Course Scheme and Syllabi

M.Tech.
Energy Technology & Management

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

School of Energy & Environment
Thapar Institute of Engineering & Technology, Patiala

Master in Technology
(Energy Technology & Management)

Total No. of Seats: 18

Admission Criteria:

Admission to ME/M.Tech. program will be open to the candidates who obtained at least 60% marks in aggregate in the qualifying examination from a recognized University.

Admission shall be made on the basis of valid GATE Score in relevant discipline. First preference will be given to the GATE qualified candidates. After offering seats to the GATE qualified candidates, admission for the remaining vacant seats (if any) will be made on the basis of merit in the qualifying degree.

Eligibility Criteria:

- BE/B.Tech. degree in any branch of Engineering or Technology (or)
- M.Sc. in all relevant branches and the Student must have studied Mathematics at Intermediate or Higher level.
- **For Sponsored candidates:** with two years of work experience after qualifying degree.

M.Tech.
(Energy Technology & Management)

Program Objectives:

- To prepare the students for successful career in the energy industry; energy regulation and management agencies; and in the academic and R&D institutions.
- To produce graduates strong in energy resources, technologies and management fundamentals, and capable in addressing the present and potential future energy problems.
- To produce energy professionals, who are sensitive to, and well aware of, the energy issues and concerns, and who can apply their specialized knowledge for the sustainable energy management.

First Semester

Course No.	Course Title	L	T	P	Cr
PMA 104	Research Methodology	2	0	2	3.0
PET ***	Fundamental of Energy Engineering	3	1	2	4.5
PET ***	Conventional Energy Technologies	3	1	2	4.5
PET ***	Renewable Energy Technologies – I	3	1	0	3.5
PET ***	Energy Conservation in Thermal Utilities	3	1	0	3.5
PET ***	Energy Auditing and Management	3	1	0	3.5
	Total	**17**	**5**	**6**	**22.5**

Second Semester

Course No.	Course Title	L	T	P	Cr
PET ***	Renewable Energy Technologies – II	3	1	2	4.5
PET ***	Energy Conservation in Electrical Utilities	3	1	0	3.5
PET ***	Energy, Environment and Climate Change	3	1	0	3.5
P** ***	Technical Report Writing & Communication Skills/Generic Elective	3	0	0	3.0
	Elective-1				3.0
	Elective-II				3.0
	Total	**12**	**3**	**2**	**20.5**

List of Electives					
Elective -1					**3.0**
PET ***	Hydrogen Fuel and Fuel Cell Technology				
PET ***	Advanced Solar Photovoltaic technologies				
PET ***	E-Vehicles And Energy Storage				
PET ***	ISO 50001 – Energy Management Systems				
PET ***	Alternative Fuels for Transportation				
Elective – II					**3.0**
PES 216	Sustainability & Cleaner Technologies				
PET ***	Modeling And Economics Of Energy Systems				
PET ***	Green Buildings				
PET ***	Bio Energy And Waste To Energy Technologies				

Note: Electives are offered on the basis of preferences and an elective is offered only if the number of students registered is five or more.

Third Semester

Course No.	Course Title	L	T	P	Cr
PET 391	Seminar	-	-	-	4.0
PET 392	Minor Project	-	-	-	8.0
PET 491	Dissertation (Starts)	-	-	-	-

Fourth Semester

Course No.	Course Title	L	T	P	Cr
PET 091	Dissertation	-	-	-	12.0

Total Credits: 67

Program Outcomes:

1. Acquire fundamental knowledge on the science of energy and on both the conventional and non-conventional energy technologies
2. Acquire expertise and skills needed for the energy monitoring, auditing and management, and for the development, implementation, maintenance and auditing of Energy Management Systems
3. Able to analyze of energy conversion systems
4. Acquire abilities to communicate, prepare, plan and implement of energy projects

PMA102: RESEARCH METHODOLOGY

L	T	P	Cr
2	0	2	3.0

Course Objectives:

Ability to elaborate the concept of distribution function ability to distinguish between a discrete and continuous random variable and discuss transformation of one-dimensional, two-dimensional variables; develop potential towards problem solving using analysis of variance techniques; able to compute and interpret Karl Pearson's correlation coefficient and Spearman's rank correlation coefficient. Able to constitute random block design, Latin square design, and derive their probability distributions

Introduction: Nature and objectives of research, Study and formulation of research problem, Scope and formulation of hypothesis, Preparation and presentation of research and project proposals, Selection of thrust research.

Introduction to Statistical Analysis: Measures of Central Tendency and Dispersion, Mean, Median, Mode, Range, Mean deviation, Standard Deviation.

Random Variables and Probability Distribution: Definition, Distributions, Functions, Mathematical Expectation, Binomial, Poisson, Geometric, Negative bionomial, Exponential, Normal and log-normal distributions.

Hypothesis Testing: Tests of Significance based on normal, t and chi-square distributions, Analysis of variance technique.

Linear Regression and Correlation: Linear regression, Least square principle and fitted models, Karl Pearson's correlation coefficient, Rank Correlation, Lines of regression.

Design of Experiments: Completely randomized design, Random block design, Latin square design, Statistical analysis and variances of estimates, Analysis of covariance.

Laboratory Work: Implementation of statistical techniques using statistical packages *viz*., SPSS, ORIGIN PRO & MATLAB, R Programming, Mathematica including evaluation of statistical parameters and data interpretation, Regression Analysis, Covariance, Hypothesis testing and analysis of variance.

Course Learning Outcomes (CLOs):

On the completion of course, students will be able to:

1. acquire skills for formulating research problems and hypotheses to be tested, and for the preparation and presentation of research/project proposals
2. interpret probability and data distribution functions and becoming capable of estimating mathematical expectations

3. analyse regression and correlation analysis, development of statistical models, and calibration, validation and use of the models
4. design of experiments for investigations and hypotheses testing relating to research problems and projects
5. acquaint with the commercially available software packages for the statistical data analysis

Recommended Books

1. *Dowdy S, Wearden S and Chilko D. Statistics for Research, Wiley Series 2nded (2004).*
2. *Walpole RE, Myers RH, Myers SL. and Ye K. Probability and Statistics for Engineers and Scientists, Pearson Education 7Thed (2002).*

Evaluation Scheme:

S.N.	Evaluation Elements	Weightage (%)
1.	MST	≥20
2.	Sessionals Evaluation (May include Assignments/Projects/Tutorials/Quizzes)	≥10
3.	Lab Evaluations	≥20
4.	EST	≥40

PET***: FUNDAMENTAL OF ENERGY ENGINEERING

L	T	P	Cr
3	1	2	4.5

Course Objectives:

The course would introduce the fundamental principles of energy intensive equipments/machinery and develope an intuitive understanding of thermal sciences along with fluid mechanism by emphasizing the physical arguments. This course familiarizes students with concepts of devices with an understanding on the principles, design, construction and operation of hydraulic machines.

Basic of thermodynamics and heat transfer: Review of laws of thermodynamics; Energy and entropy balances, Equilibrium criteria; Chemical potential; Fugacity; Raoult's Law; Conservation of Energy

Exergy analysis: Concept of exergy; Energy analysis for mixing and separation process of fluids, open and closed systems; Exergy analysis of power plant cycles and Refrigeration cycle; Exergy-economic analysis; Pinch analysis

Modes of heat transfer: Heat diffusion equations; Heat Transfer through wall; cylinder; sphere; Conduction with heat source; Dimensionless numbers; Convection with and without phase change; Condensation and boiling; Shape factor; shape factor calculations for different bodies; radiations exchange between surfaces.

Heat exchangers and evaporators: Design considerations of shell and tubes of heat exchangers and double pipe heat exchangers; shell-side heat transfer coefficient and pressure drop; LMTD; effectiveness-NTU methods; Fouling and its effects; Single effect and multiple effect evaporators (MEE).

Fluid properties and fluid mechanics basics: Properties of fluids; Hydrostatics, fluid kinematics and fluid dynamics; Pipe flow; open channel flow; Frond number, supercritical and subcritical flows and hydraulic jump; Boundary layer theory; Flow measurement; and Valves.

Laboratory Work: Heat transfer through composite wall; Thermal conductivity of lagging material on pipe / metal rod, sphere; Performance of double pipe heat exchanger; Drop wise & film wise condensation; Heat transfer in natural and forced convection; Calibration of flow meters; Determination of head losses; Energy flow in fluids.

Learning Outcomes (CLOs):

The students will be able to:

1. Design and analysis of heat exchangers, evaporators with aim to improve their performance and economy
2. Execute the exergy analysis for understanding the given physical device and process, compute the work and heat transfer and formulate the ideal approximation to the behavior.
3. Define and describe basic concepts, terminologies used in fluid statics and dynamics.

Recommended Books:

1. Nag PK, Engineering Thermodynamics, Tata McGraw Hill 3rd ed (2008).

2. Sonntag RE, Borgnakke C and Van Wylen GJ, Fundamentals of Thermodynamics, John Wiley 6th ed (2007).

3. Holman JP, Heat Transfer, McGraw-Hill 9th ed (2004).

***4.** Kern DQ, Process Heat Transfer, International Student Edition, Tata McGraw-Hill (2002).*

5. Bansal RK, Fluid Mechanics and Hydraulics Machines, Luxmi Publishers (2010)

6. Fox RW, McDonald AT and Pritchard PJ, Intodution to Fluid Mechanics, Wiley & Sons Inc, (2008)

Evaluation Scheme:

S.N.	Evaluation Elements	Weightage (%)
1.	MST	≥20
2.	Sessionals Evaluation (May include Assignments/Projects/Tutorials/Quizzes)	≥10
3.	Lab Evaluations	≥20
4.	EST	≥40

PET105: CONVENTIONAL ENERGY TECHNOLOGIES

L	T	P	Cr
3	1	2	4.5

Course Objectives: This course enables to understand various conventional energy technologies including fossil fuel based nuclear and large hydro power plants; fuel types and their combustion phenomenon and energy efficiency analysis of steam, gas, nuclear, combined cycle and hydroelectric power plants; and will also facilitate developing skills to assess and select suitable conversion devices, components and equipments.

Combustion Basics: Fuel combustion Basics and combustion technologies; Combustion equations (stoichiometric and non-stoichiometric), analysis of products of combustion, conversion of volumetric and gravimetric analysis.

Thermal energy: Steam properties and steam calculations, Thermal energy and thermal power stations; Vapour power cycles (Rankine Cycle); Reheating and Regeneration, Boiler systems, Types of boilers; Boiler heat balance sheet, Fuel handling systems; Ash handling; Treatment and conditioning of boiler feed water; Degasifiers and Deaerators; High pressure boilers.

Turbines and IC engine: Steam turbines; Turbine losses and efficiencies; Condensers and cooling towers; Cogeneration and back-pressure turbines; Gas Turbines; Combined cycle power plants and analysis; IGCC plant and binary vapour cycles; Internal combustion engine based power plants - DG sets.

Nuclear energy & Nuclear reactors: Nuclear energy – potential, challenges and opportunities; Nuclear fuels; Nuclear fusion and fission technologies; Breeder technology; Nuclear fuel enrichment; Nuclear reaction control; Components of nuclear reactors, fuel cladding, moderators, coolants, control rods, Nuclear reactor types; Recent developments in nuclear reactors; Nuclear wastes and their management; and Reactor safety and safety measures, Environmental implications of nuclear reactors.

Hydropower: Importance and potential of hydro-electric power; Hydropower - merits and demerits; Types of hydroelectric power plants; Run-of-the-river power plants; Components of a hydroelectric power plant; Classification of modern water turbines; Torque - power and efficiency; and Power house safety requirements, Environmental issues in large hydropower.

Laboratory Work: Field visit to thermal power plant, determination of dryness fraction, cooling tower, evaluation of brake power, brake thermal efficiency, brake specific fuel consumption and heat balance sheet.

Course Learning Outcomes (CLOs):

The student will be able to:

1. Apply of operation, construction and working of various conventional power plants equipment and components
2. Apply energy conversion device principles, and evaluation their operation and performance
3. Identify, trace and solve various combustion related problems and evaluate theoretically the performance of various components involved in thermal power plants

Recommended Books:

1. Wakil M, Power Plant Engineering, McGraw Hill. (2004)

2. Nag PK, Power Plant Engineering, Tata McGraw Hill Ltd. (2010)

3. Cengel YA, Thermodynamics, Tata McGraw Hill Ltd. (2014).

Evaluation Scheme:

S.N.	Evaluation Elements	Weightage (%)
1.	MST	≥20
2.	Sessionals Evaluation (May include Assignments/Projects/Tutorials/Quizzes)	≥10
3.	Lab Evaluations	≥20
4.	EST	≥40

PET 105: RENEWABLE ENERGY TECHNOLOGIES - I

L	T	P	Cr
3	1	0	3.5

Course Objectives: To introduce the fundamental concepts of renewable energy technologies with emphasis on solar and wind energy in particular. To impart knowledge of solar and wind energy with respect to its availability, utilization, collection and storage. To educate about how to utilize solar and wind energy to achieve the sustainable energy systems. To introduce various types of solar and wind energy collecting devices and their performance analysis.

Overview of new and renewable energy resources: Introduction to renewable energy technologies; Current status and future scope.

Solar energy basics: Solar radiation, Sun-earth geometry and basic earth-sun angles; Solar constant; Factors governing availability of solar energy on the earth's surface; atmospheric attenuation of solar radiation; Estimation of average daily global solar radiation; Measurement of solar radiation using pyranometer and pyrheliometer, sunshine recorder.

Solar collectors: Stationary collectors – flat plate collectors and evacuated tube collectors; Sun tracking concentrating collectors – parabolic trough collectors, Fresnel collectors, parabolic dish reflectors, Heliostat filled collectors.

Solar energy applications: Passive and active solar water heating systems; Solar space heating and cooling; Solar buildings; Green houses; Solar cooling by adsorption systems, absorption systems and by absorption refrigeration systems; Solar cookers and solar driers; Solar desalination systems. Solar thermal power generation schemes; Central receiver power plants (solar power towers); Solar chimney power plants; Dish sterling systems; Solar ponds, Thermal analysis of solar power plants.

Photovoltaic systems: Semiconductors; Photovoltaic panels; Types of photovoltaic technologies; Equipment related to photovoltaic technology – batteries, invertors, charge controllers, maximum power point tracking; size of PV system, PV applications; Concentrating photovoltaic systems; Hybrid photovoltaic/thermal systems.

Wind energy basics: Potential of Wind energy in India; Wind energy developments in India; Wind energy resources - assessment and selection of prospective wind energy sites. Wind farms; Environmental impact of wind turbine power plant; Wind diesel hybrid systems; Solar-wind hybrid systems; Wind pumps; Environmental impacts of wind farms.

Wind energy technologies and design: Wind energy conversion technologies and types; Design of wind turbine; Control systems; Planning and design of wind farms; Feasibility study and technology assessment – cost benefit analysis of wind energy projects; Installation and commissioning of Wind Energy Conversion systems (WECS); Grid integration of WECS.

Course Learning Outcomes (CLOs):

The students will be able to:

1. Design and assess solar thermal systems including solar cooker, solar dryer, solar cooler and solar heater
2. Evaluate the potential of solar and wind energy at a given location
3. Design and analyze performance characteristics of wind turbine system under varying experimental conditions

Recommended Books:

1. Duffie, J.A. and Beckmann, W.A., Solar Engineering of Thermal Processes, John Wiley & Sons (2006).

2. Goswami DY, Krieth F and Krieder JF, Principles of Solar Engineering, second edition, , Taylor and Francis Inc. (2000)

3. *. Tiwari GN, Solar Energy, NarosaPublishers, 2nd Ed (2002).*

4. Garg HP and Prakash J, Solar Energy – Fundamentals and Applications, Tata McGraw-Hill, (2004)

5. Manwell JF and Roger AL, Wind Energy: Theory, Design and Applications, Wiley Inc., (2008)

6. Sukhatme.K, Suhas P. Sukhatme, "Solar energy: Principles of thermal collection and storage", Tata McGraw Hill publishing Co. Ltd, 8th edition,2008.

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET***: ENERGY CONSERVATION IN THERMAL UTILITIES

L	T	P	Cr
3	1	0	3.5

Course description:

This course introduces the principle of working of most commonly used thermal utilities in industry and identifies the energy conservation opportunities. The students shall learn to determine the efficiency of these utilities and hence able to recommend the action plan to bring about the required improvement

Fuels And Combustion: Introduction to Fuels, Properties of Liquid Fuels, Properties of Coal, Properties of Gaseous Fuels, Properties of Agro Residues, Combustion, Combustion of Oil, Combustion of Coal, Combustion of Gas, Draft System, Combustion Controls

Boilers: Introduction, Boiler Systems, Boiler Types and Classifications, Performance Evaluation of Boilers, Boiler Blow-down, Boiler Water Treatment, Energy Conservation, Opportunities, Case Study

Steam System: Introduction, Properties of Steam, Steam Distribution, Steam Pipe Sizing and Design' Proper Selection, Operation and Maintenance of Steam Traps, Performance Assessment Methods for Steam Traps, Energy Saving Opportunities

Furnaces: Types and Classification of Different Furnaces, Performance Evaluation of , Typical Furnace, General Fuel Economy Measures in Furnaces, Case Study

Insulation And Refractories: Purpose of Insulation, Types and Application, Calculation of Insulation Thickness, Economic Thickness of Insulation (ETI)**,** Simplified Formula for Heat Loss Calculation, Refractories, Properties of Refractories, Classification of Refractories, Typical Refractories in Industrial, Use Selection of Refractories, Heat Losses from Furnace Walls

FBC Boilers: Introduction, Mechanism of Fluidized Bed Combustion, Types of Fluidize, Bed Combustion Boilers, Retrofitting of FBC Systems to Conventional Boilers, Advantage, of Fluidized Bed Combustion Boilers

Cogeneration: Need for Cogeneration, Principle of Cogeneration, Technical Option, for Cogeneration, Classification of Cogeneration Systems, Factors Influencing Cogeneration, Choice, Important Technical Parameters for Cogeneration, Prime Movers for Cogeneration, Typical Cogeneration Performance Parameters, Relative Merits of Cogeneration Systems, Case Study

Waste Heat Recovery: Introduction, Classification and Application, Benefits of Waste Heat Recovery, Development of a Waste Heat Recovery System, Commercial Waste Heat Recovery Devices

Course Learning Outcomes:

1. Gain knowledge of the working principles of the Thermal Utilities
2. Identification of energy conservation opportunities in Thermal Utilities.
3. Determine the efficiency of Thermal Utilities

Recommended Books:

1. *Sonal Desai, Handbook of Energy Audit, McGraw Hill Education (India) Private Limited (2015)*
2. *JLThrelkeld: Thermal Environmental Engineering, Second Edition (Prentice Hall,1970)*
3. *YPAbbi and Shashank Jain: Handbook on Energy Audit and Environment Management, (TERI Press, 2006)*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET***: ENERGY AUDITING AND MANAGEMENT

L	T	P	Cr
3	1	0	3.5

Course Objective:

Energy Audit helps to map the flow of energy (in its various forms) across the value chain, highlighting areas for interventions. It shall complement the knowledge gained by students in the subject 'Energy Management'. This course is designed to sensitize students on the mechanism of energy audit and the technologies/ tools typically employed to undertake an audit exercise, supported by case studies & site visits.

Energy Scenario: Primary and Secondary Energy, Commercial Energy and Non-commercial Energy, Renewable and Non Renewable Energy, Global Primary Energy Reserves, Indian Energy Scenario, Energy Needs of Growing Economy, Long Term Energy Scenario for India, Energy Pricing in India, Energy Sector Reforms, Energy Security, Energy Conservation and its Importance, Energy Strategy for the Future, Energy Conservation Act.

Basics of Energy and Its Various Forms: Various Forms of Energy, Electrical Energy Basics, Thermal Energy Basics, Units and Conversions

Energy Management And Audit: Definition & Objectives of Energy Management, Energy Audit: Types and Methodology, Energy Audit Reporting Format, Understanding Energy Costs, Benchmarking and Energy Performance, Matching Energy Usage to Requirement, Maximising System Efficiency, Fuel and Energy Substitution, Energy Audit Instruments

Material and Energy Balance: Basic Principles, The Sankey Diagram and its Use, Material Balances, Energy Balances, Method for Preparing Process Flow Chart, Facility as an Energy System, How to Carryout Material and Energy (M & E) Balance

Energy Action Planning: Key elements, Formulation, Ratification, Organizing – location of energy management, Top management support, Managerial function, Roles and responsibilities of energy manager, Accountability, Force field analysis, Marketing and communicating-training and planning, Motivation, Information system designing, barriers, strategies

Financial Management : Investment - Need, Appraisal and Criteria, Financial analysis techniques - Simple payback period, Return on investment, Net present value, Internal rate of return, Cash flows, Risk and sensitivity analysis, Financing options, Energy performance contracts and role of ESCOs

Energy Management & Government Programmes: BEE & State Development Agencies, Government & EESL Programmes, PAT Scheme, Ujala& SEEP Programmes, Municipal & Agriculture DSM Initiatives, Standards and LabellingProgramme

Case Studies / Best Practices

Large Industries (Cement/ Iron & Steel/ Thermal Power Plants)
SME Units
Power Distribution Utilities / Railways
Buildings/ Hotel/ Other Sectors

Site Visits & Practical Work

Institutional Visit
Developing Energy Audit Report

Course Learning Outcomes:

On the completion of course, students will be able to:

1. Identification of energy conservation opportunities in various industrial processes.
2. Gain knowledge on tools and techniques employed in energy auditing.
3. Comprehend an Energy Audit report, including economic parameters.

Recommended books:

1. *LC Witte, PS Schmidt and DR Brown: Industrial Energy Management and Utilization*
2. *(Hemisphere Publishing Corporation, Washington, 1998).*
3. *JL Threlkeld: Thermal Environmental Engineering, Second Edition (Prentice Hall,1970)*
4. *YP Abbi and Shashank Jain: Handbook on Energy Audit and Environment Management, (TERIPress, 2006)*
5. *WC Turner: Energy Management Handbook, Seventh Edition, (Fairmont Press Inc., 2007)*
6. *George Polimeros: Energy Cogeneration Handbook, (Industrial Press, Inc., New York, 1981*)

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET 201: RENEWABLE ENERGY TECHNOLOGIES-II

L	T	P	Cr
3	1	2	4.5

Course Objectives: This course provides knowledge, understanding and application oriented skills on biomass, ocean, tidal and geothermal energy sources and relevant technologies towards their effective utilization for meeting energy demand; in addition to developing clear understanding of these technologies to be able to select an appropriate type of plant for given energy requirements.

Biomass energy: Biomass energy resources – types and potential; Energy crops, Generation of bio fuels, Biogas, types of biogas digester, biomass-gasification, updraft and downdraft gasifier, applications of power generation, biodiesel, bio-ethanol etc.

Waste to energy: Agricultural residues and wastes including animal wastes; industrial wastes; municipal solid wastes; Incinerators, power generation potential of waste.

Ocean wave and tidal energy: Introduction to tidal and ocean wave energy; Potential sources in globe & India; Understanding of wave and current movements for tapping of energy; Estimation of energy – Maximum and minimum power ranges; Different wave energy conversion devices; Principles of tidal power generation; Components of a tidal power plant; Current technologies and future challenges in the wave, tidal stream and barrage energy production; Coastal impacts of marine based energy.

Ocean energy: OTEC Principles and technologies; Lambert's law of absorption; Major problems and operational experience; Future scope, potential and assessment of ocean thermal energy sources and conversion technologies.

Geothermal energy: Geothermal energy sources – types and potential; Physio-chemical features of geothermal reservoirs; Direct and indirect uses of geothermal energy resources; geothermal energy conversion technologies; High temperature geothermal power plants; Environment impacts.

Mini and micro hydel power plants: Pumped storage power plants; Sitting and design of mini and micro hydro power plants; Ecological and environmental concerns and impacts of hydro electric power.

Direct energy conversion systems: Magnetic Hydrodynamic (MHD) Generator: gas conductivity and MHD equations; operating principle, types and working of different MHD systems – their relative merits; MHD materials and production of magnetic fields

Thermo-electric generators: Thermo-electric effects and materials; thermo-electric devices and types of thermo-electric generators; thermo-electric refrigeration.

Thermionic generators: thermo ionic emission and materials; working principle of thermionic convertors.

Fuel Cells: thermodynamic aspects; types, components and working of fuel cells. v) Performance, applications and economic aspects of above mentioned direct energy conversions systems.

Laboratory Work: Biogas operated dual fuel engine, biodiesel production process, gasifier based dual fuel engine, methane production and anaerobic digestion process, pyrolysis, field visits; Performance characteristics of solar flat plate collector, solar stand PV system, solar water heating system.

Course Learning Outcomes (CLOs):

The students will be able to

1. Access the socio-economic impact of biomass energy
2. Formulate protocol to convert agricultural waste into energy
3. Estimate energy generated from sources like ocean based, geothermal and mini hydro system.
4. Build and evaluate pilot-scale mini-hydro power plants
5. Design solution for environmental problems associated with the unconventional oil and gas energy resources

Recommended Books:

1. Dickson MH, Geothermal Energy: Utilization and Technology, UNESCO (2005)

2. Charlier RH, Ocean Energy: Tidal and Tidal Power, R.H. Charlier, Springer-Verlag (2004)

3. Sorenson B. Renewable Energy, Elsevier 4th Ed (2010).

4. Rao S, Parulekar BB. Energy Technology: Non-conventional, Renewable and Conventional, Khanna Pub. 3rd Ed.(2005).

5. Fay JA, Golomb DS. Energy and Environment, Oxford University Press (2002)

Evaluation Scheme:

S.N.	Evaluation Elements	Weightage (%)
1.	MST	≥20
2.	Sessionals Evaluation (May include Assignments/Projects/Tutorials/Quizzes)	≥10
3.	Lab Evaluations	≥20
4.	EST	≥40

PET***: ENERGY CONSERVATION IN ELECTRICAL UTILITIES

L	T	P	Cr
3	1	0	3.5

Course Objective:

This course introduces the principle of working of most commonly used electrical utilities in industry and identifies the energy conservation opportunities. The students shall learn to determine the efficiency of these utilities and hence able to recommend the action plan to bring about the required improvement

Electrical System: Introduction to Electric Power Supply Systems, Electricity Billing, Electrical Load Management and Maximum Demand Control, Power Factor Improvement and Benefits, Transformers, System Distribution Losses, Harmonics, Analysis of Electrical Power Systems

Electric Motors: Introduction, Motor Types, Motor Characteristics, Motor Efficiency, Motor Selection, Energy Efficient Motors, Factors Affecting Energy Efficiency and Minimizing Motor, Losses in Operation, Rewinding Effects on Energy Efficiency, Speed Control of AC Induction Motors, Motor Load Survey: Methodology

Compressed Air System: Introduction, Compressor Types, Compressor Performance, Compressed Air System Components, Efficient Operation of Compressed Air Systems, Compressor Capacity Assessment, Checklist for Energy Efficiency in Compressed Air System

HVAC And Refrigeration System: Introduction, Types of Refrigeration System, Common Refrigerants and Properties, Compressor Types and Application, Selection of a Suitable Refrigeration System, Performance Assessment of Refrigeration Plants, Factors Affecting Performance and Energy Efficiency of Refrigeration Plant, Energy Savings Opportunities

Fans And Blowers: Introduction, Fan Type, Fan Performance Evaluation and Efficient System Operation, Fan Design and Selection Criteria, Flow Control Strategies, Fan Performance Assessment, Energy Saving Opportunities

Pumps And Pumping System: Pump Types, System Characteristics, Pump Curves, Factors Affecting Pump Performance, Efficient Pumping System Operation, Flow Control Strategies, Energy Conservation Opportunities in Pumping System

Cooling Towers: Introduction, Cooling Tower Performance, Efficient System Operation, Flow Control Strategies, Energy Saving Opportunities in Cooling Towers

Lighting System: Introduction, Basic Terms in Lighting System and Features, Lamp Types and their Features, Recommended Illuminance Levels for Various Tasks/Activities/Locations, Methodology of Lighting System Energy Efficiency Study, Case Examples, Some Good Practices in Lighting

DG Set System: Introduction, Selection and Installation Factors, Operational Factors, Energy Performance Assessment of DG Sets, Energy Savings Measures for DG Sets

Energy Efficient Technologies In Electrical Systems: Maximum Demand Controllers, Automatic Power Factor Controllers, Energy Efficient Motors, Soft Starter, Variable Speed Drives, Energy Efficient Transformers, Electronic Ballasts, Energy Efficient Lighting Controls

Course Learning Outcomes:

1. Gain knowledge of the working principles of the Electrical Utilities
2. Identification of energy conservation opportunities in Electrical Utilities.
3. Determine the efficiency of Electrical Utilities

Recommended Books:

1. *Sonal Desai, Handbook of Energy Audit, McGraw Hill Education (India) Private Limited (2015)*
2. *YPAbbi and Shashank Jain: Handbook on Energy Audit and Environment Management, (TERI Press, 2006)*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET ***: ENERGY, ENVIRONMENT AND CLIMATE CHANGE

L	T	P	Cr
3	1	0	3.5

Course Objectives:

This course provides understanding of the interrelationship of energy and environment, as well as enhances the knowledge of basic concepts of climate change and strategies for conservation of environmental changes

Overview: Introduction, Role of energy in economic development and social transformation: Energy and GDP, GNP and its dynamics, Impact of Energy on Economy, Energy Sources and overall energy demand and availability, Energy Security: Future Energy Options, Energy Crisis: Transition from carbon rich and nuclear to carbon free technologies; Sustainable Development Goals; National Resource Efficiency Policy; National Determinant Contributions (NDCs)

Environmental impacts of conventional energy technologies: Environmental implication of Fossil Fuels, CO2 emission in atmosphere, Limitations of traditional energy technologies, Fallout from nuclear explosions – fuel processing and radioactive waste, Radioactivity risk assessment; Effect of Hydro electric power stations on ecology and environment; Green belt; shadow cropping;

Environmental impacts of renewable energy technologies: Need for use of new and renewable energy, Criteria for the selection of new energy sources, Environmental degradation due to production and utilization by bio-energy, solar energy, tidal energy, wind energy, Geothermal energy; Power sector reforms.

Global climate change: Elements of climate; Climatic classifications; Climatic controls; Spatial and temporal patterns of climate parameters in India; Long term changes; Possible causes of climate change- External (Milankovitch variation and Solar activity) and Internal (natural and anthropogenic); Global warming; ozone hole; Montreal protocol; Kyoto protocol and recent conventions; Strategies for conservation of environmental changes induced by CO2 rise; Concept of carbon sequestration; Clean Development Mechanism (CDM) and its operationalization, modalities and procedures for CDM Project.

Course Learning Outcomes (CLOs):

The students will be able to:

1. Acquire scientific and technological knowledge on the energy aspects and associated environmental issues
2. Evaluate the environmental impacts of energy technologies
3. Correlate the climate change issues and related protocols
4. Apply modalities as well as procedures for CDM projects

Recommended books:

1. Brown CE, World Energy Resources: Charles E. Brown, Springer (2002).

2. Tiwari GN, Renewable Energy Resources: Basic Principles and Applications Narosa Publishing House (2005).

3. Dayal M, Renewable Energy Environment and Development, Konark Publishers Pvt. Ltd (1998)

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

P** ***: TECHNICAL REPORT WRITING AND COMMUNICATION SKILLS

L	T	P	Cr
3	0	0	3.0

Course objective: To introduce the students to effective professional and technical communication. The student will be exposed to the technique and strategies of writing reports and present specialized information in an accessible way with clarity, accuracy and professionalism for an easy and effective assimilation by the audience.

Essentials of Communication: Meaning, Definition, process and barriers in communication. Emergence of communication as a key concept in the corporate and the global world.
Methods and Modes of Communication: Verbal and nonverbal, Verbal Communication: Characteristics of verbal communication: Non-verbal Communication: Characteristics and types.
Effective Technical writing: Paragraph development; Forms of writing; Abstraction and Summarization of a text; Technicalities of letter writing; Styles of paper writing, review papers and research papers; Referencing styles: MLA, Chicago Style and APA.
Technical Report Writing: Definition and Importance of a technical report; salient features and characteristics; Types of Reports.
Data collection: Methods of data collection: Personal observations, telephonic interviews, personal interviews and questionnaires; Sources: Primary data and Secondary data; Data analysis and illustrations.
Structural elements of a report: Front matter, body and back matter of a report and their function.

Course Learning Outcomes:

1. Apply communication concepts for effective professional correspondence.
2. Introduce the elements of effective writing.
3. Introduce technical reports and discuss various steps involved in report writing.
4. Apply the concepts of the structural elements of report writing

Recommended books:

1. *Lesikar R.V and Flately M.E., Basic Business Communication Skills for the Empowering the Internet Generation. Tata Mc Graw Hill. New Delhi (2006).*
2. *Raman,M& Sharma, S.,Technical Communication Principles and Practice, Oxford University Press New Delhi.(2011).*
3. *Sharma, R.C. and K. Mohan. 2016. Business Correspondence and Report Writing. Fifth Edition. New Delhi: Tata McGraw Hill.*
4. *Gerson, Sharon J and Stern M. Gerson. 2000. Technical Writing: Process and Product. Third Edition. India: Pearson Education Asia.*

5. *1. Robbins, S.P., &Hunsaker, P.L.,Training in Interpersonal Skills,Prentice Hall of India New Delhi,(2008).*
6. *DiSianza,J.J&Legge,N.J.,Business and PrfofessionalCommunication,Pearson Education India New Delhi,(2009).*
7. *Technical Report Writing, Daniel Riordan, Cenage.*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET ***: HYDROGEN AND FUEL CELL TECHNOLOGY

L	T	P	Cr
3	0	0	3.0

Course Objectives:

The objective of the course is to provide comprehensive and logical knowledge of hydrogen production, storage and utilization. In addition, provides an understanding of various fuel cell technologies.

Introduction of hydrogen energy systems: Properties of hydrogen as fuel, Hydrogen pathways introduction-current uses, general introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants.

Hydrogen production processes: Thermal-Steam reformation, thermo chemical water splitting, gasification-pyrolysis, nuclear thermal catalytic and partial oxidation methods. Electrochemical-Electrolysis, photo electro chemical, Biological-Anaerobic digestion, fermentation micro-organism, PM based electrolyser.

Hydrogen storage: Physical and chemical properties, general storage methods, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, carbon based materials for hydrogen storage.

Hydrogen utilization: Overview of hydrogen utilization, IC Engines, gas turbines, hydrogen burners, power plant, domestic cooking gas, marine applications, hydrogen dual fuel engines.

Fuel cells: History – principle - working - thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell, Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, microbial fuel cells, relative merits and demerits.

Applications of fuel cells: Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space, economic and environmental analysis on usage of hydrogen and fuel cell. Future trends in fuel cells, portable fuel cells, laptops, mobiles, submarines.

Hydrogen safety: Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles, hydrogen manifold and direct injection, fumigation, NOx controlling techniques, dual fuel engine, durability studies, emissions and climate change.

Course Learning Outcomes (CLOs):

The students will be able to

1. Evaluate the performance of fuel cells under different operating conditions
2. Select and apply appropriate fuel cell technology for a given application
3. Design and develop suitable hydrogen storage system to be used along with fuel cell system
4. Design tools to minimize environmental hazards associated with the use of hydrogen storage and fuel cell technology

Recommended Books:

1. Sorenson B, Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorenson, Academic Press (2005).

2. Hordeski MF, Hydrogen and Fuel Cells: Advances in Transportation and Power, The Fairmont Press, Inc. (2009)

3. Busby RL, Hydrogen and Fuel Cells: A Comprehensive Guide, PennWell Books (2005)

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET***: ADVANCED SOLAR PHOTOVOLTAIC TECHNOLOGIES

L	T	P	Cr
3	0	0	3.0

Course Objectives:
The course intends to provide the fundamentals and physical principles behind the technology that converts solar energy into electricity. The attendees of this course will learn how solar PV systems work, typical system components, and types of solar cells with a focus on fabrication of solar cells and designing of solar PV systems.

Course Contents:
Characteristics of sun light: Wave-particle duality; Black body radiation; Solar radiation; Solar energy and photovoltaic.
Semiconductor junctions: Origin of bands in solids; Band model of solids; Crystal structure; Doping and types of semiconductors; energy band diagram; diffusion and drift of carriers; continuity equation; P-N junction and its properties; dark I-V equation of P-N junction; junction under illumination; solar cell parameters; Efficiency limits and losses in solar cells; Impact of temperature and parasitic resistance om behavior of solar cells.
Silicon solar cells: Production of solar cell grade silicon; Design and fabrication of solar cells, design of solar cells; Role of antireflection coating and textured surfaces in Si solar cells.
Thin film solar cell: Absorption coefficient and thickness of absorber material; Design of thin film solar cells; Component requirements; CIGS, CdTe, CZTS and perovskite based solar cells.
Next generation solar cells: Structure and working principle of dye-sensitized solar cells, Nanostructure based solar cells.
Solar modules: Module and circuit design; module structure; Environmental protection; Thermal considerations; Electrical insulations; Mechanical protection.
Grid connection: Introduction to technology of energy storage and grid connection.

Course Learning Outcomes (CLOs):
The student will be able to
1. Describe working principal of a p-n junction diode
2. Explain the characteristics of a solar cell
3. Describe different generations of solar cells
4. Choose appropriate materials to design a thin film solar cell
5. Design solar PV module and predict different failure modes.

Recommended Books:

1. *Solar cells: Operating principles, technology and system applications, by Martin A. Green, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.*
2. *Semiconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993.*

3. *Solid State electronic devices, Ben G. Streetman, , Prentice-Hall of India Pvt. Ltd., New Delhi 1995.*
4. *The physics of solar cells, J. Nelson, Imperial college press, 2006.*
5. *Thin-film crystalline silicon solar cells: Physics and technology, R. Brendel, Wiley-VCH, Weinheim, 2003.*
6. *Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial college*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET***: E VEHICLES AND ENERGY STORAGE

L	T	P	Cr
3	0	0	3.0

Course Objectives:

The course would introduce the principles of Electric vehicles. Different types of energy storage and charging for its implementation in vehicles, understanding various energy management strategies for electrical vehicles.

Course Contents:

Introduction to Automobiles and Vehicle Dynamics: Basics of vehicle performance, vehicle power source characterization, transmission characteristics and mathematical models to describe vehicle performance.

Electric Vehicles Overview: History of electric vehicles, social and environmental importance of electric vehicles, impact of modern drive-trains on energy supplies, Configuration of Electric Vehicles, Performance of Electric Vehicles, Traction motor characteristics, Tractive effort and Transmission requirement, Vehicle performance, Tractive effort in normal driving, Energy consumption.

Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.

Electric Propulsion unit: Introduction to electric components used in electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives.

Energy Management Strategies: Introduction to energy management strategies used in electric vehicles, classification of different energy management strategies, comparison of different energy management strategies

Energy Storage: Introduction to Energy Storage Requirements in Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices, Battery parameters, Types of Batteries, Modelling of Battery, Fuel Cell basic principle and operation, Types of Fuel Cells, PEMFC and its operation, Modelling of PEMFC, Super Capacitors.

Course Learning Outcomes (CLOs):

The students will be able to:

1. Understand working of Electric Vehicles and recent trends
2. Analyze different power converter topology used for electric vehicle application
3. Understands the energy storage units and energy management for e vehicles

Recommended Books:

1. *C.C. Chan and K.T. Chau, Modern Electric Vehicle Technology, OXFORD University Press, 2001.*
2. *M. Ehsani, Y. Gao, S. Gay and Ali Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, CRC Press, 2005*
3. *Iqbal Husain, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003*
4. *Sheldon S. Williamson, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Springer, 2013.*
5. *Chris Mi, M. Abul Masrur, David Wenzhong Gao, Hybrid Electric Vehicles Principles And Applications With Practical Perspectives, Wiley Publication, 2011.*

Evaluation Scheme:

S.N.	Evaluation Elements	Weightage (%)
1.	MST	≥20
2.	Sessionals Evaluation (May include Assignments/Projects/Tutorials/Quizzes)	≥10
3.	EST	≥40

PET*: ISO50001: ENERGY MANAGEMENT SYSTEMS**

L	T	P	Cr
3	0	0	3.0

Course Objective: Structured approach to energy management that integrates energy efficiency into daily organizational management practices, acquaintance about the standards and industrial applications of Energy management systems, Implementation & regulation of Energy management systems and Energy Auditing.

To implement the systems in accordance with ISO 50001:2018, following four step approach is suggested: Gap Analysis, Energy management systems Implementation, Bench-marking & Preparation for Audit.

Gap Analysis: Energy management systems implementation, assessment of its preparedness, Review of unit's existing energy management systems and highlight areas that require action. Assessment of the current status/ compliance with respect to requirements of the standard. This activity will help to identify the gaps and thus outcome will be to prepare the plan to address the gaps and meet the compliance with the standard.

Energy Management System Implementation: The implementation of a document system to address the specifications of the reference standard to be implemented considering the characteristics of the energy consumption at the facilities/units. The documentation system will cover:-

i. Energy Policy
ii. Energy Management Team
iii. Energy Management Systems Manual
iv. Establishing Energy Performance Indicators
v. Energy Action Plan
vi. Energy Review and Monitoring Systems
vii. Establishing internal audit team

Energy mapping study to identify, quantify and benchmark energy use, Establishing the baseline against which to measure energy performance in accordance with ISO 50001 requirements, Execution of different awareness-raising activities for implementing the system and the definition of actions for improving energy management practices, Completion of an energy audit of the facilities to obtain an energy diagnosis of operations and identifying the energy saving opportunities, Establishing systems and requirements in line with ISO 50001:2018 and Internal audit to review the compliance with ISO 50001:2018

Benchmarking:

Data collection to establish SEC and operating parameters, desk analysis, Identification of specific areas of focus, Identify areas of improvement – this will be based on discussions with operating team, site considerations, material properties, etc.

- Target benchmark establishment, Internal Benchmarking comparison, Improvement to achieve the benchmark levels will be highlighted and approximate cost economics

Preparation for Certification Audit: Establishment of systems in line with ISO 50001:2018, mock audit; confirm that Energy management systems established meet the ISO 50001 standards and subsequently determine the actions required to meet compliance compliant. The analysis and subsequent report preparation of areas of non-compliance and corrective action plan for assessment.

Course Learning Outcome:

Upon completing the course, the student will be able to:

1. Understand the systems and processes to be established to improve energy performance, energy use and energy consumption
2. Creates energy monitoring plans as well as energy analysis activities & formalizes energy policy and objectives
3. Improved drive toward innovation, reduction in energy costs & more efficient use of available energy sources
4. Enables to reduction in GHG emissions and other legislative requirements

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET*** ALTERNATIVE FUELS FOR TRANSPORTATION

L	T	P	Cr
3	0	0	3.0

Course objectives:

Upon completing the course, the student will be able to:

- Understand the current availability of petroleum based fuels, their progress and influence on environment.
- Realize the need, production and technology of utilizing different alternative liquid and gaseous fuels for transportation including alcohol, biodiesel, Compressed Natural Gas, Liquefied Petroleum Gas, Di-methyl ether, Di-ethyl ether and hydrogen.

Introduction: Overview of hydrocarbon fuels-their availability and effect on environment, Resources such as shale gas and petroleum, Gasoline and Diesel self-ignition characteristics of the fuel, octane number, Cetane number

Alternative fuels -liquid and gaseous fuels, Physico-chemical characteristics, Alternative liquid fuels, Alcohol fuels -ethanol and methanol, fuel composition, Fuel induction techniques, Fumigation, Emission of oxygenates, Applications to engines and automotive conversions,

Biodiesel formulation techniques, Transesterification, Application in diesel engines, Dimethyl ether(DME), properties fuel injection consideration general introduction to Liquefied Petroleum Gas(LPG) and Liquefied Natural Gas(LNG), Compressed natural gas (CNG) components, mixtures and kits, Fuel supply system and emission studies and control, Hydrogen combustion characteristics, Flashback control techniques, Safety aspects and system development, NOx emission control, Biogas, Producer gas and their characteristics, System development for engine application.

Course Learning Outcomes (CLOs):

The students will be able to

1. Molecular structures and Physico-chemical properties of hydrocarbon fuels and biofuels
2. Worldwide Fuel Quality and emissions norms for internal combustion engines
3. Basic working principle of internal combustion engines

Recommended Books:

1. Babu M. K. G., Subramanian K. A., Alternative Transportation Fuels: Utilization in CombustionEngines, CRC Press, 2013.

2. Willard W. P., Engineering Fundamentals of the Internal Combustion Engine, Pearson Prentice Hall, 2008.

3. Addy M. W., Khair M. K., Diesel Emissions and Their Control, SAE International, 2006.

4. Bechtold R. L., Alternate Fuels-Transportation Fuels for Today and Tomorrow, Society of

Automotive Engineers (SAE), 2002.
5. Ferguson C. R., Allan T. K., Internal Combustion Engines Applied Thermosciences, John Wiley & Sons, Inc. 2001.

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PES216: SUSTAINABILITY AND CLEANER TECHNOLOGIES

L	T	P	Cr
3	0	0	3.0

Course Objectives:

To provide acquaintance with modern cleaner production processes and emerging energy technologies; and to facilitate understanding of the need and application of green and renewable technologies for sustainable development of the society

Sustainability: Concept of sustainability, Sustainable development practices; CP and sustainable industrial practices.

Introduction: Cleaner production (CP) in achieving sustainability; Clean development mechanism (CDM); Source reduction techniques - Raw material substitution; Process modification and equipment optimization; Zero effect zero defect.

Cleaner Production: Overview of CP Assessment Steps and Skills; Basic analysis of material and energy flows; Green procurement; Identifying and reducing losses; New and low waste technologies; Product modification; Good housekeeping; CP audits.

Green Design: Green buildings - benefits and challenges; public policies and market-driven initiatives; Effective green specifications; Energy efficient design; Passive solar design; Green power; Green materials and Leadership in Energy and Environmental Design (LEED); GRIHA norms; Concept of smart cities

Emerging Energy Technologies: Concepts; Bio molecules and energy; Hydrogen and Fuel cells; Fourth generation energy systems.

Course Learning Outcomes (CLOs):

On the completion of course, students will be able to:

1. comprehend basic concepts in source reduction and waste management
2. design viable cleaner production systems utilizing steps and skills acquired
3. examine and evaluate present and future advancements in emerging and renewable energy technologies

Recommended Books:

1. *Kirkwood RC and Longley AJ(Eds.), Clean Technology and the Environment, Chapman & Hall, London (1995).*
2. *World Bank Group; Pollution Prevention and Abatement Handbook – Towards Cleaner Production, World Bank and UNEP; Washington DC (1998).*
3. *Modak P, Visvanathan C and Parasnis M, Cleaner Production Audit,Course Material on Cleaner Production and Waste Minimization; United Nations Industrial Development Organization (UNIDP) (1995).*

4. Rao S and Parulekar BB, Energy Technology: Non-conventional; Renewable and Conventional; Khanna Pub.(2005) 3rd Ed.

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20

PET***: MODELING AND ECONOMICS OF ENERGY SYSTEMS

L	T	P	Cr
2	0	2	3.0

Course Objectives: Concepts of Computer Aided Process System Engineering methods to tackle the problems of energy conversion systems modelling and optimization. The students will acquire a methodology to state the problem, identify the solving procedure, solve the problem and analyses the results

Energy Financing: Relevance of financial and economic feasibility evaluation of energy technologies and systems, Basics of engineering economics, financial evaluation of energy technologies, Social cost benefit analysis, Case studies on techno-economics of energy conservation and renewable energy technologies. Energy demand analysis and forecasting, Energy supply assessment and evaluation,

Energy Pricing: Energy demand – supply balancing, Energy models. Energy – economy interaction, Energy investment planning and project formulation. Energy pricing.

Energy Policy: Policy and planning implications of energy – environment interaction, clean development mechanism. Financing of energy systems. Energy policy related acts and regulations.

Software tools: Software for energy planning such as RETScreen, System Advisor Model, HOMER etc

Course Learning Outcomes (CLOs):

The overall aim is to provide understanding of the modelling of technical energy systemswith a focus on local and regional energy systems. HOMER and RET Screen optimization program issued as tool in the course.

After completing the course, the student should be able to:

1. Basics of at least one of the software: RETScreen, HOMER, PVSystems
2. Financial feasibility evaluation studies of renewable based energy technologies
3. Utilize knowledge from various disciplines (mathematical programming, economy, physics and energy resources, energy technologies, etc) in order to perform techno-economic analyses of renewable energy systems

Recommended Book:

1. M. Kleinpeter, Energy Planning and Policy, John Wiley & sons, 1995.
2. R. Codoni, H. Park and K.V. Ramani, Integrated Energy Planning: A Manual, Vols. I, II & III. Asian and Pacific Development Centre, Kuala Lumpur, 1985.
3. J. Parikh, Energy Models for 2000 and Beyond, Tata McGraw Hill Publishing Company Limited, 1997.

4. M.S.Kumar, Energy Pricing Policies in Developing Countries: Theory and Empirical Evidence, International Labor Organization, 1987.
5. M. Munasinghe and P. Meir, Energy Policy Analysis and Modeling, Cambridge University Press, 1993.
6. A.V.Desai, Energy Planning, Wiley Eastern Ltd., 1990.
7. H.Campbell and R.Broron, Benefit-Cost Analysis, Cambridge University Press, 2003.
8. C.S.Park, Contemporary Engineering Economics, Prentice Hall Inc., 2002

Evaluation Scheme:

S.N.	Evaluation Elements	Weightage (%)
1.	MST	≥20
2.	Sessionals Evaluation (May include Assignments/Projects/Tutorials/Quizzes)	≥10
3.	Lab Evaluations	≥20
4.	EST	≥40

PES *** GREEN BUILDINGS

L	T	P	Cr
3	0	0	3.0

Course Objectives

The Course enables to understand the need for green development, demand for green buildings and opportunities in green buildings. Identify and compare existing energy codes, green building codes and green rating systems. To gain knowledge related to the Green Buildings to sustain the environments while keeping the same comfort for the occupants at the same time.

Environmental and Economic Context: Energy use in buildings, factors affecting energy use, Energy conservation options, building HVAC, Day Lighting, Energy Efficient Lighting

Resource conservation and Design Strategies: External- Climate, Climate Zone, Building orientation, Shading Design, Window Wall Ratio and Internal Space Arrangements, Environmentally sensitive construction materials, use of VOC paint, adhesives and sealants, Foundation, Roof, Attics, Windows, Doors, Plumbing, Reduction in waste, Reduction in Air Pollution, Safety Facilities for workers during construction.

Indoor Air Quality: Volatile organic compounds, formaldehyde, models, IAQ requirements in residential, commercial, Hospital Buildings. Rainwater harvesting, Water Recycle and Reuse

Renewable Energy Utilization: Feasibility and design of Solar and Biogas Plant in Buildings Building Audit, Operation and Maintenance, Benefits of Green Buildings, Rating Programs and Certification

Course Learning Outcomes (CLOs):

On completion of this course, the students will be able

- Identify the critical sustainability issues that should be addressed in planning a building or new development.
- Estimate the green star rating of a new building.
- Identify the issues effecting indoor environmental quality.
- Select different heating and cooling ventilation systems and justify the selection
- Calculate the embodied energy of different structural systems including recycled material

Recommended Books:

1. *J. Krieder and A. Rabl, Heating and Cooling of Buildings - Design for Efficiency, McGraw*
2. *Hill, 1994.*
3. *S.M. Guinnes and Reynolds, Mechanical and Electrical Equipment for Buildings, Wiley,*
4. *1989.*

5. *A.Shaw, Energy Design for Architects, AEE Energy Books, 1991.*
6. *ASHRAE, Handbook of Fundamentals, Atlanta, 1997. e. Donald W. Abrams, Low Energy*
7. *Cooling – A Guide to the Practical Application of Passive Cooling and Cooling Energy*
8. *Conservation Measures, Van Nostrand Reinhold Co., New York, 1986.*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥35
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥25

PET *** BIO ENERGY AND WASTE TO ENERGY TECHNOLOGIES

L	T	P	Cr
3	0	0	3.0

Course Objectives: This enables to understand the concepts of waste to energy technologies, bio mass utilization in the process of energy production. Various properties of bio mass to be used as fuel and various conversion of bio mass.

Introduction to bio energy: classification of biomass and Municipal solid waste (MSW), biomass harvesting; availability and assessment, biomass to bio energy applications; characterization of biomass feedstock and physical properties, ultimate analysis, proximate analysis, calorific value, thermo gravimetric analysis, differential thermal analysis and ash fusion temperature); composition analysis of biomass (cellulose, hemi-cellulose and lignin); classification according to processing; biomass feedstocks for first, second and third generation bio fuels, hybrid bio fuels, carbon neutral fuels, supply side management of biomass.

Pre-treatment and processing of biomass: Different routes for biomass conversion to bio fuels: biochemical processes viz. anaerobic digestion, enzymatic-fermentation process, dark fermentation, ABE fermentation, chemical processes: esterification, transesterification, hydro processing, micro emulsification and thermo chemical methods: combustion, gasification, pyrolysis, partial oxidation, autothermal reforming for biofuels production.Synthesis gas conversion via Fischer Tropsch process to hydrogen, methanol, dimethyl ether and paraffinic fuels; Biomass compaction: carbonization, briquetting and palletisation, biomass-based incineration plant for heat generation; co-firing of biomass; biomass and bio fuel quality testing and norms viz. BIS, ASTM and EN methods, Euro IV & VI norms; bio fuel quality up gradation, blending.

Biomass Utilization: Biomass cookstove for cooking and heating, Utilization of Biomass derived syngas in external combustion engines including steam turbine power plant and Stirling engines, Case studies for setting up biomass based small powerplant (~ 1MW) capacity for rural electrification, techno economic case studies for biomass and MSW waste based power plants utilization of biofuels in gas turbine, internal combustion engines and fuel cells, analysis of carbon credit.

Course Learning Outcomes (CLOs):

1. The fundamental concepts of bio energy systems and environmental benefits;
2. Biomass harvesting, availability and assessment; types of biomass and their exploitation for bio energy,
3. Properties of biomass for fuel purposes; composition of biomass; bio fuels classifications
4. Different routes for biomass conversion: thermo chemical, biochemical and chemical conversion and waste biomass compaction,

5. Applications of biomass derived fuels for transportation, heat and power generation,
6. Techno- economic aspects of setting up biomass based mini and medium scale Industry

Recommended Books:

1. *Anju Dahiya (Edt), Bioenergy: Biomass to biofuels and waste to Energy, 2020*
2. *Mukunda, H. S., Understanding clean energy and fuels from biomass, Wiley India, 2011*
3. *Konur, Ozcan, Bioenergy and Biofuels, Taylor and Francis, CRC Press, 2018*
4. *Love, John; Bryant J. A., Biofuels and Bioenergy, John Wiley & Sons, 2017*
5. *Henderson, O. P., Biomass for Energy, Nova Science Publishers, 2011*
6. *Jay J. Cheng Biomass to Renewable Energy processes, Taylor and Francis, CRC Press, 2018*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	≥30
2.	EST	≥40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	≥20