PONDICHERRY UNIVERSITY
PUDUCHERRY - 605014

Syllabus & Regulations

For

P.G. Diploma in Green Energy Technology

2019

PONDICHERRY UNIVERSITY
P.G. DIPLOMA PROGRAM IN GREEN ENERGY TECHNOLOGY

(Regular, One Year Programme)

Supported by University Grants Commission, New Delhi
Under Innovative Programme – 2013

Revised Syllabus w.e.f. 2019

BACKGROUND

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

Post Graduate Diploma in Green Energy Technology offered at Pondicherry University is designed to equip students with multi-disciplinary skills and knowledge in the areas of green energy generation technologies, energy management with environmental concern. The course will be taught by a team of specialists working in the fields of green energy technology, chemical science, biological science, project management, and environmental policy. This is program is designed for one year duration, comprised of two semesters. First semester comprises hard and soft core theory courses together with laboratory practical to enrich understanding of students in the areas of Green Energy Technologies. Each theory course is designed to have a project component to explore the technical understanding and skill development. Second semester is entirely dedicated for project work and dissertation. The entire course of study requires earning at least 36 credits to qualify for the P.G.Dip. in Green Energy Technology (PGD-GET). B.E/B.Tech in Mechanical, Electrical, Civil, Electronics, Chemical or Biotechnology specialization, or M.Sc in Physics, Chemistry, Material Science, Nanoscience or Photonics with Mathematics at B.Sc level and having at least 55% marks or equivalent grade in the qualifying examination are eligible to undergo this program. Industry sponsored quota of 3 seats has been reserved for candidates. Qualification shall be same as prescribed for regular students. However students admitted under industry quota are exempt from writing entrance examination but shall write Department level / University level screening test at the time of admission. The eligibility under Industry category and the selection process for the same shall be as per Pondicherry University norms notified time to time.

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

energy resources including the environmental and ecological impact, Overall understanding about the solar photovoltaic, solar thermal, bio-energy, wind, ocean, hydro and other new means of energy generation, energy efficiency, utilization, storage and distribution methodologies.

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

In addition to above, course curriculum and syllabi will be updated time to time based on the developments. Teaching and Learning Methods includes lectures, tutorials and seminars as main methods and in addition course delivery will be enhanced by individual and group project work, laboratory work, computing workshops and industrial visits.

Assessment Methods: Teaching and assessment will be by Choice Based Credit System (CBCS). Evaluation will be through session (laboratory reports, class tests, set assignments) or by continuous assessment (designing, computer practical, seminar papers, project reports etc.) and end-semester examinations. 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 P.G.D.GET holder will gain employment in the Engineering Industry with many companies now seeking to exploit the benefits of green energy technology products and processes.
Minimum credit requirement is fixed as 36. All teaching, learning and evaluations will follow Choice Based Credit System (CBCS) which is in vogue in Pondicherry University. Bridge courses are no credit courses. All students are expected to clear bridge courses, however, exemption to do the bridge course can be obtained on the basis of recommendation of a committee of experts consisting of the faculty advisor, concerned teacher, Head, Dean, and VC's nominee in the PC.

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P.G. DIPLOMA IN GREEN ENERGY TECHNOLOGY

COURSE STRUCTURE

SEMESTER-I

Course Code	Course Title	Course Type*	L	T	P	C
CORE COURSES						
GETD511	Energy, Environment and Renewable Energy Technologies	H	3	1	0	3
GETD512	Thermodynamics, Fuels & Combustion Technology	H	3	1	0	3
GETD513	Solar Photovoltaic Devices & Energy Conversion Systems	H	3	1	0	3
GETD514	Solar Thermal Technology & Energy Conversion Systems	H	3	1	0	3
GETD515	Biological Systems, Resources & Bioenergy Technologies	H	3	1	0	3
SOFT-CORE COURSES[#] (Any Two to be taken)						
GETD516	Wind Energy Technologies	S	3	0	0	3
GETD517	Biodiesel: Feedstock Development & Fuel Production	S	3	0	0	3
GETD518	Battery and Fuel Cell Technologies	S	3	0	0	3
Practical						
GETD510	Energy Laboratory	H	0	2	4	3

Minimum No. of Credits: 24

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

 # Relevant soft core courses offered to M.Tech. (Green Energy Technology) in III Semester may also be taken (listed in Annexure I).

SEMESTER II

Course Code	Course Title	Course Type*	L	T	P	C
GETD520	Green Energy Technology Dissertations					
	Dissertation					11
	Viva Voce	H				1
	Total Credits					**12**

Evaluation:

All theory and practical courses shall have Internal Assessment marks of 40 and External Assessment Marks 60.

Dissertation Project Carries Internal Assessment Marks of 75 and External Assessment Marks of 25, Total 100.

PROFILE OF THE COURSES

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

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

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

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

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

6. Wind Energy
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.

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

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

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

Post Graduate Diploma in Green Energy Technology

Programme Specific Outcome

1. Trained manpower in the area of major renewable and clean energy technologies
2. Acquire specialization on the chosen field of renewable energy through industrial training and/or dissertation project.
3. Gaining specific understanding on fabrication and evaluation of solar cells, battery, supercapacitors and fuel cells.
4. Gaining specific understanding on design and installation of PV power plant, solar thermal devices.
5. Specific understanding on biodiesel, bioethanol and biogas production
6. Specific understanding on conversion of waste to energy and harnessing energy from the wind

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GETD511: Energy, Environment and Renewable Energy Technologies

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

Course Outcome:

- Illustrate nexus between energy, environment and sustainable development
- Describes energy in ecosystems and its impact on environment
- Introduces basics of all renewable and clean energy technologies
- Compares various renewable energy technological impacts on environment and gives insight to students about significance of hybrid renewable energy for sustainability

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, Photovoltic conversion and Photothermal 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. E H Thorndike, Energy & Environment: A Primer for Scientists and Engineers, Addison-Wesley Publishing Company
2. R Wilson & W J Jones, Energy, Ecology and the Environment, Academic Press Inc.
3. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.
4. C. S. Solanki, "Solar Photovoltaics: Fundamental Applications and Technologies, Prentice Hall of India, 2009. L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
5. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.
6. S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill (1984).
7. Energy and EnvironmentSet: Mathematics of Decision Making, Loulou, Richard; Waaub, Jean- Philippe; Zaccour, Georges (Eds.), 2005, XVIII, 282 p. ISBN: 978-0-387-25351-0
8. Energy and the Environment, 2nd Edition, John Wiley, 2006, ISBN:9780471172482; Authors: Ristinen, Robert A. Kraushaar, Jack J. AKraushaar, Jack P. Ristinen, Robert A., Publisher: Wiley, Location: New York, 2006.
9. Energy and the Challenge of Sustainability, World Energy assessment, UNDP, N York, 2000.
10. J. Goldemberg, T.B. Johansson, A.K.N. Reddy and R.H. Williams: Energy for a Sustainable World, Wiley Eastern, 1990.
11. P. Meier and M. Munasinghe: Energy Policy Analysis &Modeling, Cambridge University Press, 1993.

GETD512: Thermodynamics, Fuels & Combustion Technology

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

Course Outcome:

- Equip with fundamentals of thermodynamic principles
- Learn basics of solid, liquid and gases fuels.
- Lean in details about the fuel conversion techniques and illustrate the extraction, handling and storage of various fuels for use.
- Gives insight about combustion stoichiometry theory and practice
- Learn the engineering aspects of burners and industrial furnaces and its applications.

Unit I. Thermodynamic Systems and Cycles **[13]**

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

Unit II. Solid Fuels **[8]**

Coal: Family, origin, classification of coal; Analysis and properties; Action of heat on coal; Gasification; Oxidation; Hydrogenation and liquefaction of coal- Efficient use of solid fuels- Manufactured fuels-Agro fuels- Solid fuel handling- Properties related to combustion - handling and storage

Unit III. Liquid and Gaseous Fuels [8]

Origin and classification of petroleum; Refining; Properties & testing of petroleum products; various petroleum products; Petroleum refining in India; Liquid fuels from other sources; Storage and handling of liquid fuels. Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG; Cleaning and purification of gaseous fuels.

Unit IV. Combustion Process [8]

Ignition: Concept, auto ignition, ignition temperature; Burners: Stoichiometry and thermodynamics; Combustion stoichiometry: Methods of combustion - Combustion thermodynamics. Fuel stoichiometry relations and stimation of combustion - Dew point of products; Flue gas analysis (O2, C2, CO, NOx, SOx).

Unit V. Burners & Furnaces [8]

Fluidized bed combustion process; Basic features and design of burners for solid, liquid, and gaseous fuels; Furnaces: Industrial furnaces, process furnaces, batch & continuous furnaces; Heat source; Distributions of heat source in furnaces; Blast furnace; Open hearth furnace, Kilns; Pot & crucible furnaces; Waste heat recovery in furnaces: Recuperates and regenerators; Furnace insulation; Furnace heat balance computations; Efficiency considerations.

References

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

GETD513: Solar Photovoltaic Devices & Energy Conversion Systems

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

Course Outcome:

To gain knowledge on solar energy conversion principles, learn fundamentals of semiconductors and their application for solar cell fabrication and solar characterization. To develop understanding on solar photovoltaic power system from module assembly process and know the necessary details of establishment and commissioning of solar photovoltaic power plant

Unit I. Properties of Semiconductor [8]

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

Unit II. Device Fabrication and Characterization [10]

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

Unit III. Solar Cell Module Materials and Assembly [9]

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

Unit IV. Solar PV System Components & System Design [10]

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

Unit V. Advanced SPV Technologies [8]

Solar PV concentrators – Concentrator photovoltaic materials and devices – Hybrid SPV power systems – SPV power plant design tools and methodologies – SPV economics

References

1. Fundamentals of Photovoltaic Modules & Their Applications, by GopalNath Tiwari, ISBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.
2. Fundamentals of Solar Cells: PV Solar Energy Conversion, Alan L Fahrenbruch and Richard H Bube , Academic Press, New York , 1983
3. Photovoltaic Systems, 2nd Edition, by James P. Dunlop, ISBN:9780826913081, Publisher:American Technical Publishers, Inc. 2010
4. Photovoltaics: Design and Installation Manual, by Solar Energy International, ISBN: 9780865715202, Publisher: New Society Publishers, (2004).
5. Ben G. Streetman, Solid State electronic devices, , , Prentice-Hall of India Pvt. Ltd., New delhi 1995.
6. M. D. Archer, Clean electricity from photovoltaics, R. Hill, Imperial College Press, 2001.

GETD514: Solar Thermal Technology & Energy Conversion Systems

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

Course Outcome:

This paper aims to impart knowledge on 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.

Unit I. Solar Radiation [4]

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

Unit II. Heat Transfer [12]

Conductive and Radiative Heat Transfer: Steady state conduction in one and two dimension- Unsteady state conduction - Heat conduction with and without heat generation - heat conduction in extended surfaces - solution to 2D heat conduction equation - numerical methods and finite difference method. Heat exchange by radiation - shape factor - radiant heat exchange in different geometries. *Convective Heat Transfer:* Fluid flow: Navier-Strokes equations - Laminar and turbulent flow - boundary layer concept - solution to boundary layer problem. Heat transfer by convection - Heat transfer in laminar and turbulent flow systems - heat flow across a cylinder. Heat exchangers. Boiling and Condensations: Types of boiling - Film and drop condensation - Condensation on vertical plate and horizontal tubes.

Unit III. Solar Thermal Energy Device [11]

Selective Surfaces: Ideal coating characteristics; Types and applications; Anti-reflective coating; Preparation and characterization. Performances of solar collectors. *Flat-plate Collectors:* Effective energy losses; Thermal analysis; Heat capacity effect; Testing methods; Evacuated tubular collectors; Air flat-plate Collectors: types; Thermal analysis; Thermal drying. *Concentrating Collector:* Performance parameters; Tracking systems; Compound parabolic concentrators; Parabolic trough concentrators; Concentrators with point focus; Heliostats; Comparison of various designs: Central receiver systems, parabolic trough systems; Solar power plant; Solar furnaces.

Unit IV. Solar Cooling System [8]

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

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

Modeling of solar thermal system components and simulation; Design and sizing of solar heating systems: f – chart method and utilizability methods of solar thermal system evaluation; Development of computer package for solar heating and cooling applications; Industrial process heat: Temperaturerequirements, consumption pattern; Applications of solar flat plate water heater & air heater for industrial process heat; Designing thermal storage; Transport of energy. Solar still; Solar cooker: Solar

References

1. Solar Cell Device Physics, by Stephen Fonash, ISBN:9780123747747, Publisher: Academic Press, Publication Date: April 2010
2. Sukhatme S P., A Text Book on Heat Transfer, University Press, 1996
3. Renewable Energy Resources, John W Twidell and A D Weir, ELBS
4. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997
5. Solar Energy, S P Sukhatme, Tata McGraw Hill
6. Solar Energy Handbook, J F Kreider and Frank Kreith, McGraw Hill
7. Principles of Solar Engineering, D Y Goswami, Frank Kreith and J F Kreider, Taylor & Francis.
8. Solar Engineering of Thermal Processes, J A Duffie and W A Beckman, John Wiley and Sons, New York
9. Tiwari G.N., Suneja S., Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997.
10. Tiwari G.N., Goyal R.K., Greenhouse Technology: Fundamentals, Design Modeling and Application, Narosa Publishing House, 1998.
11. Renewable Energy: Power for a sustainable future, Godfrey Boyle (Ed), The Open University, Oxford University Press.

GETD515: Biological Systems, Resources & Bioenergy Technologies

L T P C

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

Course Outcome:

- Introduce fundamentals of biological systems necessary to grasp bioenergy concepts
- Understand global bioenergy scenario and relate to bioenergy resources in India.
- Learn various biofuel types and its characteristics
- Develop understanding of various types of bioenergy conversion systems in practice
- Basic knowledge on algal culture, biomass harvest and biodiesell production
- Understanding on national and international standards of biodiesel.

Unit I. Introduction to Biomolecules [9]

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

Unit II. Biomass [6]

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

Unit III. Biochemical Conversions [9]

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

Unit IV. Thermochemical & Chemical Conversions [12]

Thermochemical Conversion: Direct combustion, incineration, pyrolysis, gasification and liquefaction; economics of thermochemical conversion. Biogasification: Biomethanation process, biogas digester types, biogas utilisation; Waste to energy. Chemical Conversion: Hydrolysis & hydrogenation; solvent extraction of hydrocarbons; solvolysis of wood, biocrude, biodiesel production via chemical process; catalytic distillation; transesterification methods; Fischer-Tropsch diesel: chemicals from biomass.

Unit V. Biofuels Standards & Power Generation [9]

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

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

GETD510: GREEN ENERGY LABORATORY

L T P C

(Hard Core Course) 0 2 4 3 90L

Course Outline:

A. Lectures:

Basic concepts: Terminology used in experimental methods i.e. sensitivity, accuracy, uncertainty, calibration and standards; experimental system design and arrangement.

Analysis of experimental data: Analysis of causes and types of experimental errors, uncertainty and statistical analysis of experimental data.

Data acquisition and processing: Data acquisition methods, data storage and display, examples of application in typical energy system.

Apparatus design and construction: Conceptual, substantive and detail designs of experiments; illustration of thermal energy equipment/devices and their accessories.

Experiment plan and execution: Preparatory work for carrying out experiments; range of experimental study, choice of measuring instruments, measurement system calibration, data sheets and log books, experimental procedure, etc; applications.

Technical Communication: Report preparation of experimental work, use of graphs, figures, tables, software and hardware aids for technical communication.

B. Laboratory:

Renewable Energy Technologies

1. Solar: Solar radiation analysis, Experimental study on thermal performance of solar water heater, solar dryers, solar PV cell characterization and its networking, solar cooker, Building duelling solar cells
2. Radiometry: Luxmeter circuit designing, Pyranometer circuit designing
3. Biomass: Experimental study on thermal performance and efficiency of biomass downdraft gasifier and sampling and analysis of air and flue gas from biomass energy systems i.e. gasifier, combustor and cook stoves using gas chromatography technique. Biogas production by anaerobic digestion and analysis.
4. Fuels: Density, Viscosity, Flash-point, Fire-point Pour-point, ASTM distillation of liquid fuels.
5. Proximate and ultimate analysis, calorific value of solid fuels.
6. Storage: Programmable batteries

References

1. Garg H.P., Kandpal T.C., Laboratory Manual on Solar Thermal Experiments, Narora Publishing House, New Delhi, 1999.
2. Holman, Jack P. (1984) Experimental Methods for Engineers, McGraw-Hill Book Company.
3. Doebelin, Ernest O. (1995) Engineering Experimentation – Planning, Execution, Reporting, McGraw-Hill,
4. Polak, P. (1979) Systematic Errors in Engineering Experiments, Macmillan Press Ltd.
5. Annual Book of ASTM standards, Section I – V, Vol. 05.01-05.05, 2002-2003.
6. Experiments with renewable energy-students guide- ISBN 1-928982-22-0
7. African journal of Biotechnology, Vol 9(12), pp 1719 (2010)

GETD516: Wind Energy Technologies

L T P C

(Soft-core course) **3 0 0 3 45L**

Course Outcome:

Student will learn to wind energy potential of a place, understand the various component of wind energy conversion system, get introduced to working of wind turbine and its control systems. Familiarize with different type of wind electric power generators.

Unit I. Wind Energy Potential [8]

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

Unit II. Wind Energy Conversion [12]

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 [8]

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

Unit V. Wind Power Generation & Control [9]

Wind electric generators – Fixed speed induction generators – Voltage Source Converters – Double fed induction generators – Fully rated convertors. Power quality from wind turbines.

Unit V. Wind Energy Application [8]

Wind forms – Stand-alone and Grid-connected systems - Hyrbidsystems.Wind pumps: Performance analysis, design concept and testing; Economics of wind energy utilization; Wind energy in India; Case studies.

References

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

GETD517: Biodiesel: Feedstock Development & Fuel Production

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

Course Outcome:

- Develop understanding how to culture algae biomass for biodiesel production.

- Familiarise with challenges and limitation of biodiesel production, alternate production processes, and its techno-economical evaluation.
- Learn the biodiesel properties, national and international biodiesel standards in force.

Unit I. **[**10]

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

Unit II. **[**7]

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

Unit III. **[**8]

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

Unit IV. **[**8]

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

Unit V. **[**12]

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. Algae by Linda E. Graham and Lee W. Wilcox, Printice Hall (2000)
2. Biofuels Engineering Process Technology by Caye M. Drapcho et al. Mc. Graw Hill (2008)
3. Fresh water Algae: Identification and use as bioindicator by Edward Bellinger and David Saigee; Wiley-Blackwell, 2010. ISBN 978-0-470-05814-5
4. Hand book of microalgae culture: Biotechnology and Applied Phycology, Edited by Amos Richmond, Blackwell Science, 2004. ISBN 0–632–05953–2
5. Algal Culturing Techniques, Edited by R. Andersen, Academic Press 2004. ISBN: 9780120884261
6. Algae Biofuel by S K Bhatnagar, AtulSaxena, Stefan Kraan; Studium Press (India) Pvt. Ltd. (2011)
7. Success & Visions for Bioenergy: Thermal processing of biomass for bioenergy, biofuels and bioproducts, Edited by A V Bridgwater, CPL Press September 2007.
8. Anthony San Pietro, Biochemical and Photosynthetic aspects of Energy Production, Academic Press, New York, 1980.
9. National Algal Biofuels Technology Roadmap, US DOE, Office of Energy Efficiency & Renewable Energy, Biomass Program (2010); www.biomass.energy.gov.

GET618: Battery and Fuel Cell Technologies

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

Course Outcome:

- Gain knowledge on fabrication technology of battery and fuel cells
- Gain knowledge on lead-acid and lithium-ion batteries components
- Acquired know-how about fabrication and evaluation of lithium-ion battery
- 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, Zinc-Air 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.

SEMESTER II

GETD520: Green Energy Technology Dissertations

(Hard Core Course) Full-time Dissertation Project

Course Outcome

1. Student shall specialize through industrial training and/or research work in the renewable energy field of their choice.

2. Trained on design, fabrication and testing of energy devices

4. Exposed to entrepreneurship potential in renewable energy technologies.

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

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

Dissertation Credits: 11

Viva Voce Credits: 1

Total Credits: 12

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ANNEXURE- I

Course Code	CourseTitle	Course Type*	L	T	P	C
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
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	GreenBuildingConcept	S	3	0	0	3
GETY531	Advance Heat Transfer for Energy Engineering	S	3	0	0	3
GETY532	Electrical Power Generation and Power System	S	3	0	0	3
GETY618	Carbon Sequestration at Landscape Level	S	3	0	0	3

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