MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Centre for Energy and Environment

Bachelor of Technology - Open Electives

SYLLABUS

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RET 651 PHOTOVOLTAIC SYSTEMS				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:
CO1: To discuss the aspects of the basics of solar radiation, PV system, semiconductor technology to enable learners to analyse and estimate solar power at different locations
CO2: To dissipate the knowledge for estimating different losses in solar energy systems.
CO3: To discuss theories and parameters for designing small or large solar power plant.

Course Content

Unit 1	Fundamentals of solar PV cells and systems: semiconductors as basis for solar cells materials and properties, P-N junction, I-V and QE curves of solar cells
Unit 2	BOS for power plant: Supporting structures, mounting and installation, battery storage, power condition unit, selection of cables and balance of systems, maintenance and schedule, Monitoring, Data Management,
Unit 3	Solar PV power plant: Estimating power and energy demand, site selection, land requirements, choice of modules, economic comparison, balance of systems, off grid systems, grid interface, simulation with software. sources of losses and prevention. Performance Analysis and Financial Analysis. Preparing DPR.
Unit 4	Recent developments in commercial solar cell technologies and systems. Standards and testing of PV modules. Concentrator solar cells, reflector and lens based versions. Performance in Indian climatic conditions. Low, medium and high concentration.
References	1.Solar Photovoltaics: Fundamentals, Technologies and Applications by Chetan Singh Solanki, Prentice Hall India, 3rd Edition. ISBN 9788120351110 2.Terawatt Solar Photovoltaics, Roadblocks and Opportunities Edited by M. Tao, Springer, 2014 edition. ISBN 978-1- 4471-5643- 7 3.Handbook of Photovoltaic Science and Engineering, Edited by A. Luque and S. Hegedus, John Wiley & Sons, Ltd, 2012 edition. ISBN 978-0- 470-72169- 8

RET 652 - WIND AND HYDRO ENERGY SYSTEMS				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: To understand wind energy basics and resource assessment techniques.

CO2: To create an understanding on aerodynamics of wind turbine, components of wind turbine, and power generation

CO3: To understand the basics of hydroelectric generators, constructive structure and design of hydropower plants.

Course Content

Unit 1	Wind Energy Basics: Status, Advantages and disadvantages of wind energy systems, Advantages and disadvantages, Types of wind energy converters, local Effects on wind, site selection: roughness length, wind shear, Wind Speed Variability, Obstacles to wind flow,
Unit 2	Working principles of wind energy: Energy content in wind, Energy Conversion at the Blade, Wind variations: Weibull distribution.
Unit 3	Components of a wind energy converter: Rotor Blades, Gearboxes, Synchronous or Asynchronous Generators, Towers, Miscellaneous components, Turbine Selection. Operation and Control of Wind Energy Converters: grid requirements, Issue of Noise and Its Control, Power Curve and Capacity Factor, Pitch control, Stall Control, Yaw Control
Unit 4	Hydropower basics: Water Cycle in Nature, Classification of Hydropower Plants, Status of Hydropower Worldwide, Advantages and Disadvantages of Hydropower, Operational Terminology, Legal Requirements Working principles: Locating a Hydropower Plant, Basics of Fluid Mechanics for hydro power, single and multiple reservoir system, cascaded power plants

Unit 4	Important Parts of Hydropower Station: Turbine, Electric Generator, Transformer and Power House, Structural parts: Dam and Spillway, Surge Chambers, Stilling Basins, Penstock and Spiral Casing, Tailrace, Pressure Pipes, Caverns, auxilliary parts. Hydraulic turbines: Classification of Hydraulic Turbines, Theory of Hydro Turbines: Francis, Kaplan, Pelton turbines, efficiency and selection of turbine.
References	1. Freris L.L., Wind Energy Conversion Systems, ISBN 978-0139605277 Prentice Hall 1990. 2. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ISBN 978-0791812051, 1994. 3. Johnson, G.L., Wind Energy Systems, Prentice Hall, ISBN 978-0139577543, 1985. 4. Wagner, Hermann-Josef, Mathur, Jyotirmay, Introduction to Hydro Energy Systems Basics, Technology and Operation, Springer ISBN 978-3-642-20709-9, 2011 5. Wagner, Hermann-Josef, Mathur, Jyotirmay, Introduction to Wind Energy Systems Basics, Technology and Operation, Springer ISBN 978-3-642-32976-0, 2013 6. Wagner, Hermann-Josef, Mathur, Jyotirmay, Introduction to Wind Energy Systems Basics, Technology and Operation, Springer, 2013 ISBN 978-3-642-32976-0 7. https://www.coursera.org/learn/wind-energy and https://nptel.ac.in/courses/108105058/24

RET 653 - ENERGY AND ENVIRONMENTAL POLICIES				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

CO1: To understand the need for government policies in energy and environment sector.
CO2: To learn the nexus between economic growth, energy and climate policies, and energy demand
CO3: To analyze the possibilities and limitations of various policy measures.

Course Content

Unit 1	Introduction to Energy codes and policies: Energy Conservation act, Electricity Act and amendments. International scenario: world energy outlook, international protocols for energy and environment, governing and nodal national/international agencies and their role. Import and export position, Resources, Reserves, All India Energy Scenario, Energy Security - Concept, Trade-Off between Energy Security and Climate Change
Unit 2	Financial tools: incentives and subsidies, calculation of required subsidy for penetration, concept of shadow price Concept of micro-financing for RE, funding agencies for RE projects in India, application development for RE funding Tariff policies, use of Demand Side Management as a policy tool
Unit 3	Global Warming, International Environmental Policy Practices, Emissions Trading System (ETS), UNFCCC, Kyoto protocol, Clean development mechanism (CDM), Joint implementation, Emission targets, COPs, NAPCC, INDC and latest national/international government policies. Waste Management Practices and policies.
Unit 4	Renewable Energy Policy, Incentives and subsidies, Foreign Investment, Role of MNRE, IREDA, Bio Energy Policy, Solar Policy, Hydro Policy, Wind policy, National Solar Mission, Renewable purchase obligations, Feed in Tariffs, Renewable Energy Certificates, Hydro Power Policy, Small/Large Scale National policy on Hydropower in India, India EV Policy, Other schemes –

	Saubhagya, UJALA, UDAY, RFMS, Smart Cities, etc.
References	1. SC Bhattacharyya. Energy Economics, Concepts, Issues, Markets and Governance, Springer Science & Business Media, (2011) ISBN 978-0-85729-268-1. 2. RS Axelrod & SD VanDeveer (Eds.). The Global Environment: Institutions, Law, and Policy. CQ Press; Fifth edition (2019). ISBN 1544330146 3. TF Braun & MG Lisa. Understanding Energy and Energy Policy. Zed Books, (2014) ISBN 1780329342 4. Kandpal, Tara Chandra, and Hari Prakash Garg. Financial evaluation of renewable energy technologies. MacMillam India Limited, 2003. 5. Nersesian, Roy L. *Energy economics: markets, history and policy*. Routledge, 2016, ISBN-13: 978-1138858374, ISBN-10: 1138858374. 6. Zweifel, Peter, Aaron Praktiknjo, and Georg Erdmann. *Energy economics: theory and applications*. Springer, 2017, ISBN 978-3-662-53022-1.

RET 654 - ENERGY MARKETS				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: To understand the architecture of energy markets

CO2: To analyse risk management practices in the energy sector

CO3: To understand the theory of electricity markets and critically engage with market design issues and policy questions.

Course Content

Unit 1	**Introduction:** Mechanism of energy markets; comparative market systems; determination of prices, demand supply curve, economics of Perfect Competition, and Monopoly, oligopoly, Natural Monopoly,, Models for competition, theory of the firm, market equilibrium, pareto efficiency
Unit 2	**Energy Market Structures**: Market structures of gas, oil, coal, emission and electricity markets, Global Market for Coal, gas and oil, marginal cost, design of competitive prices, Regulatory Bodies, Energy markets and economic efficiency, Net energy analysis, Energy Security
Unit 3	**Market Architecture:** OTC and auctions, spot and forward markets, market clearing, architectural controversies, two settlement system, perfect competition characteristics, Market power and market failure
Unit 4	**Risk and Risk management in energy:** Risk and Risk management in energy including demand and price volatility and use of financial derivatives; and the impact of financial market trends and regulatory changes in the energy industry.
Unit 5	**Markets for Electrical Energy**: Structure of electricity market, day ahead, real time markets, gate closures, electricity pool, suitability of market clearing methods on market architecture, Power, Energy, Ancillary Services, Transmission market, Market power, need of regulations.

References	1. Kaminski, Vincent. *Energy markets*. Risk Books, 2012. 2. James, Tom. *Energy markets: price risk management and trading*. John Wiley & Sons, 2012. 3. Kirschen, Daniel S., and Goran Strbac. *Fundamentals of power system economics*. John Wiley & Sons, 2018. 4. Peirce, William Spangar. *Economics of the energy industries*. Greenwood Publishing Group, 1996.

RET 655 –DECENTRALIZED ENERGY SYSTEMS				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: To illustrate the concept of distributed generation, scope and challenges in off-grid systems implementation

CO2: To analyze the rural energy availability and planning, impact of energy access to livelihood improvement of the community.

CO3: To study concept of Micro-grid and its configuration, simulation tools for hybrid system design

Course Content

Unit 1	Need and advantage of decentralized energy systems, Decentralized generation technologies, Costs and choice of technology, demand and benefits, overview of forecasting and program development, Economic and financial analysis of decentralized electrification projects, Decentralized versus Centralized generation, Traditional power systems, Load curves and analysis
Unit 2	Integrated Rural Energy Planning (IREP); rural electrification, Linkages with rural livelihoods, rural industries and social development; efficient/appropriate renewable energy technologies for rural areas, Study on energy potential in study locations. Smart Grid: Definition, applications; smart grid communications, advanced metering infrastructure, demand response, energy

	consumption scheduling; renewable energy generation based Micro-grid
Unit 3	Scope and challenges in implementing off grid solutions; Policy and regulatory framework for decentralized electricity in India, Integrated Energy Policy, Power for All, Electricity Act, RGGVY, Village Energy Security Programme (VESP). Status of grid connected and off grid distributed generation (national and International), Case studies on various national and international distributed energy generation systems.
Unit 4	Hybrid system architectures, advantages and disadvantages, System components, control strategies, and the use of storage, other demand-side technologies evaluation, Optimal design of hybrid energy systems, energy economics of integrated energy systems; Sample problems and case studies, Simulation tools like HOMER, RETSCREEN, etc.
References	[1] Bollen M. H. and Hassan F. (2011); Integration of Distributed Generation in the Power System, Wiley-IEEE Press [2]Zerriffi H. (2011); Rural Electrification: Strategies for Distributed Generation, Springer [3]Jenkins N. Strbac G. and Ekanayake J. (2009); Distributed Generation, The Institution of Engineering and Technology [4]Keyhani A. (2011); Design of Smart Power Grid Renewable Energy Systems, Wiley–IEEE Press [5]Tester J. W. (et al.) (2012); Sustainable Energy: Choosing among Options, Second Edition, The MIT Press [6] Bhattacharyya S. (Ed.) (2013); Rural electrification through decentralised Off-grid systems in Developing Countries, Springer [7]Zerriffi H. (2011); Rural Electrification: Strategies for Distributed Generation, Springer

RET 656 : ENERGY MANAGEMENT AND AUDIT				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO3: CO1:Students can evaluate the techno economic feasibility of the energy conservation technique adopted through audit

CO2:Students will gain the ability to identify the efficiency improvement process in any industry

CO3:Students will gain the ability to identify the demand supply gap of energy in Indian scenario

Course Content

UNIT 1	Energy in Indian scenario, Energy Conservation, Indian Energy Conservation Act 2001 and its Features, Energy efficiency, Energy management, Necessity of Energy Management, Strategic Approach for Energy Management (Key Step Approach), designing an energy management program. Role of Energy auditor/manager, management and organization of energy conservation programs in industries, Bureau of Energy Efficiency Guidelines and Programmes, Energy Star Rating.
UNIT 2	Energy Accounting and Analysis: spreadsheet set-up, the energy use index , energy-using systems., identifying potential measures, Energy Management Control Systems, industrial audit opportunities Understanding the Utility Bill : Electric charges and Thermal Charges, Energy consumption in industries: Energy and material flow assessment, specific energy consumption, industry benchmarks for energy consumption. concept of ESCO, energy performance contracting.
UNIT 3	Energy Auditing Basics : Types and Levels of energy audits, The audit process, Pre and Post site work, the audit report, Survey Instrumentation : general audit instrumentation, temperature measurements, measuring building losses, applications of IR thermography, measuring combustion

	systems, measuring heating ventilation and air conditioning (HVAC) system performance.
UNIT 4	Energy conservation in industrial systems: boilers, furnaces, pumps, fans and blowers, steam system, motors and transformers, power factor, load management, The Electrical System Audit , The Mechanical System Audit, Verification of System Performance , The Physical Plant Audit and case studies, Retrofit Considerations , Audits to Industrial Assessments: energy conservation opportunities, waste minimization opportunities, process improvement opportunities, Renewable energy system audit.
REFERENCES	1. Guide to Energy management, by Barney L.Capehart, Wayne C.Turner, and William J.Kennedy, The fairmont press, INC. Fourth edition 2. Handbook of Energy Audits by Albert Thumann. CRC press 9th ed. 3. http://www.nptelvideos.in/2012/11/energy-resources-and-technology.html

RET 657 - BIOMASS ENERGY SYSTEMS				
Prerequisite: Nil	L	T	P	C
Total hours:40	3	0	0	3

Course Outcomes:

CO1:To enable students for analysing and describing the nature and principles of bioenergy systems.

CO2:To develop, designs and distinguish the bioenergy systems and learn technical analysis.

CO3:To create understanding to critically evaluate the environmental benefits and consequences of bioenergy production.

Course Content

Unit 1	Biomass: Biomass resources, types, production, classification and characterisation; Techniques for biomass assessment. Concept of Waste segregation, management and treatment.
Unit 2	Thermochemical Conversion: Direct combustion, incineration, pyrolysis. Biomass gasifiers; types of gasifiers, Sizing selection and design of gasifiers. Biomass stoves, improved chulha and designs. Biomass fired boilers and types; Biomass pyrolysis – types, manufacture of charcoal, manufacture of pyrolytic oils and gases; Design and operation of pyrolysis units. Plastic waste management, plastic pyrolysis type of technologies.
Unit 3	Biological Conversion: Biodegradation substrate; Anaerobic digestion, process parameters of biomethanation; chemical kinetics and biomethanation process, biogas plant types, biogas plant design, biogas purification and utilisation; environmental and social impacts; bioconversion of substrates into bioethanol. Concept of Biorefinery and Circular Economy
Unit 4	Chemical Conversion: Biodiesel and biohydrogen production, Fischer-Tropsch diesel hydrolysis and hydrogenation; solvent extraction of hydrocarbons; solvolysis of wood; biocrude; catalytic distillation.

Unit 5	Co-firing and co-generation, Biomass integrated gasification/combined cycles systems, Energy plantation/crops, food security and environmental impacts of biomass conversion to energy; energy from waste.
References	1. Capareda S, Introduction to biomass energy conversion, CRC Press. ISBN: 978-1-466-51333-4 2. Brown RC and Stevens C, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Wiley and Sons. ISBN: 978-0-470-72111-7 3. Vaughn C. Nelson, Kenneth L. Starcher, Introduction to Bioenergy (Energy and the Environment), CRC Press. ISBN: 978-1-498-71698-7 4. Yebo Li and Samir Kumar Khanal, Bioenergy: Principles and Applications, Wiley-Blackwell. ISBN: 978-1-118-56831-6 5. Ted Weyland, Bioenergy: Sustainable Perspectives, Callisto Reference. ISBN: 978-1-632-39633-4 Video links: https://nptel.ac.in/noc/individual_course.php?id=noc18-bt15 https://www.youtube.com/watch?v=fR0chD3Ob1M

RET 658 -PV TECHNOLOGIES				
Prerequisite:	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: To discuss the suitability of different PV technologies, both structural and material view point in different climatic conditions.

CO2: To dissipate the knowledge for estimating energy losses in PV cells.

CO3: To discuss the production mechanism and cost involved in different PV technologies

Course Content

Unit 1	Introduction, History and overview of different types of solar cells/panels, theory and working principle of silicon Solar cells and modules. Relation between different solar cell parameters. Optical and electrical modelling of crystalline silicon solar cell.
Unit 2	Fabrication of crystalline silicon solar cells and Modules. International certification of solar panels and Indian scenario. Wafer based silicon solar cells and its market trend. Cost breakup of wafer based solar panels, future trends. Semi-transparent solar cells and related materials, applications in buildings (BIPV).
Unit 3	Bi-facial solar cells and its theory. Hetero-junction with intrinsic thin layer (HIT) solar cells, structure and working principle, comparison with conventional c-Si solar cells.
Unit 4	Multi-junction solar cells, its working principles. Polymer, organic, dye sensitized and quantum dot solar cells, structure, working principle, present applications, near future trends.
References	1. Terawatt Solar Photovoltaics, Roadblocks and Opportunities Edited by M. Tao, Springer, 2014 edition. 2. Handbook of Photovoltaic Science and Engineering, Edited by A. Luque and S. Hegedus, John Wiley & Sons, Ltd, 2012 edition. 3. Practical Handbook of Photovoltaics: Fundamentals and Applications Edited by

	A. Mcevoy, T.Markvart, L. Castañer, Elsevier, 2nd edition 4. Building integrated photovoltaics, by S. Roberts & N. Guariento, Germany, 2009 edition 5. Photovoltaics System Design and Practice Edited by H. Haberlin, John Wiley & Sons, Ltd, 2012 edition. 6. Photovoltaics Fundamentals, Technology and Practice Edited by K. Mertens, John Wiley & Sons, Ltd 7. https://nptel.ac.in/courses/113104084/

RET 659 ENERGY STORAGE TECHNOLOGY				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: To discuss different aspects and parameters of electrical energy storage systems.

CO2: To understand utilization, sizing and operation of energy storage systems.

CO3: To create an understanding on energy storage integration and hybrid energy storage systems.

Course Content

Unit 1	Introduction of energy storage technology, requirement for energy storage, Current status, electricity storage services and benefits, cost performance and maturity of storage technology, methods and tools for evaluation of storage, future prospect of storage.
Unit 2	Introduction to Electrochemical energy storage: lead acid battery, Li ion battery, Ni metal hydride battery, Flow Battery, Capacitor etc. Comparison, Ragone plot and state-of-art application, their function and deployments. Technical characteristics, introduction to battery states and their estimation methods, battery based hybrid storage system, battery aging. Performance characteristics, testing, safety, standards and system sizing. Case study/project.
Unit 3	Thermal energy storage (TES) methods - Sensible TES, Latent TES, Thermochemical TES, Selection depending on the application. Types of storage systems Design and operation of thermal storage systems - Performance characteristics, testing, safety, standards and system sizing, Case study/project.
Unit 4	Hydrogen energy: hydrogen economy, Hydrogen based energy storage, safety

Unit 5	Mechanical energy storage systems, flywheel energy storage (FES), pumped hydropower storage (PHS), and compressed-air energy storage (CAES). Comparison and application state-of-art including principle, function and deployments. Performance characteristics, testing, safety, standards and system sizing. Case study/project based on mechanical energy storage. Introduction to Hybrid energy storage systems
References	(1) Energy Storage Edited by Md. Rafiqul Islam Sheikh. Publisher Sciyo. ISBN 978-953-307-119-0 (2) Energy Storage –Technologies and Applications Edited by Ahmed Faheem Zobaa. Publisher Intech Publishers. ISBN 978-953-51-0951-8 (3) Energy Storage Edited by Marc A. Rosen. Publisher Nova Science Publishers Inc. ISBN 1613247087, 9781613247082 (4) Emerging Advanced Energy Storage Systems: Dynamic Modeling, Control and Simulation Edited by Marcelo Gustavo Molina. Publisher Nova Science Publishers Inc. ISBN 1613243928, 9781613243923 (5) Energy Storage: High-Impact Strategies - What You Need to Know: Definitions, Adoptions, Impact, Benefits, Maturity, Vendors Edited by Kevin Roebuck. Publisher Tebbo. ISBN 1743333404, 9781743333402 (6) Large Energy Storage Systems Handbook Edited by Edited by Frank S. Barnes Jonah G. Levine. Publisher CRC Press Taylor & Francis Group ISBN 978-1-4200-8601-0

RET 660- ENERGY ECONOMICS				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: Use appropriate economic theory to analyse investment decisions in energy resources

CO2: To apply economic theory to identify the factors that influence markets for energy commodities

CO3: To understand the concepts of energy demand forecasting and its management

Course Content

Unit 1	**Introduction:** Energy and Economics, sector wise consumption of energy resources: Electricity-Fuel-Transportation, Energy Scenario and supply position of different energy sectors: Indian and International Level – Coal, Oil, Natural Gas, RE, Hydro, Nuclear
Unit 2	**Energy Economics fundamentals:** Simple Payback Period, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation, Energy Chain, Primary energy analysis and Life Cycle Assessment
Unit 3	**Energy Demand Forecasting**: Simple and advanced Techniques, Econometric Approach to Energy Demand Forecasting, End-Use Method of Forecasting, Input–Output Model, Scenario based approach, ANN based approach, Hybrid Approach, Energy Demand Analysis
Unit 4	**Economics of Demand/Load Management**: Demand Side Management, Cost Effectiveness of DSM, Introduction to DSM, concept of DSM, benefits of DSM, different Techniques of DSM, methods of DSM Load control, DSM planning

References	1. Bhattacharyya, Subhes C. *Energy economics: concepts, issues, markets and governance*. Springer Science & Business Media, 2011, ISBN 978-0-85729-268-1. 2. Financial evaluation of renewable energy technologies, a book by TC Kandpal, 1982. 3. Zweifel, Peter, Aaron Praktiknjo, and Georg Erdmann. *Energy economics: theory and applications*. Springer, 2017 4. Aris Spanos, "Statistical Foundations of Econometric Modelling" Cambridge University Press. 5. Energy Demand – Analysis, Management and Conservation, Ashok V. Desai, Wiley Eastern Ltd., New Delhi.,1990. 6. Demand Side Management Jyothi Prakash, TMH Publishers

RET 661 –ENERGY AND ENVIRONMENT				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: To present an overview of different energy sources, their environmental impact with respect to development.

CO2: To think laterally and originally, conceptualize and solve environmental problems due to energy use

CO3: To evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions on energy generation after considering public health and safety

Course Content

Unit 1	Types of energy and its utilization - Energy characteristics – Energy measures, Country Energy Balance Construction - Examples Trends in energy use patterns, energy and development linkage. Energy poverty and Human Development Indices, Energy and Human Development, Energy development index; Understanding the link between economic growth and energy consumption
Unit 2	Fundamentals of environment - Water cycle - Oxygen cycle - Carbon cycle - Nitrogen cycle - Phosphorous cycle - Bio-diversity - Environmental aspects of energy utilization - Public health issues related to environmental pollution.

	Environmental effects of energy extraction: Air-Water-Noise-Soil-Radioactive Pollution due to energy use: Classification pollutants, sources of emission and quality standards - characteristics - Factors influencing pollutants - Analysis of pollutants.
Unit 3	Conflict between energy consumption and environmental pollution, Economic approach to environmental protection and management, Energy Environment interactions at different levels, energy efficiency, Role of technology up-gradation and alternative resources on reduction of CO_2 emission; Methodology for CO2 assessment; UNFCCC baseline methodologies for different conversion process, estimation of emission from fossil fuel combustion; Case studies
Unit 4	Future Energy Systems: classification of energy sources: conventional (coal, oil and gas) and renewable sources (solar, biomass, wind, hydro, geothermal, tidal, OTEC); quality and concentration of energy sources; worldwide progress in renewable energy. Environmental aspects of renewable energy projects
References	1. Energy and the Challenge of Sustainability, World energy assessment, UNDP New York, 2000. 2. AKN Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997. 3. Nebojsa Nakicenovic, Arnulf Grubler and Alan McDonald Global energy perspectives, Cambridge University Press, 1998 4. Fowler, J.M., Energy and the environment, 2nd Edn., McGraw Hill, New York, 1984

RET 662 - MEASUREMENTS IN THERMAL SYSTEMS				
Prerequisite:	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

A student who completes the course is expected to acquire,

CO1: an ability to design experiments and measurement systems

CO2: an ability to identify suitable measurement systems and conduct experiments

CO3: an ability to carry out uncertainty analysis of measured data

Course Content

Unit 1	Importance of measurement and experimentation; primary and derived quantities, characteristics of measurement systems, time response of measurement systems, System response- first and second order systems and analysis, error estimates and uncertainty analysis, propagation of uncertainty
Unit 2	Statistical analysis of experimental data- normal error distributions (confidence interval and level of significance, Chauvenet's criterion), Chi-square test of goodness of fit, method of least squares (regression analysis, correlation coefficient), multivariable regression, error estimates using Gaussian distribution, Static and dynamic characteristics; dimensional analysis and similitude, Design of experiments
Unit 3	Measurement of pressure - Manometers, bourdon tube pressure gage, diaphragm gage, bellow gage, McLeod gage, Pirani gage and ionization gage, piezoelectric transducers. Measurement of temperature - Temperature measurements based on thermal expansion of materials, thermocouples, resistance-based temperature sensors, pyrometer, bimetallic and liquid crystal thermometer, temperature sensors for measurement of transient temperature, measurement in high temperature and cryogenic conditions. Measurements of thermal and physical properties - Viscosity - Use of Poiseuille

	flow, falling, rotating and oscillating bodies - Thermal conductivity of solids and liquids - Low conductivity and metallic - Steady and unsteady states - Measurement of specific heat of gases.
Unit 4	Measurement of flow rate - obstruction flowmeters, rotameters, turbine flowmeters, thermal mass flowmeters, flow velocity measurements using pitot and static pressure probes. Flow velocity measurements - Laser Doppler Velocimetry, Hot Wire Anemometry, Particle Image Velocimetry, Particle Image Density, Stereoscopic PIV for Three-Component Velocity Measurements, Image-Based Methods.
References	1. T.-W. Lee: Thermal and Flow Measurements, CRC Press, 2008. 2. J.P. Holman: Experimental Methods for engineers, McGraw Hill Education; 7th ed., 2017 3. S. P. Venkateshan: Mechanical Measurements, ANE Books, 2008 4. E.R.G. Eckert and R.J. Goldstein: Measurements in Heat Transfer, McGraw Hill, 1976 5. E.O. Doebelin: Measurements Systems: Application and Design.

RET 663 - DESIGN OF THERMAL ENERGY SYSTEMS				
Prerequisite: Nil	L	T	P	C
Total hours:40	3	0	0	3

Course Outcomes:

CO1: To design energy systems for engineering applications and assess their performance

CO2: To analyze energy systems under design and off-design operating conditions.

CO3: To optimize the performance of different energy systems

Course Content

Unit 1	Engineering design fundamentals - Designing a workable system - Economic evaluation - Fitting data - Design optimization - Knowledge based system design. Heat exchanger design calculations - Evaporators and condensers temperature concentration pressure characteristics- Cooling towers -Pressure drop and pumping power Pump characteristics - Manufacturer's specifications - Relations among performance characteristics - Pump system operation - Cavitation prevention - Fans and nozzles.
Unit 2	Modeling and simulation principles - Modelling overview-levels of analysis, steps in model development, examples of models. Hardy-Cross method - Multivariable Newton-Raphson simulation method - Simulation of renewable energy systems/Case studies - Simulation using differential equations - Mathematical modeling of thermodynamic properties - Steady state simulation of large systems - Simulation of dynamic systems. Examples of energy systems simulation
Unit 3	Optimisation: Objectives/constraints, problem formulation. Unconstrained problems-Necessary & Sufficient conditions. Constrained Optimisation-Lagrange multipliers, constrained variations, Kuhn-Tucker conditions. Case studies of optimisation in Energy systems problems. Dealing with

	uncertainty-probabilistic techniques. Linear programming - Dynamic programming - Non-traditional optimization techniques
Unit 4	Measurement systems: time response of measurement systems, System response- first and second order systems and analysis, error estimates and uncertainty analysis, propagation of uncertainty. Statistical analysis of experimental data- normal error distributions (confidence interval and level of significance, Chauvenet's criterion), Chi-square test of goodness of fit, method of least squares (regression analysis, correlation coefficient), multivariable regression, error estimates using Gaussian distribution, Static and dynamic characteristics; dimensional analysis and similitude, Design of experiments
References	1.Adrian Bejan, George Tsatsaronis, Michael Moran, Thermal Design and Optimization, John Wiley, 1995, ISBN: 978-0-471-58467-4. 2. Y. Jaluria, Design and Optimization of Thermal Systems, 2e, CRC Press, 2008, ISBN 9781498778237. 3. W.F. Stoeker, Design of Thermal Systems, 3e, McGraw Hill, 2011, ISBN 10: 125900239X / ISBN 13: 9781259002397. 4. C. Balaji, Essentials of Thermal System Design and Optimization, ANE books, 2011, ISBN 13: 9781439891544. 5. Fabio De Bellis, "Energy Systems Simulation and Optimization", Lambert academic, ISBN-13: 978-3848420216. 6. S. P. Venkateshan: Mechanical Measurements, ANE Books, 2008 7. E.R.G. Eckert and R.J. Goldstein: Measurements in Heat Transfer, McGraw Hill, 1976 8. E.O. Doebelin: Measurements Systems: Application and Design.

RET 664- SOLAR THERMAL SYSTEMS				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes:

CO1: To discuss different aspects and parameters of solar energy to enable learners to design solar thermal system

CO2: To educate the learner for tackling different issues and challenges of various solar thermal collectors

CO3: To understand the power generation aspects from solar thermal systems

Course Content

Unit 1	Solar Radiation: Basics of Solar Radiation, instruments for measuring solar radiation, solar radiation geometry, apparent motion of the sun, local apparent time, predicting the availability of solar radiation, global, beam and diffuse radiation, empirical equations, solar radiation on tilted surfaces.
Unit 2	Liquid Flat plate Collector: Basic elements, performance analysis, transmissivity - absorptivity, heat transfer coefficients and correlations, collector efficiency and heat removal factors, the effects of various parameters, types of other liquid flat-plate collectors, transient analysis.
Unit 3	Concentrating Collectors: Type of concentrating collectors and their general characteristics, geometry, heat transfer correlations, performance analysis.
Unit 4	Codes and standards, Performance analysis of miscellaneous solar applications: Solar Air heaters, solar pond, solar still, solar refrigeration, Solar distillation, Solar drying, Applications of solar flat plate water heater & air heater for industrial process heat.

References	1. S. P. Sukhatme and J. K Nayak, Solar Energy, 4th Edition, McGraw-Hill Education Pvt., 2018, ISBN 978-93-5260-711-2. 2. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, 4th Edition, Wiley, 2013, ISBN 978-0-470-87366-3 3. D. Y. Goswami, Principles of Solar Engineering, 3rd Edition, CRC Press, 2015, ISBN 978-1-4665-6379-7