PhD Courses

Learning Outcome based Course Structures

2024

Department of Energy Engineering

Assam Science and Technology University

Tetelia Road, Jalukbari, Guwahati – 781013, Assam, India

http://astu.ac.in/astu/

PhD Courses for Energy Engineering

Course Code	Course Title	Scheme of Studies Per Week L– T - P	Credits C
Core Courses (Paper I, II & III)			
Paper I			
DEE2401	Doctoral Research Methodology for Energy Engineering	2-0-0	2
Paper II			
DEE2402	Energy, Environment and Climate Change	2-0-0	2
Paper III			
DEE2403	Research and Publication Ethics	2-0-0	2
Elective Courses (Paper IV & V)			
DEE2404	Decentralized Energy System	3-0-0	3
DEE2405	Power Generation and System Planning	3-0-0	3
DEE2406	Energy Conservation and Waste Heat Recovery	3-0-0	3
DEE2407	Fuel & Combustion Technology	3-0-0	3
DEE2408	Waste to Energy Technologies	3-0-0	3
DEE249	Energy Storage System	3-0-0	3
DEE2410	Energy Efficient Building	3-0-0	3
DEE2411	Energy Audit and Management	3-0-0	3
DEE2412	Fuel Cells and Hydrogen Energy	3-0-0	3
DEE2413	Hydro Power Management	3-0-0	3
DEE2414	Advanced Solar Thermal and Photovoltaic systems	3-0-0	3
DEE2415	Wind Power Technology	3-0-0	3
DEE2416	Advanced Solar Thermal Technology	3-0-0	3
DEE2417	Bioenergy and Biomass Conversion Technology	3-0-0	3
DEE24118	Advanced Solar Photovoltaic Technology	3-0-0	3
DEE2419	Hybrid Renewable Energy Systems Design	3-0-0	3
DEE2420	Advanced Characterization Techniques	3-0-0	3

PAPER-I

(as per UGC Recommendation)

Course code	Course Name	L– T - P	C
DEE2401	Doctoral Research Methodology for Energy Engineering	2-0-0	2

Course Outcomes:

CO1: Understand research problem formulation in the field of energy.
CO2: Plan and Execute Doctoral Research in Energy Engineering & Technology
CO3: Understand the significance of Intellectual Property Right in technological research and innovation activities
CO4: Protect intellectual property of research outcomes

Course Content:

Unit 1: Research problem: definition, sources and characteristics. Common errors in selecting a research problem, Scope and objectives in a research problem.

An outlook on energy study from historical perspectives, Current trends and future directions in energy science and engineering researches, understanding the international and national priority of energy research in selected areas **(5 hrs)**

Unit 2: Approaches of Effective literature reviews, investigation of solutions for research problem, visualization, conceptualization, data collection, analysis, interpretation
Research Methodology: Experiments, Quantitative Methods. Computational techniques etc
Selection of a Research Topic in the field of energy, Preparation of plan of research work in energy related fields: understanding the essential elements. **(8 hrs)**

Unit 3: Reporting research outcomes, Effective technical writing, how to write research manuscript, Process of thesis preparation **(5 hrs)**

Unit 4: Nature of Intellectual Property: Patents, Designs, Trade and Copyright.

Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. **(5 hrs)**

Unit 5: Recent advancements in IPR, IPR of Energy systems, processes and products: examples. Understanding the significance of IPR in relevant research field: on the basis of traditional knowledge and case studies. **(4 hrs)**

Unit 6: Understanding the concept of research funding; financial, administrative and other kind of supports in research.

Major publishing houses, funding organizations and contributors related to energy research **(3 hrs)**

References:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.
7. Asimov, "Introduction to Design", Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
10. Kothari C R (2004) Research Methodology: Methods and Techniques. New Age International Private Limited Publishers, New Delhi
11. Drake P (2010) Practitioner Research at Doctoral Level: Developing Coherent Research Methodologies. Routledge Publisher
12. Bly R W and Blake G (2002) Elements of Technical Writing 1 New ed Edition. Pearson
13. E-contents to be also provided

PAPER-II

Course code	Course Name	L– T - P	C
DEE2402	**Energy, Environment and Climate Change**	**2-0-0**	**2**

Course Outcomes:

CO1: Understand contemporary issues related to energy, environment and climate change

CO2: Examine feasibility of renewable energy technology from the perspectives of energy conservation and management

CO3: Discuss the prospects of clean energy technology for combating climate change

CO4: Assess socio- and techno-economic aspects of renewable energy technology deployment

Course contents:

Energy Implications: (10 hrs)

Energy conversion and utilization- Solar, biomass, hydro power, wind and other sources of energy. Power generation from different energy sources, Energy demand; Economics importance of utilization of different energy sources Energy conservation and management-basic concepts, Energy conservation opportunities in household, transport, lighting etc. Energy Conservation Act, Cost-benefit analysis of renewable energy systems; factors that impact selection of energy technologies and policy

Energy – Environment interactions: (5 hrs)

Impact of fossil fuel utilization on environment, Fossil resource scarcity, Global warming, Green House Gas emissions, impacts, mitigation; Ecosystem Sustainability; Clean energy technologies;

Dealing with Climate change Consequences: (6 hrs)

Emission targets; Measures to reduce GHGs; Climate Change Act; International responses,CDM activities in Industries; Emission benchmarks, United Nations Framework Convention on Climate Change (UN FCCC); Sustainable development; Kyoto Protocol; Conference of Parties (COP); Clean Development Mechanism (CDM); Prototype Carbon Fund (PCF)

Governments policies for mitigation and adaptation: (3 hrs)

Price-based mechanisms such as cap-and-trade and carbon taxes, complementary non-price policies, and concepts of justice that frame the political negotiations; Carbon Market; Commerce of Carbon Market, Environmental Transformation Fund

Technology Perspective: (3 hrs)

Strategies for technology innovation and transformation, carbon sequestration, strategic management of carbon emissions

Carbon Trading: (3 hrs)

The concept of carbon credits, standard and branched credits and mechanisms, alternative trading models, global and Indian scenarios

Text Books:

[1] Stern, N.(2007). The Economics of Climate Change. The Stern Review. Cambridge University Press, New York.

[2] Barrett,S.(2007). Why Cooperate? The Incentive to Supply Global Public Goods. Oxford University Press, Oxford.

[3] Capoor, K., Ambrosi, P.(2008). State and Trends Of The Carbon Market (2008). The World Bank, Washington D.C.,May 2008. Available at: /http://siteresources. worldbank.org/ NEWS /Resources /State &Trends formatted 06 May10pm.pdf.

[4] Hodge B. K. Alternative Energy Systems, Publisher: Wiley; New Edition

[5] Hinrichs & Kleinbach. Energy: Its Use and the Environment, Fourth edition, Thompson Learning, 2005

[6] Craig R. Humphrey, Tammy L. Lewis, and Frederick H. Buttel Belmont. Environment, Energy, and Society: A New Synthesis. CA: Wadsworth Group, 2002.

[7] Kandpal T.C., H. P. Garg (2003) ; Financial Evaluation of Renewable Energy Technology, Macmilan India Ltd. New Delhi

PAPER-III

(as per UGC Recommendation)

Course code	Course Name	L– T - P	C

DEE2403	Research and Publication Ethics	2-0-0	2

Course Outcomes:

CO1: Recognize the publication ethics and publication misconducts
CO2: Understand the philosophy of science and ethics and research integrity
CO3: Develop hands-on skills to identify research misconduct and predatory publications.
CO4: Differentiate indexing and citation databases, open access publication and research metrics
CO5: Use plagiarism tools

Course Content:

Theory

Unit 1: PHILOSOPHY AND ETHICS (3hrs)

1. Introduction to Philosophy: definition, nature and scope, concept, branches
2. Ethics: Definition, moral philosophy, nature of moral judgments and reactions.

Unit 2: SCIENTIFIC CONDUCT (5hrs.)

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication and Plagiarism (FFP)
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data

Unit 3: PUBLICATION ETHICS (7 hrs.)

1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME etc.
3. Conflicts of interest
4. Publication misconduct: Definition, concept, problems that lead to unethical behavior and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals.

Practice

Unit 4: OPEN ACCESS PUBLISHING (4hrs.)

1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

Unit 5: PUBLICATION MISCONDUCT (4 hrs.)

A. Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2 hrs.)

1. Use of plagiarism software like Turnitin, Urkund and other open source software tool

Unit 6: DATABASES AND RESEARCH METRICS (7 hrs.)

A. Databases (4hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus etc.

B. Research Metrics (3hrs.)

1. Impact factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, i10 index, altmetrics

References:

1. Bird, A (2006). Philosophy of Science. Routledge.
2. MacIntyre, Alasdair (1967) A Short History of Ethics. London.
3. P. Chaddah, 2018 Ethics in Competitive Research : Do not get scooped; do not get plagiarized, ISBN: 978-9387480865
4. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academies Press.
5. Resnik, D.B. (2011). What is ethics in research & why is it import. National Institute of environmental Health Sciences, 1-10. Retrieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/ index.cfm
6. Beall, J.(2012). Predatory Publishers are corrupting open access. Nature,489 (7415), 179-179. https://doi.org/10.1038/48917a
7. Indian National Science Academy (INSA), Ethics in Science Education, Research AND Governance (2019) ISBN:978-81-939482-1-7. https://www.insaindia.res.in/pdf/Ethics_Book.pdf

PAPER-IV and PAPER-V

(two courses to be selected from below)

Course code	Course Name	L– T - P	C
DEE2404	**Decentralized Energy System**	**3-0-0**	**3**

Course Outcomes

CO1: Review distributed energy generation systems
CO2: Analyze Wind/PV System modeling for decentralized energy generation
CO3: Explain micro-grid configuration
CO4: Assess the feasibility of decentralized energy systems
CO5: Identify the factors effecting the performance of energy storages systems

Course Content:

Distributed Generation: Reasons for growth, extent of DGs, Issues with DGs, Policy/institutional issues, market/financial issues, social/environmental issues, DG Plant Types, DG Machinery & its control, Integration issues, Technical impacts of DGs, Economic impact of DGs, Impact on transmission and generation systems, Security and reliability. International DG Integration Experience. **(5 hrs)**

Wind/PV System Modelling: Wind/PV variability and uncertainty. Forecasting methods

and applications. **(5 hrs)**

System studies: Power flow studies, Fault studies, Stability studies, Transient studies, Inertia and Frequency Response studies. Power Quality Issues. **(5 hrs)**

System balancing & imbalance handling: Flexibility Issues, Ramping issues, Inertia and Frequency Response Issues, Role of storage and DR and related issues, Large scale storage for grid stability / Backup. **(5 hrs)**

Technical regulations for the interconnection of DGs to the power systems: Overview of technical regulations, Active power control, Frequency control, Voltage control, Technical solutions for new interconnection rules. Protection of DGs. Feasibility of integrating Large-Scale Grid Connected DG, Policy, Market and Regulatory Interventions, Regulatory challenges, Viability of DG integration in deregulated electricity market. **(5 hrs)**

• **Economics of DG:** Value of power from DGs, Market value of power from DGs, Loss reduction, Investment reduction, Connection costs and charges, Distribution use of system charges, Allocation of losses in distribution networks with DG, Alternative framework for distribution tariff development.

DGs in areas of limited transmission capacity. DGs in distribution networks. Active Management of Distribution systems. Ancillary Services with DGs, Markets for Ancillary Services. DER Management, Virtual Power Plants. **(5 hrs)**

Micro Grids: Concept, Design, Modelling, Operation and Analysis. Role in Energy Reliability, Cold Load Pick Up and Sustainability. **(5 hrs)**

Energy Storage: Type and modelling of storage systems. Scheduling issues, Ancillary services from energy storage, Role in Energy Security, Reliability and Stability. **(5 hrs)**

Optimal design tool:

Optimal design of hybrid energy systems, energy economics and cost optimization of integrated energy systems; Sample problems and case studies, Simulation tools like H OMER, RETSCREEN etc. renewable energy based Micro-grid **(5 hrs)**

Text Books:

1. Math H. Bollen, Fainan Hassan, "Integration of Distributed Generation in the Power System", WileyIEEE Press, 2011.

2. Willis H. Lee and Scott W. G., "Distributed Power Generation Planning and Evaluation", Marcel Dekker, Inc, New York, 2000.

3.B. Fox, D. Flynn L. Bryans, N. Jenkins, M. O' Malley, R. Watson and D. Milborrow, "Wind Power Integration: Connection and System Operational Aspects" IET, 2007.

4.Loi Lei Lai, Tze Fun Chan, "Distributed Generation: Induction and Permanent Magnet Generators" Wiley-IEEE Press, 2007.

5. Komarnicki, Przemyslaw, Lombardi, Pio, Styczynski, Zbigniew , "Electric Energy Storage Systems", Springer, 2017.

6. Garcia-Valle, Rodrigo, Peças Lopes, João A, "Electric Vehicle Integration into Modern Power Networks", Springer, 2012.

Course code	Course Name	L– T - P	C
DEE2405	Power Generation and System Planning	3-0-0	3

Course Outcomes

CO1: Understand principles of power generation planning
CO2: Analyze business models for power industry
CO3: Design advanced models for power transmission and distribution

Course Content:

Modeling of Power System Components

The need for modeling of power system, different areas of power system analysis. Models of non-electrical components like boiler, steam & hydro-turbine & governor system. Transformer modeling such as auto-transformer, tap-changing & phase shifting transformer. **(10 hrs)**

System Planning

Introduction, Objectives & Factors affecting to System Planning , Short Term Planning, Medium Term Planning, Long Term Planning, Reactive Power Planning. **(5 hrs)**

Load Forecasting

Introduction, Factors affecting Load Forecasting, Load Growth Characteristics, Classification of Load and Its Characteristics, Load Forecasting Methods (i) Extrapolation (ii) Co-Relation Techniques, Energy Forecasting, Peak Load Forecasting, Reactive Load Forecasting, NonWeather Forecasting, Weather Forecasting, Annual Forecasting, Monthly Forecasting, Total Forecasting. **(8 hrs)**

Generation Planning

Objectives & Factors affecting Generation Planning, Generation Sources, Generation System Model, Loss of Load (Calculation and Approaches), Outage Rate, Capacity Expansion, Scheduled Outage, Loss of Energy, Evaluation Methods. Interconnected System, Factors Affecting Interconnection under Emergency Assistance. **(8 hrs)**

Transmission Planning

Introduction, Objectives of Transmission Planning, Network Reconfiguration, System and Load Point Indices, Data required for Composite System Reliability. **(6 hrs)**

Distribution Planning

Radial Networks - Introduction, Network Reconfiguration, Evaluation Techniques, Interruption Indices, Effects of Lateral Distribution Protection, Effects of Disconnects, Effects of Protection Failure, Effects of Transferring Loads, Distribution Reliability Indices. Parallel & Meshed Networks -Introduction, Basic Evaluation Techniques, Bus Bar Failure, Scheduled Maintenance, Temporary and Transient Failure, Weather Effects, Breaker Failure. **(8 hrs)**

Text Books:

1. Modern Power System Planning - X. Wang & J.R. McDonald, McGraw Hill Book Company

2. Power System Planning - R.N. Sullivan, Tata McGraw Hill Publishing Company Ltd.

References:

1. Electrical Power Distribution Engineering - T. Gonen, McGraw Hill Book Company
2. Reliability Evaluation of Power System - Roy Billinton & Ronald N. Allan, Springer Publication
3. Generation of Electrical Energy - B.R. Gupta, S. Chand Publications
4. Electrical Power Distribution A.S. Pabla Tata McGraw Hill Publishing Company Ltd.
5.Electricity Economics & Planning - T.W.Berrie, Peter Peregrinus Ltd., London

Course code	Course Name	L– T - P	C
DEE2406	Energy Conservation and Waste Heat Recovery	3-0-0	3

Course Outcomes

CO1: Understand different approach for waste heat recovery
CO2: Design strategies for enhancing performance of energy systems using waste heat recovery techniques
CO3: Analyze energy conservation, management and planning of industrial processes incorporating waste heat recovery

Course Content:

Principle of energy conservation: Introduction; Quality of energy; Importance of exergy analysis; Available Energy referred to a cycle; Availability in a finite process; Available Energy from a finite energy source; Demonstration of quality of energy based on exergy; Exergy balance for closed and open system; Tools for exergy analysis **(5 hrs)**

Recovery of Waste Heat: Introduction; Methods of utilization of waste heat; Total energy approach; Combined plant; GT-ST power plant; MHD-Steam power plant; Thermionic Generation; Thermoelectric generators **(5 hrs)**

Performance criteria for CHP: Energy Utilization factor, Fuel Energy saving ratio, Rational efficiency, Rational criteria **(4 hrs)**

Waste heat recovery through Heat Exchanger: Sources of waste heat recovery, Potential application of waste heat, Essential consideration in making optional choice of waste heat recovery device, Waste heat recovery system, Some concepts on Heat exchanger, Classification of waste heat recovery exchangers, Gas to Gas waste heat recovery, Spiral plate heat exchanger, Heat wheels/Rotary regenerator, Storage type of Regenerative Heat Exchanger, Rothemuhle Regenerator, Pebble bed heat exchanger, Plate heat exchanger, Shell and tube heat exchanger, Metallic Radiative recuperators, Run around coil **(8 hrs)**

Gas to Liquid Heat Recovery: Introduction, Classification of WHRB **(3 hrs)**

Waste Heat Recovery Devices: Introduction, Thermal conductivity of a heat pipe, Characteristics of a heat pipe, Application of heat pipe, Limitation of Heat Pipe, pressure drop analysis for 1-D incompressible flow in a heat pipe, Condition for flow in a heat pipe,

Working fluid, Desirable properties of Working fluid, Factor responsible for performance of heat pipe, Construction material, wick material, Rating of Heat pipe

Heat pump : Introduction, Working fluid, Heat pipe size, Type of Heat Pumps, Different type of heat pump

Heat recovery from incineration plant : Introduction, Classification of incinerator Organic Rankine Cycle : Introduction, Daimler Benz Organic Rankine cycle **(8 hrs)**

Energy Storage: Introduction, Energy Management, Energy Storage system, Pumped hydro energy storage system, Compressed air energy storage, Energy Storage by Fly wheels, Electrical Battery storage system, Super Conducting Magnetic Energy storage, Thermal energy Storage, Pressurized Water thermal sensible energy storage system, Latent Heat Energy Storage, Chemical Reaction Storage, Storage in Chemical reaction **(7 hrs)**

Energy Economics: Pay Back period, Return of Investment Method, Straight line depreciation, Reducing Balance depreciation, Sinking fund depreciation **(5 hrs)**

References:

1. Proceedings of CD Programme, QIP by P. Mahanta, Associate Professor Dept. of ME, IITG.
2. K. Annamalai and I.K. Puri , Advanced Thermodynamics Engineering, CRC Press, 2002.
3. A Bejan, Advance Engineering Thermodynamics, John Wiley, New York, 1988.
4. P.K. Nag, Power Plant Engineering 2nd Edition, Tata Mc Graw Hill Publishing Company Limited, New Delhi 2007.
5. G Wall, Exergy – A useful concept, Physical Resource Theory Group, Goteborg , 3rd Edition, 1986.
6. M.M. El-Wakil, Power Plant Technology, Mc-Graw Hill, 1985.

Course code	Course Name	L– T - P	C
DEE2407	**Fuel & Combustion Technology**	**3-0-0**	**3**

Course Outcomes

CO1: Identify the characteristics of solid, liquid and gaseous fuels
CO2: Understand the importance of advanced fuels and their properties
CO3: Analyse the performance of combustion processes
CO4: Assess the design and efficiency of combustion devices
CO5: Examine the emission characteristics in combustion systems

Course Content:

Solid Fuels: Coal: Family, origin, classification of coal; Analysis and properties; Action of heat on coal; Gasification; Oxidation; Hydrogenation and liquefaction of coal- Efficient use of solid fuels-Manufactured fuels-Agro fuels- Solid fuel handling- Properties related to combustion - handling and storage **(8 hrs)**

Liquid and Gaseous Fuels: Origin and classification of petroleum; Refining; Properties & testing of petroleum products; various petroleum products; Petroleum refining in India;

Liquid fuels from other sources; Storage and handling of liquid fuels. Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG; Cleaning and purification of gaseous fuels. **(8 hrs)**

Advanced Fuels: Clean Coal Technology, Coal Bed Methane, Gas Hydrates and Shale Gas/Oil **(6 hrs)**

Theory of Combustion Process: Ignition: Concept, auto ignition, ignition temperature; Burners: Stoichiometry and thermodynamics; Combustion stoichiometry: Methods of combustion - Combustion thermodynamics. **(8 hrs)**

Fuel stoichiometry and analysis: Fuel stoichiometry relations; Estimation of air required for complete combustion; Estimation of minimum amount of air required for a fuel of known composition; Estimation of dry flue gases for known fuel composition; Calculation of the composition of fuel & excess air supplied, from exhaust gas analysis; Dew point of products; Flue gas analysis (O2, CO2, CO, NOx, SOx). **(10 hrs)**

Burner Design and Furnaces: Fluidized bed combustion process; Burners: Propagation, various methods of flame stabilization; Basic features and design of burners for solid, liquid, and gaseous fuels; Furnaces: Industrial furnaces, process furnaces, batch & continuous furnaces; Advantages of ceramic coating; Heat source; Distributions of heat source in furnaces; Blast furnace; Open hearth furnace, Kilns; Pot & crucible furnaces; Waste heat recovery in furnaces: Recuperates and regenerators; Furnace insulation; Furnace heat balance computations; Efficiency considerations. **(5 hrs)**

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. E
5. J. D. Gilchrist , Fuels, Furnaces & Refractories, Pergamon Press.

Course code	Course Name	L– T - P	C
DEE2408	Waste to Energy Technologies	3-0-0	3

Course Outcomes

CO1: Understand wastes generated from different sources and due to human activities

CO2: Identify the link of legal, technical and management principles for production of energy form waste.

CO3: Design waste management strategies for simultaneous energy generation and value

addition

CO4: Assess feasibility of different waste to energy conversion processes

Course Content:

Introduction to Energy from Waste: (15 hrs)

Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

Solid Waste Management: Solid Waste Sources, types, composition, Properties, Municipal SolidWaste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste, Status of technologies for generation of Energy from Waste Waste Treatment and Disposal: Aerobic composting, incineration, Furnace type anddesign, Medical waste /Pharmaceutical waste treatment Technologies, incineration,Environmental impacts, Measures to mitigate environmental effects due to incineration

Land Fill method of Solid waste disposal: 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

Conversion of Waste to Energy: (30 hrs)

Biomass Pyrolysis: Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications. Unit-III:

Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production - Urban waste to energy conversion - Biomass energy programme in India.

Text Books/References:

1. C Parker and T Roberts (Ed), Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985

2. Desai, Ashok V., Non Conventional Energy, Wiley Eastern Ltd., 1990.

3. KL Shah, Basics of Solid and Hazardous Waste Management Technology, Prentice Hall, 2000

4. C. Y. Were Ko-Brobby and E. B. Hagan, Biomass Conversion and Technology, John Wiley & Sons, 1996.
5. M Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
6. G Rich et.al, Hazardous Waste Management Technology, Podvan Publishers, 1987 5. AD Bhide, BB Sundaresan, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983
7. Khandelwal, K. C. and Mahdi, S. S., Biogas Technology - A Practical Hand Book - Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983
8. Naomi B Klinghoffer and Marco J Castaldi,"Waste to Energy Conversion Technology" Woodhead Publishing, 2018.
9. Lisa Branchini, "Waste-to-Energy: Advanced Cycles and New Design Concepts for Efficient Power Plants", Springer, 2015.
10. Challal, D. S., Food, Feed and Fuel from Biomass, IBH Publishing Co. Pvt. Ltd., 1991.
11. P. Basu, "Biomass Gasification and Pyrolysis: Practical Design and Theory", AcademicPress, 2010.
12. Gary C. Young, "Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons", Wiley, 2010.

Course code	Course Name	L– T - P	C
DEE249	**Energy Storage System**	**3-0-0**	**3**

Course Outcomes

CO1: Understand the concept of different forms of energy storage
CO2: Analyze energy storage potential of advanced materials and systems
CO3: Design sustainable solutions for energy storage applications
CO4: Compare the performance and production costs of different energy storage **solutions**

Course Content:

Introduction: Energy Demand and Storage, Different types of energy storage; Mechanical, Chemical, Biological, Magnetic, Comparison of Energy Storage technologies **(5 hrs)**

Thermal Storage: Thermal energy storage: Principles and applications, Sensible and Latent heat, Phase Change Materials; Energy and Exergy analysis of thermal energy storage, solar energy and thermal energy storage, case studies **(10 hrs)**

Mechanical and Electrical Storage: Flywheel and compressed air storage; Pumped hydro storage; Hydrogen energy storage, Capacitor and super capacitor, Electrical double layer Capacitor: Principles, performance and applications **(10 hrs)**

Other Storage Types: Hydrogen as energy carrier and storage; Hydrogen resources and production; Basic principle of direct energy conversion using fuel cells; Thermodynamics of fuel cells; Fuel cell types: AFC, PAFC, PEMFC, MCFC, SOFC, Microbial Fuel cell; Fuel cell performance, characterization and modeling; Fuel cell system design and technology, application for power and transportation **(10 hrs)**

Battery: Battery: fundamentals and technologies, characteristics and performance

comparison: Leadacid, Nickel-Metal hydride, Lithium Ion; Battery system model, emerging trends in batteries **(5 hrs)**

Applications: Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage: Greenhouse heating; Drying and heating for process industries. **(5 hrs)**

Text Book:

1. Huggins R. (2010); Energy Storage, Springer
2. Ter-Gazarian A. (2011); Energy Storage for Power System, Second Edition, The Institution of Engineering and Technology

Reference Book:

1. O'Hayre R. Cha S. Colella W. and Prinz F.B. (2009); Fuel Cell Fundamentals, Second Edition, Wiley
2. Narayan R. and Viswanathan B. (1998); Chemical and Electrochemical Energy System, Universities Press
3. Dincer I. and Rosen M.A. (2010), Thermal Energy Storage: System and Applications, Second Edition, Wiley
4. Rahn C.D. and Wang C. (2013); Battery Systems Engineering, First Edition, Wiley

Course code	Course Name	L– T - P	C
DEE2410	**Energy Efficient Building**	**3-0-0**	**3**

Course Outcomes

CO1: Review the principles of energy conservation opportunities in buildings
CO2: Analyze thermal comfort of buildings based on engineering principles
CO3: Design feasible solution for thermal energy management in building
CO4: Assess thermal performance of building architecture and building materials

Course Content:

Introduction: Energy management concept in building, Energy auditing in buildings **(5 hrs)**

Climatic Aspects: Classification of climate zones, Bioclimatic classification of India; Climate analysis for Nat-Vent Buildings, Mixed Mode Buildings and conditioned buildings; Passive design concept for various climatic zones; Integrations of landscape to building design; Urban Heat Island, Case studies on typical design of selected buildings in various zones **(5 hrs)**

Architecture: Vernacular architecture: Vernacular architecture in Indian context, factors which shape the architecture, Building material and construction techniques; Case studies on vernacular architecture of Rajasthan, Northeast India; Low cost buildings, alternate building materials, climate responsive buildings **(7 hrs)**

Energy Efficient Building: Energy efficient buildings, Green buildings, Intelligent buildings, Building integrated photovoltaics (BIPV), Building codes and rating systems: LEED, GRIHA, ECBC, Thermal properties and Energy content of building materials **(7 hrs)**

Simulations: Building energy simulations, Tool like TRNSYS etc, building management systems/automation, Artificial and Day lighting in buildings **(5 hrs)**

Energy Conservation Techniques: Energy conservation techniques in Air Conditioning Systems; Estimation of building loads, passive and low energy concepts and applications, passive heating concepts: Direct heat gain, Indirect heat gain, Isolated gain and Sunspaces; Passive cooling concepts: Evaporative cooling, Radiative cooling; Application of wind, water and Earth for cooling; Shading, Paints and cavity walls for cooling; Roof radiation traps; Earth air-tunnel; Design of efficient day lighting systems **(8 hrs)**

Green Buildings: Green buildings – definition and attributes; Genesis of green buildings; Design aspects of green building, Economic aspects of green buildings, Energy and environmental management; Green buildings in India; Case studies. **(8 hrs)**

Text Book:

1. Sodha M.S. Bansal N.K. Bansal P.K. Kumar A. and Malik M.A.S. (1986); Solar Passive Building, Science and Design, Pergamon Press
2. Gallo C. Sala M. and Saying A.A.M. (1988); Architecture: Comfort and Energy, Elsevier Science

Reference Book:

1. Nayak J.K. and Prajapati J.A. (2006); Handbook on Energy Conscious Buildings; Solar Energy Centre, New Delhi
2. Underwood C.P. and Yik F.W.H. (2004); Modelling Methods for Energy in Buildings, Blackwell Publishing
3. Parsons K.C. (2003); Human Thermal Environments, Second Edition, Taylor and Francis
4. Majumder M. (2009); Energy Efficient Buildings, TERI, New Delhi

Course code	Course Name	L– T - P	C
DEE2411	**Energy Audit and Management**	**3-0-0**	**3**

Course Outcomes:

CO1: Understand and apply the concept of energy management and energy management opportunities

CO2: Identify energy auditing methodologies for preparing a sample energy audit report (walk through and detailed)

CO3: Evaluate performance and efficiency of machines, devices, industrial equipments and systems

CO4: Assess energy conservation opportunities in households, MSMEs and large scale industries

Course Content:

Introduction: Definition and objective, Need & Scope for Energy Audit **(5 hrs)**

Electrical Energy Management: Conservation in motors, pumps and fan systems; energy efficient motors. **(5 hrs)**

Thermal Energy Management: Energy conservation in boilers, steam turbines and

industrial heating systems;; Cogeneration and waste heat recovery; Thermal insulation; Heat exchangers and heat pumps; Building Energy Management. **(8 hrs)**

Energy Audit Methodology: Need for energy audit, Type of energy audit, Ten step methodology for detailed energy audit, Pre audit phase activities, Detailed energy audit activities **(6 hrs)**

Identification of Energy Conservation Opportunities: Fuel substitution, Energy generation, Energy distribution, Energy uses by processes, Technical and economical feasibility, Sample worksheet for economic feasibility, Classification of Energy Conservation Measures **(8 hrs)**

Energy Audit Reporting Format: Report on detailed energy audit, Content, Energy Costs, Bench marking, & energy performance, Matching energy uses to requirement, Maximizing system efficiency **(7 hrs)**

Energy Audit Instruments: Key Instruments for Energy Audit : Electrical Measuring Instrument, Combustion analyser, Fuel efficiency monitor, Fyrite, Contact thermometer, Infrared Thermometer, Pitot Tube and Manometer, Water flow meter, Speed measurements, Leak detector, Lux meters **(6 hrs)**

References:

1. CB Smith, Energy Management Principles, Pergamon Press, NewYork, 1981
2. P. O'Callaghan: Energy Management, McGraw - Hill Book Company, 1993.
3. Y P Abbi and Shashank Jain. Handbook on Energy Audit and Environment Management, TERI Publications, 2006
4. NPC Energy Audit manual and report
5. Energy management handbook, John Wiley and Sons – Wayne C. Turner
6. Guide to energy management, Cape Hart, Turner and Kennedy
7. Cleaner production – Energy Efficiency Manual for GERIAP, UNEP, Bangkok prepared by National Production Council.

Course code	Course Name	L– T - P	C
DEE2412	Fuel Cells and Hydrogen Energy	3-0-0	3

Course Outcomes

CO1: Identify different methods of hydrogen production and storage
CO2: Understand working principle of fuel cell
CO3: Identify suitable components for design of fuel cell systems
CO4: Compare performance of different types of fuel cell
CO5: Design and Fabricate fuel cell system considering its techno-economic feasibility study

Course Content:

Fuel Cell Basics: Fuel cell definition, Difference between batteries and fuel cells, fuel cell history, components of fuel cells, principle of working of fuel cells Fuel cell thermodynamics - second law analysis of fuel cells, efficiency of fuel cells fuel cell

electrochemistry - Nernst equation, Electrochemical kinetics, Butler-Volmer equation **(8 hrs)**

Fuel cell classification and performance: Classification by operating temperature/electrolyte type, Fuel Cell Performance, Activation, Ohmic and Concentration over potential **(6 hrs)**

Fuel cell design and components: Cell components, stack components, system components Overview of intermediate/high temperature fuel cells - Solid oxide fuel cells (SOFC), Molten carbonate fuel cells (MCFC), Phosphoric acid fuel cells (PAFC) Polymer Electrolyte fuel cells ,Heat and mass transfer in polymer electrolyte fuel cells, water management in PEFCs, Current issues in PEFCs, Direct methanol fuel cells (DMFC) - Electrochemical kinetics methanol oxidation, Current issues in MFCs, Fuel crossover in DMFCs, Water management in DMFCs, high methanol concentration operation, limiting current density **(10 hrs)**

Hydrogen Energy: Production of hydrogen from fossil fuels, electrolysis, thermal decomposition, photochemical and photo-catalytic methods **(8 hrs)**

Hydrogen production methods: Production of hydrogen from fossil fuels, electrolysis, thermal decomposition, photochemical and photo-catalytic methods **(7 hrs)**

Hydrogen storage methods: Metal hydrides, metallic alloy hydrides, carbon nano-tubes, sea as source of deuterium **(6 hrs)**

Text Books/Reference:

1. J Larminie and A Dicks, Fuel Cell Systems Explained, 2nd Edition, Wiley,2003
2. Xianguo Li, Principles of Fuel Cells, Taylor and Francis, 2005
3. S Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer €
4. O'Hayre, SW Cha, W Colella and FB Prinz, Fuel Cell Fundamentals, Wiley, 2005
5. A Faghri and Y Zhang, Transport Phenomena in Multiphase Systems, Elsevier 2006

Course code	Course Name	L– T - P	C
DEE2413	Hydro Power Management	3-0-0	3

Course Outcomes

CO1: Review the basics of hydro power generation
CO2: Understand working principle of different components of hydroelectic power plant
CO3: Assess the reliability and environmental impact of hydro power projects
CO4: Develop a roadmap for hydro power management in global and Indian context

Course Content:

Basic Hydro Power Concepts: History of Hydro Power development , Importance of Hydro energy in the National Economy, Hydro Power Concepts , World and, Indian Hydro Energy Potential , Calculation of Hydro energy Potential of a Water Source , Hydro Power R & D Centres/ Institutions, Component Manufacturing Industry at International and National level **(12 hrs)**

Water Mills: Designs of Traditional Water Mills Worldwide , Improved Water Mills :

Turbines 1-5KW, , Relevance for hilly regions, Design considerations of a Water Mill System , MNRE Scheme, Present Status of Improved Water Mills **(11 hrs)**

Hydro Power Plants: Design considerations of a Hydro Energy Power Plant ,Components of hydroelectric power plant, Various types of Turbines, hydro potential and exploitation in India, Micro hydal Power Projects , Major hydroelectric Power Plants in India, Hydro power projects in Western Himalayas, Environmental Impact of Large Hydro power Projects, Case studies **(12 hrs)**

Economics, Policy, Organization, Regulations: Economic and financial assessments, planning process, Economics of hydro policies and initiatives of Government for promotion of hydropower, organizations involved in hydropower development, Financing of hydropower projects, Legal issues, , Implications of hydropower development from privatization, Sustainable use of natural resources and its implications on project economy, Implications on project development from Environmental Impact Assessment [EIA processes, Design, cost estimates and cost benefit analysis, Economic risk- and sensitivity analyses, corporate social responsibility **(10 hrs)**

Text Books/References:

1. G Brown, Hydro Electric Engineering: Vol. I, II, III
2. Nigam, A Hand Book of Hydro Electric Engineering, Nem Chand.
3. B Honningsvåg, Hydropower in the New Millennium, Proceedings of the 4th International Conference on Hydropower Development, Hydropower '01, Bergen, Norway, Taylor and Francis, 20-22 June 2001
4. F Koester, Hydroelectric Developments and Engineering: A Practical and Theoretical Treatise on the Development, Design, Construction, Equipment and Operation of Hydroelectric Transmission Plants, D. Van Nostrand Co.,Original from the New York Public Library, 1909
5. BR Gupta, Generation Electrical Energy, S. Chand & Co.

Course code	Course Name	L– T - P	C
DEE2414	**Advanced Solar Thermal and Photovoltaic systems**	**3-0-0**	**3**

Course Outcomes

CO1: Review the basic principles of solar energy utilization
CO2: Discuss the materials and components used in solar thermal and PV systems
CO3: Design solar thermal systems for different applications
CO4: Evaluate performances of solar thermal and PV systems
CO5: Design feasible projects on solar PV and solar thermal plant installation and maintenance

Course Content:

Solar Radiation: Solar Constant, Global, Beam and Diffuse radiation, Hourly, Daily and Seasonal variation of solar radiation, Sun-earth angles, Instruments for measurement of solar radiation **(7 hrs)**

Photo thermal systems: Flat-Plate Collectors, Solar Concentrators, Solar water heating systems, solar dryers, solar distillation, Solar space heating and cooling systems **(12 hrs)**

Photovoltaic systems: Fundamentals of Semiconductor and Solar Cells, Generation of Solar Cell (Photovoltaic) Materials, Photovoltaic (PV) Module and PV Array, Photovoltaic Thermal (PVT) Systems, Degradation of Solar Cell Materials **(12 hrs)**

Design and modeling of solar energy systems: F-chart method, φ -F Chart method, Utilizability modelling & simulation of solar energy systems **(8 hrs)**

Economic analysis of solar energy systems: Life-Cycle Cost Analysis, Net Present Value (NPV), Analytical Expression for Payout Time, Benefit–Cost Analysis **(6 hrs)**

Text Book:

1. SP Sukhatme, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill,1984
2. JA Duffie and WA Beckman, Solar Engineering of Thermal Processes, John Wiley, 1991

Reference:

1. GN Tiwari, Arvind Tiwari, Shyam : Handbook of Solar Energy – Springer
2. Garg HP, J Prakash, Solar Energy: Fundamentals and Applications, Tata McGraw Hill, New Delhi, 1997
3. DY Goswami, F Kreith and JF Kreider, Principles of Solar Engineering,Taylor and Francis
4. GN Tiwari, S Suneja, Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997

Course code	Course Name	L– T - P	C
DEE2415	**Wind Power Technology**	**3-0-0**	**3**

Course Outcomes

CO1: Review the basic principles of wind power generation
CO2: Discuss the materials and components used in wind power tecvhnology
CO3: Evaluate performances of wind energy conversion systems
CO4: Assess the design and environmental safety aspects of wind power plant installation

Course Content:

Wind Energy Basics: Global circulation, Forces influencing Wind - Pressure gradient force and Coriolis force, Local and Regional Wind systems, Atmospheric Boundary Layer, Atmospheric Stability, Surface Wind, Characteristic variables of wind and other related atmospheric parameters, Wind Data

Power extracted from wind – stream tube model, linear momentum theory, power coefficient, Betz limit. Extreme winds calculation of theoretical power developed by the wind turbine **(10 hrs)**

Wind Energy Atlas: Use of Wind Energy Data, Wind Speed Statistics, Weibull, Rayleigh and Normal distributions, Topographic Maps, Wind data of India **(5 hrs)**

Measurement and Instrumentation: Concept of Measurement System, Anemometers, Wind sensing systems, Recording systems, Global Positioning System **(5 hrs)**

Wind Turbines: Types, Rotor elements, Horizontal and vertical axis wind turbines, slip stream theory. Calculation of axial thrust and efficiency, Pitch and stall regulation, Lift and drag coefficients, thrust and torque calculations, Tip losses, Characteristics of horizontal axis wind turbines and power curve. Concepts of blade design, Wind pumps. Matching of pump and turbine characteristics **(10 hrs)**

Wind Turbine Siting: Basic approaches to Siting, Siting in homogeneous terrain and complex terrain **(5 hrs)**

Wind Power farm Design: On land and offshore micro siting, Wind turbine energy production and Capacity Factor **(5 hrs)**

Environment Safety: General Principles, guidelines and acceptable limits, Noise and Electro Magnetic Interference due to wind mills **(5 hrs)**

Text Books /References:

1. Meteorological Aspects of the Utilization of Wind as an Energy Source, Technical Note No 175, World Meteorological Organization
2. EH Lysen, Introduction to Wind Energy, CWD Report 82-1, Consultancy Services Wind Energy Developing Countries, May 1983
3. T Burton, Handbook of Wind Energy, John Wiley and Sons
4. GL Johnson, Wind Energy Systems, Printice Hall Inc, New Jersy, 1985
5. www.windpower.dk
6. EH Lysen, Introduction to Wind Energy, CWD Report 82-1, Consultancy Services Wind Energy Developing Countries, May 1983
7. E Hau, Wind Turbines- Fundamentals: Technologies, Application, Economics, Springer - Verlag Berlin -Heidelbeg, 2000
8. DNV- Riso Guidelines for Design of Wind Turbines, 2nd Edition, RisoNationalLaboratory, Denmark, 2002
9. Hansen, Martin, O, L, Aerodynamics of Wind Turbine, James and James (Science Publishers) Ltd, London 2000

Course code	Course Name	L– T - P	C
DEE2416	**Advanced Solar Thermal Technology**	**3-0-0**	**3**

Course Outcomes

CO1: Review the basic principles of solar energy utilization
CO2: Identify advanced methods of solar thermal energy storage
CO3: Analyze the performances of solar thermal systems specially designed for domestic level and small scale applications
CO4: Assess the techno-economic feasibility and environmental impacts of industrial processes incorporating solar thermal conversion technology

Course Content:

Overview of Solar thermal Energy Research Technology, and Industry: Introduction, Basics of solar thermal energy, application in industry and research **(5 hrs)**

Flat-plate Collectors: Liquid Flat Collector, Materials for Flat plate Collectors , Energy balance for Flat Plate Collectors, Overall Heat Loss Coefficient , heat transfer between Parallel surfaces , Heat capacity effect, Testing methods, Types of Flat Plate Collectors: Liquid Flat Plate Collectors, Air flat-plate Collectors-Thermal analysis, Evacuated tubular collectors. Design of solar heating system **(10 hrs)**

Solar Thermal Energy Storage: Solar Energy Storage, Sensible storage, Latent heat storage, Thermo-chemical storage, Design of storage system **(7 hrs)**

Concentrating Collector Designs: Classification, design and performance parameters, tracking systems, Compound parabolic concentrators, parabolic trough concentrators, Concentrators with point focus, Heliostats **(7 hrs)**

Vapor absorption Refrigeration cycle: Water, ammonia and lithium bromide-water absorption refrigeration systems, Solar operated refrigeration systems, solar desiccant cooling, Current Status of Solar cooling **(6 hrs)**

Industrial Applications of Solar Heat: Temperature requirements, consumption pattern, Solar Passive Heating and Cooling, Solar Thermal Power Plant, Modeling of Solar Thermal Systems, Solar Desalination, Solar Drying, Solar Cooking, Solar Greenhouse technology: Fundamentals, design, modeling and applications in agriculture and space heating **(6 hrs)**

Design of Solar Heating System: Design and Sizing of Solar Heating Systems f – chart method and utilizability methods of solar thermal system evaluation **(4 hrs)**

Texts Books/References:

1. SP Sukhatme, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill,1984
2. JA Duffie and WA Beckman, Solar Engineering of Thermal Processes, John Wiley, 1991
3. B Sorensen, Renewable Energy, (2nd Ed), Academic press, New York, 2000
4. Garg HP, J Prakash, Solar Energy: Fundamentals and Applications, Tata McGraw Hill, New Delhi, 1997
5. DY Goswami, F Kreith and JF Kreider, Principles of Solar Engineering,Taylor and Francis
6. GN Tiwari, S Suneja, Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997

Course code	Course Name	L– T - P	C
DEE2417	Bioenergy and Biomass Conversion Technology	3-0-0	3

Course Outcomes

CO1: Expand the understanding on modern bioenergy and advanced biofuels: raw materials, conversion technologies and applications

CO2: Identify suitable biomass waste and bio-resource for biofuel production
CO3: Design sustainable bio-refinery concept for conversion of locally available biomass to bioenergy and value-added products
CO4: Analyze the technoeconomic feasibility and life cycle assessment of biofuels

Course Content:

Bioenergy Status: Bioenergy Resources, World Bioenergy Potential, India's BioenergyPotential, Current Technology and Research Status **(5 hrs)**

Thermo-chemical conversions: Direct Combustion, Technology of Biomass gasification, Pyrolysis and Liquefaction, Bio- Chemical Conversion: anaerobic digestion, alcohol production from biomass, Chemical conversion process: hydrolysis and hydrogenation **(10 hrs)**

Energy Efficient Wood Stoves: Traditional Stoves , Energy Efficient Cooking and Space heating Stoves, Metal Stoves Improved Gasifier Stoves , Current Research Status, Pollution due to smoke emissions **(5 hrs)**

Biogas Technology: Technology of Biogas production, Biogas Plants , Digester types, Digester design, Chemical kinetics and mathematical modeling of bio- methanation process, Dung, Vegetable Waste and Night Soil and Municipal Waste based Biogas plants, Bio gas as fuel for transportation ,Lighting , Running Dual Fuel Engines, Electricity generation, Bio gas Bottling Plant Technology, Application of Bio gas slurry in agriculture , Design of Biogas for cold climates **(10 hrs)**

Biomass Gasifiers: History , Principle , Design of Bio mass Gasifiers , updraft gasifier, down draft gasifier, zero carbon biomass gasification plants, Gasification of plastic-rich waste, applications for cooking, electricity generation, Gasifier Engines, Operation of spark ignition and compression ignition engine with wood gas, methanol, ethanol and biogas, Biomass integrated gasification/combined cycles systems **(10 hrs)**

Environmental Policy Issues related to Bioenergy Technologies: Environmental policy on Bio-Energy technology and environmental impact analysis **(5 hrs)**

Text Books /References:

1. KC Khandelwal, SS Mahdi, Biogas Technology - A Practical Handbook, Tata McGraw Hill, 1986
2. RC Maheswari, Bio Energy for Rural Energisation , Concepts Publication, 1997
3. J Twidelland T Weir, Renewable Energy Resources, Taylor and Francis (Ed), New York, USA, 2006
4. B Sorensen, Renewable Energy,2nd Ed, Academic press, New York, 2000
5. G Boyle (Ed), Renewable energy: Power for a sustainable future, Oxford, OUP, 1996
6. Thomas B Johansson et.al, (Ed), Renewable energy: Sources for Fuels and electricity, Earthscan Publishers, London, 1993
7. S Silveira , Bioenergy - Realizing The Potential ELSEVIER, 2005
8. DD Hall and RP Grover, Biomass Regenerable Energy, John Wiley, New York, 1987
9. AS Pietro, Biochemical and Photosynthetic aspects of Energy Production, Academic Press, New York, 1980

Course code	Course Name	L– T - P	C
DEE24118	Advanced Solar Photovoltaic Technology	3-0-0	3

Course Outcomes

CO1: Review the current trends in solar photovoltaic technology
CO2: Develop solar cells for solar photovoltaic applications
CO3: Assess performance of solar photovoltaic systems
CO4: Analyze quality of different components of centralized and decentralized solar photovoltaic systems
CO5: Design feasible projects on solar PV power plant installation and maintenance

Course Content:

Overview of Solar PV Research, Technology and Industry: Basics of solar PV technology, Its application to research and industry **(5 hrs)**

Solar Cells: Conversion of Solar energy into Electricity - Photovoltaic Effect, Equivalent Circuit of the Solar Cell, Analysis of PV Cells: Dark and illumination characteristics, Figure of merits of solar cell, Efficiency limits, Variation of efficiency with bandgap and temperature, Efficiency measurements, High efficiency cells, Recent developments in Solar Cells, Role of nano-technology in Solar cells **(8 hrs)**

Fabrication Technology for Solar Cells: High efficiency multi-junction solar cell, Quantum well solar cell, Technology for the fabrication of thin film cells, Optical concentration, Effect of temperature on Cell performance, Thermo photovoltaic effect **(8 hrs)**

Solar Photovoltaic System Design: Solar cell array system analysis and performance prediction, Shadow analysis: Reliability, Solar cell array design concepts, PV system design, Design process and optimization: Detailed array design, Voltage regulation, Maximum tracking, Quick sizing method, Array protection **(8 hrs)**

Solar Photo Voltaic System Testing: Sun Simulator, Testing and performance assessment of Solar PV generator, Electronic Control and Regulation, Power Conditioning, Converters and inverter, Concentrating system, System design and configuration **(8 hrs)**

SPV Power Systems: Centralized and decentralized SPV systems, Stand alone, hybrid and, grid connected system, System installation, Operation and Maintenance, Application of PV for lighting, Water pumping. Refrigeration, Telecommunication, Cathodic Protection etc., Solar PV Power Plant Status-Case Studies, Hybridization Engineering, Hybrid systems, Grid integration. Building Integrated PV Systems, PV market analysis and Economics of SPV systems **(8 hrs)**

Text Books/ References:

1. AL Fahrenbruch and RH Bube, Fundamentals of Solar Cells: PV Solar Energy Conversion, Academic Press, New York, 1983
2. T Bhattacharya, Terrestrial Solar Photovoltaic, Narosa Publishers Ltd, New Delhi LD

Partain (ed), Solar Cells and their Applications, John Wiley and Sons, Inc, New York, 1995
3. RH Bube, Photovoltaic Materials, Imperial College Press, 1998
4. HS Rauschenbach, Solar Cell Array Design Handbook, Van Nostrand Reinfold Company, New York, 1980
5. R Messenger and J Vnetre, Photovoltaic Systems Engineering, CRC Press Stand Alone PV Systems: A Handbook of Recommended Design Practices, Report No SAND 87-7023, Sandia National Lab USA 6. F Kreith and JF Kreider, Principles of Solar Engineering, McGraw-Hill (1978) 7. J Twidell and T Weir, Renewable Energy Resources, Taylor and Francis (Ed), New York, USA, 2006

Course code	Course Name	L– T - P	C
DEE2419	**Hybrid Renewable Energy Systems Design**	**3-0-0**	**3**

Course Outcomes

CO1: Identify possibilities for integration of renewable energy technologies and related systems
CO2: Design flexible energy storage hybrid systems incorporating renewable energy technologies
CO3: Analyze enhancement in system performance after integration of renewable energy systems
CO4: Assess technoeconomic feasibility of hybrid energy conversion system

Course Content

Introduction to Hybrid Energy System: Definition, Need for Hybrid Energy System, Hybrid System as Source of Renewable Energy, Benefits and Risk Issues. **(7 hrs)**

Hybrid Renewable Energy System: Current Status of Research on Configurations of different hybrid renewable energy system (Wind + solar PV, Solar PV + fuel cells, Biomass + solar CSP, Biodiesel + wind, Gas + solar CSP, Coal + solar CSP and Geothermal + solar PV), Control and Sizing Methodologies, Techno economic feasibility analysis of different combination. **(10 hrs)**

Grid Connected Wind & Solar Energy Conversion Systems Grid connectors: Connection issues, Wind farm and its accessories, Grid related problems, Generator control, Performance improvements, Different schemes, Power converters for Grid connected, Wind Energy Conversion System and Grid connected Solar Energy Converter systems, Hybrid Systems, Types of Cogeneration processes. **(10 hrs)**

Hybrid system based power generation for rural electrification: Demand Assessment, Resource Assessment, Barriers/Constraints, Power reliability analysis, Unit Sizing Optimization using tool such as HOMER, HOGA, and RESTSCREEN. **(8 hrs)**

Energy storages for hybrid systems:

Overview of electrical energy storage technol8ogies, Mechanical storage systems: pumped hydro storage (PHS), flywheel energy storage (FES), compressed air energy storage (CAES)

and gravity energy storage systems (GES); Electostatic and magnetic energy storage systems: super capacitor energy storage (SCES) and super conducting magnetic energy storage (SMES); Thermal energy storage (tes) systems, Chemical energy storage (ces) systems. **(10 hrs)**

Text Book:

1. Mukherjee D., Fundamental of Renewable Energy System, New Age International, 2004

2. Huggins, R., Energy Storage: Fundamentals, Materials and Applications, Springer, 2010.

Course code	Course Name	L– T - P	C
DEE2420	**Advanced Characterization Techniques**	**3-0-0**	**3**

Course Outcomes:

CO1: Explain the basic principles of the instrumental methods

CO2: Learn the instrumentation of the characterization techniques

CO3: Interpret results of the analytical methods

CO4: Assess quality of raw materials and products on the basis of instrumental analysis

Course contents:

Unit-1

Applications of UV-Visible, IR and Raman spectroscopy in physicochemical analysis of chemical compounds or molecules: Fourier transforms infrared spectroscopy **(5 hrs)**

Unit-2

Electrical resistivity in bulk and thin films, Hall effect, Magneto-resistance

Magnetic characterization techniques: Introduction to Magnetism, Measurement Methods, Measuring Magnetization by Force, Measuring Magnetization by Induction method

Types of measurements using magnetometers: M-H loop, temperature dependent magnetization, time dependent magnetization, Measurements using AC susceptibility, Magneto-optical Kerr effect.

NMR spectroscopy (^{1}H & ^{13}C): Structural elucidation of molecules by NMR, Double resonance, saturation, Nuclear Overhouser effect (NOE) and dynamic nuclear magnetic resonance, ^{13}C NMR spectroscopy – chemical shift, ^{13}C coupling constant, 2D- NMR spectroscopy, Multinuclear NMR, Variable temperature experiments. **(10 hrs)**

Unit-3

Electron paramagnetic resonance spectroscopy (EPR) spectroscopy,

Photoelectron spectroscopy: X-ray diffraction, EXAFS, XPS, UPS spectroscopy, Neutron Powder Diffraction method, Reflection High energy electron Diffraction (RHEED), Low

energy Electron Diffraction (LEED)

Phase identification, indexing and lattice parameter determination, Laser spectroscopy, Mössbauer Spectroscopy **(10 hrs)**

Unit-4

Thermoanalytical methods: Thermogravimetric analysis (TGA), differential thermal analysis (DTA) and differential scanning calorimetry (DSC).

Electrochemical methods: Coulometry, polarography, anode-stripping voltametry, pulse techniques, cyclic voltametry, electrogravimetry, spectroelectrochemistry.

Chromatographic methods: Adsorption, liquid-liquid partition, ion–exchange, paper and thin-layer chromatography, gel permeation chromatography and gas chromatography, size exclusion chromatography, HPLC, advanced HPLC (integrated systems), electrophoresis.

Mass spectrometry: Instrumentation, mass spectral fragmentation of organic compounds, API and ESI mode, LCMS, GCMS.

Radiochemical methods: Tracers in chemical analysis, isotopic exchange, isotopic dilution technique. **(10 hrs)**

Unit-5

Transmission Electron Microscopy (TEM); Basic Electron scattering, Concepts of resolution, TEM instruments,Various imaging modes, Analysis of micrographs

Optical microscopy, Scanning Electron Microscopy (SEM), Rutherford backscattering spectrometry, Atomic Force Microscopy (AFM), Scanning Probe Microscopy

Atomic absorption spectroscopy (AAS), light scattering, neutron scattering, osmometry, tensiometry, ultrasonic absorption study. **(10 hrs)**

Text Books:

[1] Willard, H. H. Instrumental Methods of Analysis, (East West Press, 1998).

[2] Nakamoto, K. Infrared and Raman Spectra: Inorganic and Coordination Compounds, 6th edn., (John Wiley, 2009).

[3] Banwell, C. N., Mc.Cash, E. M. Fundamentals of Molecular Spectroscopy, (Tata McGraw Hill, 1994).

[4] Hollas, J. M. Modern Spectroscopy, (John Wiley, 1996).

[5] Drago, R. S. Physical Methods for Chemistry, (Saunders Company, 1992).

[6] Pavia, D.L., G.M. Lampman, G.S. Kriz, J. R. Vyvyan, Spectroscopy, (Cengage India, 2008)