John Wiley & Sons, 1998.

3. Yunus A. Cengel, Introduction to Thermodynamic and Heat Transfer, McGrew Hill Company, Inc. (1997).
4. Frank W. Schmidt. Robert E. Henderson and Carl H. Wolgemuth, Introduction to Thermal Sciences: Thermodynamics, Fluid Dynamics, Heat Transfer, John Wiley and Sons Inc. (1993).
5. M.N. Oziesik, Heat Transfer - A Basic Approach, McGrew Hill Book Co., New Delhi.
6. M.Becter, Heat Transfer: A Modem Approach
7. S.P. Shukatme, Heat Transfer, Orient Longman, New Delhi.
8. W.H. Giedt, Principles of Engineering Heat Transfer, D.Van Norstand Company Inc.(1961)
9. F. Kireth, Radiation Heat Transfer, International Text book Co., Semton, USA (1962).

GETY 532 Electrical Power Generation and Power System Analysis

L T P C

(Soft Core Course) **3 0 0 3 45L**

Unit I. Power Generation [13]

Thermodynamic analysis of Conventional Power Plants. Advanced Power Cycles, Kalina (Cheng) Cycle, IGCC, AFBC/PFBC, Steam Turbine - Superheater, reheater and partial condenser vacuum. Combined Feed heating and Reheating. Regenerative Heat Exchangers, Reheaters and Intercoolers in Gas Turbine power plants. Hydro power plants - turbine characteristics. Auxiliaries - Water Treatment Systems, Electrostatic Precipitator / Flue gas Desulphurisation, Coal crushing / Preparation - Ball mills / Pulverisers, ID/FD Fans, Chimney, Cooling Towers Synchronous generator operation, Power angle characteristics and the infinite bus concept, Dynamic analysis and modeling of synchronous machines, Excitation systems, Prime-mover governing systems, Automatic generation control, Auxiliaries, Power system stabilizer, Artificial intelligent controls. Tariff and Economic aspects in power Generation: Terms commonly used in system operation, various factors affecting cost of generation: Load curves, load duration curves, Connected load, maximum load, Peak load, base load and peak load power plants, load factor, Plant capacity factor, Plant use factor, Demand factor, diversity factor, Cost of power plant, Tariffs.

Unit II. Electrical Power System Analysis [12]

Electrical Power System Analysis: Network modeling and short circuit analysis: Primitive network, Y bus an Z bus matrices formulation, Power invariant transformations, Mutually coupled branches Z bus, Fault calculations using Z bus, Power flow solutions: AC load flow formulations, Gauss-siedel method, Newton Raphson method, Decoupled power flow method, Security analysis: Z bus methods in contingency analysis, Adding and removing multiple lines, Interconnected systems, Single contingency and multiple contingencies, Analysis by DC model, System reduction for contingency studies, State Estimation: Lone power flow state estimator, Method of least squares, Statistics error and estimates, Test for bad data.

Unit III. Power Transmission [7]

Power quality of AC Transmission: Overhead and cables, Transmission line equations, Regulation and transmission line losses, Reactive power compensation, Flexible AC transmission, HVDC Transmission: HVDC converters, Advantages and economic considerations converter control characteristics, Analysis of HVDC link performance, Multi terminal DC system, HVDC and FACTS.

Unit IV. Distribution **[6]**

Distribution: Distribution systems, Conductors size, Kelvin's law performance calculations and analysis, Distribution inside and commercial buildings entrance terminology, Substation and feeder circuit design considerations, Distributions automation, Futuristic power generation.

UNIT V. Power System Monitoring **[7]**

Monitoring the power system, Determination of variance, Improving state estimates by adding measurements, Hierarchical state estimation, Dynamic state estimation, Power system stability: transient and dynamic stability, Swing equation, Electric power relations, Concepts in transient stability, Method for stability assessment, Improving system stability.

Text/References

1. Power Generation, Operation, and Control by Allen J. Wood and Bruce F. Wollenberg, John Wiley & Sons, 2003.
2. Power System Control and Stability by P. M. Anderson and A. A. Fouad, Wiley-IEEE Press, 2002.
3. Electric Energy Systems Theory: An Introduction by Olle I Elgerad, T M H Edition, 1982.
4. HVDC Transmission: Power Conversions Applications in Power Systems by Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee, Wiley – IEEE Press, 2009.
5. Electric Power Transmission System Engineering Analysis and Design by Turan Gonen, CRC Press, 2009.
6. Power system stability and control by P. Kundur. McGraw-Hill, 1994.
7. R.W.Haywood, Analysis of Engineering Cycles, 4th Edition, Pergamon Press, Oxford, 1991.
8. D. Lindsay, Boiler Control Systems, Mcgraw Hill International, London, 1992.
9. H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.
10. T.M. O' Donovan, Short Term Forecasting: An introduction to the Box Jenkins Approach, Wiley, Chichester, 1983
11. A.B.Gill, Power Plant Performance, Butterworths, 1984.
12. Wood, A.J., Wollenberg, B.F., Power Generation, operation & control, John Wiley, New York, 1984.

GETY 618: Green Concepts in Buildings

L T P C

(Soft Core Course) **3 0 0 3 45L**

Pre-requisite (undergraduate degree in civil engineering)

Learn the process of energy cost in developing dwelling for human activity.

Unit I. **[9]**

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. **[9]**

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. **[9]**

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. **[9]**

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. **[9]**

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.

References

1. K.S.Jagadish, B. U. Venkataramareddy and K. S. Nanjundarao. Alternative Building Materials and
2. Technologies. New Age International, 2007.
3. Low Energy Cooling For Sustainable Buildings. John Wiley and Sons Ltd, 2009.
4. 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.

C. 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. Sustainable Building Design Manual. Vol 1 and 2, Teri, New Delhi, 2004. Hill, 2001.
7. Osman Attmann Green Architecture Advanced Technologies and Materials. McGraw Hill, 2010.
8. Michael F. Ashby Materials and the Environment, Elsevier, 2009.
9. Jerry Yudelson Green building Through Integrated Design. McGraw Hill, 2009.
10. Mili M. Ajumdar (Ed) Energy Efficient Building in India. Teri and Mnes, 2001/2002.
11. T. N. Seshadri et al Climatological and Solar Data for India. CBRI and Sarita Prakashan, 1968.
12. Fundamentals of Integrated Design for Sustainable Building By Marian Keeler, Bill Burke
13. The New Solar Electric Home: The Photovoltaics How-To Handbook, by Joel Davidson, ISBN:
14. 9780937948095, Publisher: Aatec Publications, Publication Date: July 1987.

GETY 618: Carbon sequestration at landscape level

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- Learn the concept of CO2 generation and fixation in the globe.
- Familiarize the international laws, convention and regulation on carbon sequestration
- Develop basic understanding on biomass synthesis, available energy potential, its exploitation, current scenario in India.

Unit I. Climate change and International agreements [9]

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. Primary productivity: mechanisms and assessment [10]

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. Biogeochemistry [10]

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. Remote sensing and spatial analysis [12]

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. Biomass as a major source of energy in India [4]

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.

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.

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