MAULANA AZAD NATIONAL INSTITUTE OF TECHNOLOGY,

BHOPAL–462003

Energy Centre

Scheme and Syllabus

M.Tech. in Renewable Energy (RE) Full Time wef July 2025

Course Code.	Subject	Schemes of studies periods per week			Total Credits
		L	T	P	
EN RE 1101	Renewable Energy Systems	3	-	-	3
EN RE 1102	Energy Audit and Conservation	3	-	-	3
EN RE 1103	Energy Storage Technologies	3	-	-	3
EN RE 1151-1159	Department Elective -1	3	-	-	3
EN RE 1161-1169	Department Elective –2	3	-	-	3
EN RE 1104	Renewable Energy Lab-I	-	-	2	1
EN RE 1105	Energy Audit Lab	-	-	2	1
EN RE 1106	Seminar-I	-	-	2	1
EN RE 1107	Minor Project-1(Self Learning)				2
HS 1101	Communication Skills	-	-	2	-
Total Hours:23 **Total Credits:20**		**Total Semester Credits**			**20**

Second Semester:

Course Code	Subject	Schemes of studies periods per week			Total Credits
		L	T	P	
EN RE 1201	Wind Energy Systems Wind	3	-	-	3
EN RE 1202	Solar Energy Systems	3	-	-	3
EN RE 1251-1259	Department Elective -3	3	-	-	3
EN RE 1261-1269	Department Elective -4	3	-	-	3
	Open Elective	3	-	-	3
EN RE 1203	Renewable Energy Lab-II	-	-	2	1
EN RE 1204	Energy Modelling and Simulation Lab	-	-	2	1
EN RE 1205	Seminar-II	-	-	2	1
EN RE 1206	Minor Project-2 (Self Learning)			2	2
Total Hours: 23 **Total Credits:40**		**Total Semester Credits**			**20**

Third Semester:

Course Code	Subject	Schemes of studies periods per week			Total Credits
		L	T	P	
EN RE 2101	Dissertation Phase-I	-	-	40	20
Total Hours: 40 **Total Credits:60**		**Total Semester Credits**			**20**

Fourth Semester:

Course Code	Subject	Schemes of studies periods per week			Total Credits
		L	T	P	
EN RE 2201	Dissertation Phase-II	-	-	40	20
Total Hours: 40 **Total Credits:80**		**Total Semester Credits**			**20**

Department Elective		Open Elective	
Department Electives – 1			Introduction to Urban Planning
EN RE 1151	Economics and Planning of Energy		Bioprocess Engineering
EN RE 1152	Power Plant Engineering		Biophysics Tools and Techniques
EN EM 1153	Energy Efficiency in Electrical Utilities		Analytical Techniques
EN EM 1154	Alternative Fuels		Green Technology & Processes
EN RE 1155	Operation Research and Optimization		Solid Waste Management
Department Electives –2			Basic Concept of GIS
EN RE 1161	Hydrogen and fuel cells		Road Safety
EN RE 1162	Small Hydro Power		Machine Learning
EN RE 1163	Power Controllers for Energy Systems		Advanced Data Structures and Algorithms
EN RE 1164	Biomass and Waste Management		Nanotechnology and Nanoscience
EN EM 2151	Climate Change and Carbon Sequestration		Electric Machines & Applications
Department Electives – 3			Control and Instrumentation
EN EM 1251	Energy Efficiency in Thermal Utilities		Introduction to Fuzzy Logic
EN RE 1252	Energy from waste		Neural Networks and its Applications
EN RE 1253	Green Buildings		Intellectual Property Rights for Engineers
EN RE 1254	Ocean and Geothermal Energy		Applied Psychology: Human Centered Design and Engineering
EN EM 1255	Research Methodology		Advanced Operations Research
Department Electives – 4			Computing Technologies
EN RE 1261	Smart and Micro Grid		Value Engineering
EN RE 1262	Integrated Energy Systems		Design Thinking
EN RE 1263	Electric Vehicles		Mechatronics and NDT in Engineering
EN RE 1264	Energy policies		Advanced Instrumentation Methods for Material Analysis
EN RE 1265	Pollution Control Technologies		Smart Materials and their Application
			Engineering Startup Management

Detailed Syllabus

1. **EN RE 1101** Renewable Energy Systems

Name of Program	M.Tech Renewable Energy	Semester I	Session 25-26
Name of Course	Renewable Energy Ssytems		
Course Code	EN RE 1101		
Core/ Elective/other	Core Subject		
Prerequisite:			
1.	Basic Engineering all disciplines		
COURSE OUTCOMES:			
1.	**CO1:** Analyse current energy scenario and significance of renewable energy sources, to understand sustainable development, to impart knowledge about working of small hydro system		
2.	**CO2:** Understand the solar radiation, solar thermal and solar photovoltaic		
3.	**CO3:** To impart working of wind energy, andmake Understand the basic concepts of biomass and bio -energy conversion process and applications		
4.	**CO4:** Its objectives is to give knowledge of Fuel cell, Hydrogen energy and MHD generation		
5.	**CO5:** To impart harnessing methods ofGeothermal resources and Ocean and Tidal Energy		
Description of Contents in brief:			
1.	Renewable and Non-renewable Energy sources, Energy for sustainable development, Renewable Energy Sources- Indian scenario and worldwide developments, present status and future trends. SMALL HYDRO POWER- Types of hydro power plants and their schemes, small hydro systems, mini-micro-pico hydro, Selection of site, Essential features and Elements of SHP-Water Ways, intake gates, power canal, surges in power canal and penstocks. Types & working of surge tanks, Hydraulic Turbines – Types, working, Hydrological analysis, Rainfall and its measurement, Runoff indices, hydrograph Potential of a river or a basin, pondage, Estimation of available power, Load curves, load factor, diversity factors and their significance, Numericals		
2.	SOLAR ENERGY-Solar radiation spectrum; The Photo Voltaic effect; p-n junction; different types; characteristics; Effect of temperature; insolation level & tilt and other angles; Solar cell Technologies: thin film, Wafer, Emerging ones, Solar cell I-V characteristics, fill factor and other parameters, Photovoltaic modules, Balance of PV system: Battery storage; Charge regulators, Concept of Maximum Power Point Tracking, PV Applications. Solar Thermal Conversion Devices and Applications, Solar Thermal collectors and their types, solar ponds; dryers; distillation; solar cooker, Central Receiver Thermal power plant		
3.	WIND ENERGY-Principle of Wind Energy Conversion, Potential, sources of atmospheric winds, Wind resource characteristics and assessment; anemometry, Site selection, Types of Wind Turbines and their Characteristics, Regions of wind installations, disadvantages, challenges BIO-ENERGY: Sources, Availability, Biomass conversion processes combustion, gasification, pyrolysis, liquification. Biogas production mechanism, Gasifiers Applications, Bio-methanation, Basics of anaerobic processes, Bio Gas plants components and classification, types comparison, urban waste Incineration plants, Landfill Gas plants, Liquid Bio Fuels, applications, Bio Energy programs in India		
4.	HYDROGEN ENERGY -Hydrogen Energy, Sources, Properties, Suitability as a fuel, Hydrogen Production Methods, Hydrogen Storage, transportation, cost and economy, Safety issues, FUEL CELL: Basics Fuel cell, difference between batteries and fuel cells,		

	Components of fuel cells, principle of working of fuel cell, Fuel cell classification types and applications MHD Generation principles and systems, Advantages, its status and applications
5.	GEOTHERMAL Energy: Geothermal resources, classification, Hydrothermal system, Hot dry rock systems, Geo-pressured reservoirs, Magma energy, Utilization of geothermal resources OCEAN THERMAL ENERGY: OTEC technology progress, working principle, OTEC resources & site requirement, potential harnessing regions current status, Challenges. OCEAN WAVE ENERGY: basics of wave motion, wave energy generation, potential harnessing regions, current status, Wave energy conversion devices, Advantages and disadvantages., TIDAL ENERGY: Tidal causes and working principle, Tidal power Basic modes of operations, potential harnessing regions, current status, Challenges.
List of Text Books:	
1.	R. K. Rajput, Non-conventional Energy Sources and Utilization, S.Chand
2.	B. H. Khan, Non-conventional Energy Resources, 2 edition, TMH Publication
List of Reference Books	
1.	Chetan Singh Solanki, Renewable energy Systems, Prentice Hall India Limited
2.	G. D. Rai, Solar Energy Utilisation, Khanna Publication
3.	Recent Advances in Thermochemical Conversion of Biomass, 1st Edition by Pandey & **Bhaskar** & **Stöcker** &**Sukumaran**
URLs:	
1.	www.seci.co.in
2	www.nrel.gov
3	www.nsefi.in

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Renewable and Non-renewable Energy sources	• Energy for sustainable development, Renewable Energy Sources- • Indian scenario and worldwide developments, present status and future trends
L2-3	Small Hydro Power	• Types of hydro power plants and their schemes, small hydro systems, mini-micro-pico hydro, Selection of site, • Essential features and Elements of SHP-Water Ways, intake gates, power canal, surges in power canal and penstocks.
L4-6	Estimation of available hydro power and types of hydro turbines	• Types & working of surge tanks, Hydraulic Turbines • Types, working, Hydrological analysis, Rainfall and its measurement, Runoff indices, hydrograph Potential of a river or a basin, pondage, • Estimation of available power, Load curves, load factor, diversity factors and their significance, Numericals
L7-10	Solar Energy	• Solar radiation spectrum; The Photo Voltaic effect; p-n junction; different types; • Their characteristics; • Effect of temperature; insolation level & tilt and other angles;
L11-14	Solar cell Technologies	• Solar cell Technologies: thin film, Wafer,

		• Emerging ones, Solar cell I-V characteristics, fill factor and other parameters, • Photovoltaic modules, Balance of PV system: Battery storage; Charge regulators, • Concept of Maximum Power Point Tracking, PV Applications. Solar Thermal Conversion Devices and Applications,
L15-16	Solar Thermal Conversion Devices	• Solar Thermal collectors and their types, solar ponds; dryers; distillation; solar cooker, CSP • Central Receiver Thermal power plant
L17-18	Principle of Wind Energy	• Principle of Wind Energy Conversion, Potential, sources of atmospheric winds, Wind resource characteristics and assessment; anemometry, Site selection, • Types of Wind Turbines and their Characteristics, Regions of wind installations, disadvantages, challenges
L19-20	Biomass	• Sources, Availability, Biomass conversion processes combustion, gasification, pyrolysis, liquification. Biogas production mechanism, • Gasifiers Applications, Bio-methanation, Basics of anaerobic processes, Bio Gas plants components and classification,
L21-23	Biomass and landfills	• Types comparison, urban waste Incineration plants, • Landfill Gas plants, Liquid Bio Fuels, applications, Bio Energy programs in India
L24-26	Hydrogen Energy	• Hydrogen Energy, Sources, Properties, Suitability as a fuel, Hydrogen Production Methods, • Hydrogen Storage, transportation, cost and economy, Safety issues,
L27-29	Fuel Cell classification	• Basics Fuel cell, difference between batteries and fuel cells, Components of fuel cells, principle of working of fuel cell, • Fuel cell classification types and applicationsMHD Generation principles and systems, Advantages, its status and applications
L30-34	Geothermal Energy	• Geothermal resources, classification, Hydrothermal system, Hot dry rock systems, • Geo-pressured reservoirs, Magma energy, Utilization of geothermal resources
L35-40	Ocean Wave Energy	• OTEC technology progress, working principle, OTEC resources & site requirement, • potential harnessing regions current status, • Challenges.: basics of wave motion, wave energy generation, potential harnessing regions, current status, • Wave energy conversion devices, Advantages and disadvantages., • Tidal causes and working principle, Tidal power • Basic modes of operations, potential harnessing regions, current status, Challenges.

2. **EN RE 1102** Energy Audit and Conservation

Name of Program	M.Tech Renewable Energy	Semester I	Session 25-26
Name of Course	Energy Audit and Conservation		
Course code	EN RE 1102		
Core/ Elective/other	Core Subject		
Prerequisite:			
1.	Basic Electrical Engineering		
2.	Basic Thermodynamics		
Course Outcomes:			
1.	**CO1:** Identify and assess the energy conservation/saving opportunities in different electric system.		
2.	**CO2:** Interpret energy conservation policies and practices in India.		
3.	**CO3:** Demonstrate skills required for energy audit and management.		
4.	**CO4:** Prepare energy flow diagrams and energy audit report.		
5.	**CO5:** Suggest cost-effective measures towards improving energy efficient and energy conservation.		
Description of Contents in brief:			
1.	Energy Audit, types of energy audit; Energy Audit approach: optimizing the input energy requirement; Energy audit instruments.		
2.	Energy Management: Concept of energy management, energy demand and supply, economic analysis; Duties and responsibilities of energy managers,		
3.	Energy conservation Act. Energy Conservation: Basic concept, energy conservation in Household, Transportation, Agricultural, service and Industrial sectors, Lighting, Heating Ventilation & Air Conditioning.		
4.	Energy Action Planning, Monitoring and Targeting. Demand Side management concept, Energy Efficient Practices and Technologies		
5.	Tariffs and Power factor improvement in power system		
List of Text Books:			
1.	General Aspects of Energy Management & Energy Audit Bureau of Energy Efficiency(BEE) Learning materials		
List of Reference Books			
1.	Hand book of Energy Audits by Albert Thuman, Ninth Edition CRC Press		
2.	Energy Management and Conservation Handbook by Kreith & Goswami, Routledge –Taylor and Francis group		
URLs:			
1.	www. beeindia.gov.in		
Lecture Plan (50 Lectures):			
LECTURE NO.	**TOPIC**	**Contents**	
L1	Present Energy Scenario	Commercial and Non-Commercial Energy, Primary Energy Resources, Commercial Energy Production, Final Energy Consumption, Energy Needs of Growing Economy, Long Term Energy Scenario	
L2-4	Energy Conservation	Energy Conservation and its Importance, Energy Strategy for the Future, Energy Conservation Act-2001 and its Features.	

L5-8	Energy Audit:	Definition, Energy audit- need, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance Energy audit Instruments demos and description
L9-13	Financial Management:	Investment-need, Appraisal and criteria, Financial analysis techniques-Tutorial questions
L14-18	Energy Monitoring and Targeting:	Defining monitoring & targeting, Elements of monitoring & targeting, Data and information-analysis, Techniques - energy consumption, Production, Cumulative sum of differences (CUSUM). Tutorial questions
L19-23	Electrical system:	Electricity billing, Electrical load management and maximum demand control, Tariff types Tutorial questions
L24-29	Power factor	Power factor improvement and its benefit, Selection and location of capacitors, Performance assessment of PF capacitors, Distribution and transformer losses. Numerical practice on Power Factor Tutorial questions
L30-33	Electric motors:	Types, Losses in induction motors, Motor efficiency , Factors affecting motor performance, Rewinding and motor replacement issues Energy saving opportunities with energy efficient motors. Numerical practice on motor efficiency
L34-37	Energy Efficient Technologies in Electrical Systems:	Maximum demand controllers, Automatic power factor controllers, Energy efficient motors, Soft starters with energy saver, Electronic ballast, Energy efficient transformers Tutorial questions
L38-40	HVAC systems :	Coefficient of performance, Capacity, Factors affecting Refrigeration and Air conditioning system performance and savings opportunities. Tutorial questions
L41-43	Refrigeration System:	Vapour compression refrigeration cycle, Refrigerants, Vapour absorption refrigeration system: Working principle, Types and comparison with vapour compression system, Saving potential Numerical practice on Refrigeration
L44-46	Lighting System:	Definitions,Light source, types, Choice of lighting, Luminance requirements Energy conservation avenues in lighting systems, Occupancy sensors, Energy efficient lighting controls, Tutorial questions
L47-50	Case Studies	Energy Conservation in Street Lights Energy Conservation in Agriculture sector Energy Conservation in Industries Energy conservation in residential and commercial buildings

3. EN RE 1103 Energy Storage Technologies

Name of Program	M. Tech Renewable Energy	Semester I	Session 25-26
Name of Course	Energy Storage Technologies		
Course Code	EN RE 1103		
Core/ Elective/other	Core Subject		
Prerequisite:			
1.	Basic Electrical and Electronics Engineering		
2.	Basic Thermodynamics and mechanical engineering		
COURSE OUTCOMES:			
1.	**CO1:** The course aims to provide a need based detailed understanding of energy storage techniques involving electrochemical, mechanical, impact of energy storage in an electric power system on power quality, power reliability and overall system efficiency.		
2.	**CO2:** To impart enough knowledge about Mobile v/s Fixed Energy Storagesystem, SMES and Ultra Caps		
3.	**CO3:** The student should be able to Compare and contrast methods of energy storage management in terms of cost, size, weight, reliability, efficiency and lifetimes.		
4.	**CO4:** Its objectives is to sensitize students to the basic Latent heat storage, Phase change materials (PCM) residential and utility scale applications		
5.	**CO5:** To also educate students about the Other emerging forms of energy storage including carbon-based Solutions, bulk energy storage.		
Description of Contents in brief:			
1.	Need of Energy storage, Principles of energy storage, Different modes of energy storage, Technology Types, Electrochemical Energy Storage: Battery storage including lead acid, lithium ion, flow, and emerging battery technologies, analysis of design considerations and application specific needs. Impacts on system cost in terms of life cycle, environmental, and reliability of the end solutions. Fuel Cells types, Proton exchange membrane (PEM) including direct methanol, phosphoric acid, alkali, solid oxide, and molten carbonate. Operation, benefits, economics, life times and failure mechanisms, application in the bulk power and energy system		
2.	Mobile v/s Fixed Energy Storage-advantages and disadvantages of. vehicle to grid applications and opportunities to leverage existing and emergent technology to provide additional grid support functions. Super Conducting Magnetic Energy Storage (SMES) operation, theory of usage and emergent research. large utility scale energy storage facilities. Ultra-Capacitors operation, applications, and emerging technologies, usage in mobile applications and close proximity to renewable energy sources.		
3.	Mechanical Energy Storage -Pumped Hydro: Pumped hydro bulk off-grid connected storage capacity worldwide. hydro capacity and availability, System cost, capacity, conversion efficiency, and siting. Compressed Gas: Compressed gas storage technologies for bulk energy storage, capacity and efficiency,. System cost, capacity, conversion efficiency, and siting along with barriers to adoption, applications in carbon capture and sequestration.. Flywheel: flywheel capacity, availability, efficiency in transportation, uninterruptible power supply (UPS), pulse power, and bulk storage.		
4.	Thermal Energy Storage-Heat transfer fluids, molten salt storage, Basics of Sensible heat storage, Stratified storage, cold reservoirs Rock bed storage,		

	geothermal power production Thermal storage in buildings, Earth storage Aquifers storage. Basics of Latent heat storage, Phase change materials (PCM) residential and utility scale applications
5.	Miscellaneous other forms-Hydrogen as energy storage, equipments requirement for hydrogen production, storage, dispensing & utilization. Other forms of energy storage including carbon based solutions as well as their impacts on the environment, Diesel, natural gas, recovered methane, bio-diesel, solar thermal etc. Integration of the energy storage media, its effects on the bulk power, design tradeoffs to understand environmental impacts, cost, reliabilities, and efficiencies for commercialization of bulk energy storage.
List of Text Books:	
1.	Energy Storage by Mullick and Garg
2.	Advanced Energy Storage Technologies and Their Applications (AESA), Energies 2018
List of Reference Books	
1.	Energy Storage Science & Technology by Pendse
2	Energy Storage: Fundamentals, Materials and Applications by Huggins, Robert
URLs:	
Energy storage.org	
www.eesi.org	
https:// beeindia.gov.in	

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Energy Storage	• Need of Energy storage, • Principles of energy storage, • Different modes of energy storage, Technology Types
L2-3	Electrochemical Energy Storage	• Electrochemical Energy Storage: Battery storage including lead acid, lithium ion, flow, and emerging battery technologies • Analysis of design considerations and application specific needs.
L4-6	Impacts on system cost and Energy system mechanism	• Impacts on system cost in terms of life cycle, environmental, and reliability of the end solutions. • Fuel Cells types, Proton exchange membrane (PEM) including direct methanol, phosphoric acid, alkali, solid oxide, and molten carbonate. • Operation, benefits, economics, life times and failure mechanisms, application in the bulk power and energy system
L7-10	Emergent technology for additional grid support	• Mobile v/s Fixed Energy Storage-advantages and disadvantages of. vehicle to grid applications • Opportunities to leverage existing and emergent technology to provide additional grid support functions.

L11-14	Super Conducting Magnetic Energy Storage	• Super Conducting Magnetic Energy Storage (SMES) operation, theory of usage and emergent research. • large utility scale energy storage facilities.
L15-16	Usage in mobile applications	• Ultra-Capacitors operation, applications, and emerging technologies • Usage in mobile applications and close proximity to renewable energy sources.
L17-18	Mechanical Energy Storage - Pumped Hydro	• Pumped hydro bulk off-grid connected storage capacity worldwide. • Hydro capacity and availability, System cost, capacity, conversion efficiency, and siting.
L19-20	Compressed Gas	• Compressed gas storage technologies for bulk energy storage, capacity and efficiency, • System cost, capacity, conversion efficiency, and siting along with barriers to adoption, applications in carbon capture and sequestration.
L21-23	Flywheel	• Flywheel capacity, availability, efficiency, in transportation, uninterruptible power supply (UPS), pulse power, and bulk storage.
L24-26	Thermal Energy Storage	• Heat transfer fluids, molten salt storage, Basics of Sensible heat storage, • Stratified storage, cold reservoirs Rock bed storage, geothermal power production Thermal storage in buildings, Earth storage Aquifers storage.
L27-29	heat storage	• Basics of Latent heat storage, Phase change materials (PCM) residential and utility scale applications
L30-34	Other forms of energy storage	• Miscellaneous other forms-Hydrogen as energy storage, equipments requirement for hydrogen production, storage, dispensing & utilization. • carbon based solutions as well as their impacts on the environment, Diesel, • Natural gas, recovered methane, bio-diesel, solar thermal etc.
L35-40	Other forms of energy storage	• Integration of the energy storage media, its effects on the bulk power, • Design tradeoffs to understand environmental impacts, cost, reliabilities, and efficiencies for commercialization of bulk energy storage.

4. HS 1101 Communication Skills

Name of Program	M.Tech Renewable Energy	**Semester: I**	Session: 25-26

Name of Course	Communication Skills
Course Code	HS 1101
Core / Elective / Other	Audit Course

Prerequisite:	
1.	
Course Outcomes:	
1.	To help postgraduate students improve their technical communication skills related to listening, Speaking, reading, writing.
2.	To enable students to organise, comprehend, write, and present short and long forms of any technical work within the broad framework of the scientific method
3.	To help students adhere to ethical norms of scientific communication.
Description of Contents in brief:	
1.	**Unit I: Scientific Method and its Relationship to Technical Communication** Basics of technical communication, Formulation of hypothesis, Paragraph organisation, Argument development, Evidence and elaboration
2.	**Unit II: Listening and Reading Skills** Note taking, Survey of literature, Different reading strategies
3.	**Unit III: Writing Skills** Report writing, Peer review skills, Summary and abstract writing, Bibliography and references, Data Analysis and Presentation, Visual communication
4.	**Unit IV: Speaking Skills** Elevator pitch, Oral presentation, Slides for presentation, Group discussions, Interview skills
5.	**Unit V: Ethics in Communication** Ethics in education and research, Copyrights and plagiarism, Authorship, Gender and diversity, Net etiquettes and workplace communication
List of Text Books:	
1.	Arora, V.N., and Lakshmi Chandra. Improve your Writing. 1981. New Delhi: Oxford UP, 2001.
2.	Graff Gerald, and Birkenstein Cathy. “They Say I Say”-The Moves That Matter in Academic Writing. W.W.Norton and Company. Fourth edition. 2018
3.	Lesikar, Raymond V and Marie E. Flatley. Basic Business Communication: Skills for Empowering the Internet Generation: Ninth Edition. New Delhi: Tata McGraw-Hill Publishing Company Ltd., 2002.
List of Reference Books:	
1.	Graff Gerald, and Birkenstein Cathy. “They Say I Say”-The Moves That Matter in Academic Writing. W.W.Norton and Company. Fourth edition. 2018
2.	Kumar Sanjay, and Lata Pushp. Communication Skills. 2011. Oxford University Press, 2015
3.	Raman Meenakshi, and Sharma Sangeeta. Technical Communication: Principles and Practice. 2015. Oxford University Press, 2015
Lecture Plan (about 40-50 Lectures):	
Lecture No.	**Topic**

L 1-2	Basics of technical communication
L 3	Formulation of hypothesis
L 4-5	Paragraph organisation
L 6	Argument development
L 7	Evidence and elaboration
L 8	Note taking
L 9-10	Survey of literature
L 11	Different reading strategies
L 12-13	Report writing
L 14-16	Peer review skills
L 17-18	Summary and abstract writing
L 19-20	Bibliography and references
L 21-25	Data Analysis and Presentation
L 26-27	Visual communication
L 28	Elevator pitch
L 29-33	Oral presentation
L 34	Slides for presentation
L 35-37	Group discussions
L 38-40	Interview skills
L 41	Ethics in education and research
L 42-43	Copyrights and plagiarism
L 44	Authorship
L 45	Gender and diversity
L 46	Net etiquettes
L 47- 48	Workplace communication

Second Semester

5. EN RE 1201 Wind Energy Systems

Name of Program	M.Tech Renewable Energy	Semester II	Session 25-26
Name of Course	Wind Energy System		
Course code	EN RE 1201		
Core/ Elective/other	Core Subject		

Prerequisite:	
1.	Basic Mechanical Engineering
2.	Basic Fluid Mechanics
Course Outcomes:	
1.	**CO1:** Knowing the importance of wind energy potential.
2.	**CO2:** Interpret wind energy harnessing practices in India.
3.	**CO3:** Demonstrate skills required for wind turbine maintenance.
4	**Co4:** Suggest cost-effective measures towards improving wind energy harnessing methods.
Description of Contents in brief:	
1.	Historical developments, latest developments, state of art of wind energy technology.
2.	Characteristics of wind: Nature of atmospheric winds; wind resource characteristics and assessment, anemometry, wind statistics
3.	Speed frequency distribution, effect of height, wind rose, Weibull distribution, atmospheric turbulence, gust wind speed, effect of topography Aerodynamics of blade and rotor.
4.	Wind turbine design, Control Mechanisms: Wind turbine dynamics, Wind farm: design, Planning.
List of Text Books:	
1.	Wind Energy Comes of Age by Paul Gipe, John Wiley & Sons Inc.
2.	Wind power project & development by Joshua Earnest
List of Reference Books	
1.	Non conventional energy resources by B.H KHAN
URLs:	
1.	https://niwe.res.in

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Introduction	An Overview of the Fundamentals of Wind Energy
L2		Historical developments of wind energy and Wind turbine, Historical developments of wind energy in world and India.
L3		Latest developments of wind energy and Wind turbine in world and India
L4		Wind Energy Opportunities, and the Energy Industry
L5	Measurements	Measuring the Energy in Wind, How Wind Energy Is Transformed into Electricity
L6		An Overview of Wind Energy Economics
L7		State of art of wind energy technology.

L8	Site selection	Initial site selection, Project feasibility assessment. The measure–correlate–predict technique
L9		Micrositing Site, investigations and Public consultation
L10		Characteristics of wind: Nature of atmospheric wind resource characteristics and assessment
L11		Causes of wind,Measurement,Wind force scale, Enhanced Fujita scale and Station model
L12		Wind power, Theoretical power captured by a wind turbine, Practical wind turbine power and Global climatology
L13		On-site wind measurements should be taken prior to deciding to purchase a wind turbine
L14		The data collected will determine the wind resource and help with wind turbine selection and economic value.
L15		Mini Test
L16	Weibull distribution	Power output profile of wind turbines,Wind statistics and the Weibull distribution.
L17		Effect of height, wind rose, Weibull distribution
L18-20		The nature of turbulence, The boundary layer and Turbulence intensity
L21-23		Turbulence spectra, Length scales and other parameters and Cross-spectra and coherence functions
L24-26		Aerodynamics of Horizontal-axis Wind Turbines, The Actuator Disc Concept, Momentum theory and Power coefficient
L27-29	Betz Criteria	The Betz limit, The thrust coefficient, Rotor Disc Theory ,Wake rotation ,Angular momentum theory Maximum power
L30-32		Vortex Cylinder Model of the Actuator Disc, Vortex cylinder theory
L33-35		Relationship between bound circulation and the induced velocity
L36		Root vortex, Torque and power
L37		Axial flow field, Tangential flow field and Radial flow field
L38	Aerodynamics	Quasi-steady aerofoil aerodynamics, Aerodynamic forces caused by aerofoil acceleration
L39		he effect of the wake on aerofoil aerodynamics in unsteady flow and Numerical
L40		Wind turbine design, Analysis Methods,The blade design and Design Alternatives
L41		Wind turbine dynamics,Blade Dynamic Response, Modal analysis
L42		Wind turbine dynamic analysis codes and Aeroelastic stability
L43	Wind farm Design	Wind Farm Design: Planning, Research and Commissioning, maximum installed capacity (due to grid connection etc) site boundary
L44		location of dwellings that may be affected by flickering shadows cast by rotating blades

6. EN RE 1202 Solar Energy Systems

Name of Program	M.Tech Renewable Energy	Semester II	Session 25-26
Name of Course	Solar Energy Systems		
Course Code	EN RE 1202		
Core/ Elective/other	Core Subject		
Prerequisite:			
1.	Basic Electronics Engineering		
2.	Basic Thermodynamics		
COURSE OUTCOMES:			
1.	**CO1:** The course aims to provide detailed understanding of Solar Worldwide potential ,insolation measuring and predictions		
2.	**CO2:** The student should be able to understand Solar thermal Concentrators designs and uses		
3.	**CO3:** To impart enough knowledge aboutSolar Thermal Systems And Their Applications		
4.	**CO4:** Its objectives is to sensitize students to the basic concept of Solar PV array, series parallel combinations and operations		
5.	**CO5:** To develop understanding of Solar PV Home lighting systems and other applications		
Description of Contents in brief:			
1.	SOLAR ENERGY Worldwide potential and Indian National developments, National Alliances and mission for solar energy promotion. Solar radiation spectrum, Extra-terrestrial Radiations Estimation, Solar Energy Terrestrial Radiations Sun-Earth Measurement Angles, associated definitions, derivations &numerical, Solar Radiation insolationmeasuring and predictions Instruments		
2.	SOLAR THERMAL ENERGY: Principles of applied heat transfer, Conversion Devices, Solar thermal collectors, types, advanced collectors, Solar thermal Concentrators, Types and Uses, optical design of concentrators.		
3.	SOLAR THERMAL SYSTEMS AND THEIR APPLICATIONS, solar water heater, solar dryers, solar stills distillation; solar cooker, Solar ponds, solar cooling and refrigeration, Solar energy storage options		
4.	SOLAR PHOTOVOLTAIC CONVERSION: Photo Voltaic effect, solar cell Technologies: thin film generations, Solar cell and its I-V characteristics, fill factor, other associated definitions, derivations & numericals. Solar cell PV string, PV module, PV array, series parallel combinations and operations Effect of temperature, insolation level & tilt angle		
5.	TYPES OF PV SYSTEMS AND APPLICATIONS, Photovoltaic modules; Battery storage; Charge regulators, Maximum Power Point Tracking, derivations & numerical, Applications of solar PV, Solar lanterns, Solar PV pumps, Home lighting systems, Stand Alone and Grid Connected systems		
List of Text Books:			
1.	G. D. Rai, Solar Energy Utilisation, Khanna Publication,		
2.	Solar Energy, G. N. Tiwari, Narosa Publishing House		
3.	S. P. Sukhatme, Solar Energy - Principles of thermal collection and storage, McGraw-Hill Education (India)		
List of Reference Books			

1.	Chetan Singh Solanki, Solar Photovoltaics: Fundamental Technologies and Applications, 2 edition, Prentice Hall India Limited
2.	Concentrating Solar Power Technology: Principles, Developments and Applications: by K Lovegrove, W Stein
3	J. A. Duffie W. A. Beckman, Solar Engg of Thermal Processes, Wiley
URLs:	
1.	www.seci.co.in
2	www.nrel.gov
3	www.nsefi.in

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Solar Energy	• Worldwide potential and Indian National developments, • National Alliances and mission for solar energy promotion
L2-3	Solar radiation spectrum	• Solar radiation spectrum, Extra-terrestrial Radiations Estimation, • Solar Energy Terrestrial Radiations Sun-Earth
L4-6	Solar Radiation Instruments	• Measurement Angles, associated definitions, derivations • Numerical, Solar Radiation insolationmeasuring and predictions Instruments
L7-10	Solar Thermal Energy	• Principles of applied heat transfer, Conversion Devices, • Solar thermal collectors, types, advanced collectors,
L11-14	Solar Thermal Energy	• Solar thermal Concentrators, • Types and Uses,optical design of concentrators.
L15-16	Application of Solar Thermal Energy	• Solar water heater, solar dryers, • solar stills distillation; • solar cooker, Solar ponds,
L17-18	Application of Solar Thermal Energy	• solar cooling and refrigeration, • Solar energy storage options
L19-20	Solar Photovoltaic Conversion	• Photo Voltaic effect, Solar cell Technologies: • thin film generations, Solar cell and its I-V characteristics, fill factor,
L21-23	Solar Photovoltaic Conversion	• Other associated definitions, derivations &numericals. • Solar cell PV string, PV module, • PV array, series parallel combinations and operations
L24-26	Types of PV Systems	• Effect of temperature, insolation level & tilt angle • derivations & numerical,
L27-29	Photovoltaic modules	• Photovoltaic modules; Battery storage; Charge regulators,

		• Maximum Power Point Tracking
L30-34	PV Systems And Applications	• Solar lanterns, Solar PV pumps , • Home lighting systems ,
L35-40	More Applications	• Applications of solar PV, • Stand Alone • Grid Connected systems

Departmental Electives

Departmental Electives-1

EN RE 1151 Economics and Planning of Energy

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Economics and Planning of Energy		
Course code	EN RE 1151		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Renewable Energy		
2.	Operation Research		
Course Outcomes:			
1.	**CO1:** Understand the role of energy in economic activity		
2.	**CO2:** Describe the methods to assess alternative energy projects, technologies, and policies.		
3.	**CO3:** Discuss the structure of energy markets and patterns of energy production and consumption.		
4.	**CO4:** Evaluate the alternative energy policy options.		
5.	**CO5:** Overview the Global Energy Challenges and impact of high energy prices		
Description of Contents in brief:			
1.	Introduction to Energy Economics: Energy Basics, Energy Accounting Framework, Accounting of Traditional Energies, Special Treatments of Some Entries in the Energy Balance, analysis of Energy Balance Information, Alternative Presentation of Energy Accounting Information, Evolution of Demand Analysis		
2.	Economic Foundations of Energy Demand, Factor Analysis, Analysis Using Physical Indicators, Energy Demand Analysis Using the Econometric Approach, Disaggregation of Demand, Sectoral Energy Accounting, Analysis at the Sectoral Level.		
3.	Introduction to Energy Demand Forecasting, Econometric Approach to Energy, Demand Forecasting, End-Use Method of Forecasting, Common Energy Demand Analysis Models.		
4.	Basics of the Economic Analysis of Projects, Economic Versus Financial Investment Analysis, Indicators of Cost-Benefit Comparison, Uncertainty and Risk in Projects, Economics of Electricity Supply, Investment Decisions in the Power Sector, The Economics of Renewable Energy Supply, The Economics of Bio-fuels.		
List of Text Books:			
1.	Subhes C. Bhattacharyya (auth.)-Energy Economics_ Concepts, Issues, Markets and Governance-Springer-Verlag London (2011).		

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Introduction to Energy Economics	Energy Basics, Energy Accounting Framework, Accounting of Traditional Energies
L2	Introduction to Energy Economics	Special Treatments of Some Entries in the Energy Balance
L3	Introduction to Energy Economics	Analysis of Energy Balance Information
L4	Introduction to Energy Economics	Alternative Presentation of Energy Accounting Information
L5-6	Introduction to Energy Economics	Evolution of Demand Analysis
L7-8	Introduction to Energy Economics	Economic Foundations of Energy Demand, Factor Analysis

L9-10	Introduction to Energy Economics	Analysis Using Physical Indicators
L11-12	Introduction to Energy Economics	Energy Demand Analysis Using the Econometric Approach
L13-14	Introduction to Energy Economics	Disaggregation of Demand, Sectoral Energy Accounting
L15	Introduction to Energy Economics	Analysis at the Sectoral Level.
L16	Tutorial -1	Problem & Solution, Discussion
L17-18	Introduction to Energy Demand Forecasting	Econometric Approach to Energy
L19-20	Introduction to Energy Demand Forecasting	Demand Forecasting
L21-22	Introduction to Energy Demand Forecasting	End-Use Method of Forecasting
L23-24	Introduction to Energy Demand Forecasting	Common Energy Demand Analysis Models.
L25-26	Basics of the Economic Analysis	Economic Versus Financial Investment Analysis, Indicators of Cost-Benefit Comparison
L27	Tutorial -2	Problem & Solution, Discussion
L28-29	Basics of the Economic Analysis	Uncertainty and Risk in Projects
L30-31	Basics of the Economic Analysis	Economics of Electricity Supply
L32	Tutorial -3	Problem & Solution, Discussion
L33-34	Energy Markets and Principles of Energy Pricing	Investment Decisions in the Power Sector
L35-36	Energy Markets and Principles of Energy Pricing	The Economics of Renewable Energy Supply
L37-40	Energy Markets and Principles of Energy Pricing	The Economics of Bio-fuels
L41-44	Energy Markets and Principles of Energy Pricing	Government Intervention and Role of Government in the Sector
L45-48	Energy Markets and Principles of Energy Pricing	Energy Pricing and Taxation
L49	Tutorial -4	Problem & Solution, Discussion
L50	Case Studies -1	Recent trends in Energy Market

EN RE 1152 Power Plant Engineering

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Power Plant Engineering		
Course code	EN RE 1152		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Basic Mechanical Engineering		
2.	Basic Thermodynamics		
Course Outcomes:			
1.	**CO1:** Ability to understand different practices in power plant engineering.		
2.	**CO2:** Interpret Power Plant generating practices in India.		
3.	**CO3:** Demonstrate skills required for steam turbine maintenance.		
4.	**CO4:** Suggest cost-effective measures towards improving thermal energy harnessing methods in Power Plant.		
Description of Contents in brief:			
1.	Layout of Steam, Hydel, Diesel, MHD, Nuclear and Gas turbine Power Plants Combined Power cycles – comparison and selection, Load duration Curves		
2.	Steam boilers and cycles Fluidised Bed Boilers. Fuel and ash handling, Combustion Equipment for burning coal, Mechanical Stokers		
3.	Pulveriser, Electrostatic Precipitator, Draught- Different Types, Surface condenser types, cooling Towers		
4.	Types of Reactors, Pressurized water reactor, Boiling water reactor, Waste disposal and safety Hydel Power plant- Essential elements, Selection of turbines, governing of Turbines.		
5.	Types of diesel plants, components, Selection of Engine type, applications-Gas turbine power plant- Fuels- Gas turbine material – open and closed cycles- reheating – Regeneration and intercooling – combines' cycle		
6.	Geo thermal, Pumped storage –Solar central receiver system Cost of electric Energy, Fixed and operating costs-Energy rates- Types tariffs- Economics of load sharing, comparison of various power plants.		
List of Text Books:			
1.	Arora S.C and Domkundwar S, "A Course in Power Plant Engineering", DhanpatRai, 2001.		
2.	Nag P.K ,"Power Plant Engineering". Third edition Tata McGraw- Hill ,2007.		
List of Reference Books			
1.	EI-Wakil M.M ,Power "Plant Technology," Tata McGraw-Hill 1984		
2.	K.K.Ramalingam , " Power Plant Engineering ", Scitech Publications, 2002.		
3	G.R,Nagpal , "Power Plant Engineering", Khanna Publishers 1998		
4	G.D.Rai, "Introduction to Power Plant technology" Khanna Publishers, 1995		
URLs:			
1.	https:www.ntpc.co.in		
Lecture Plan (about 40-50 Lectures):			

LECTURE NO.	TOPIC	Contents
L1	Power Plant: Introduction	Introduction about the subject
L2		Power Plant: Introduction
L3		Layout of Steam, Diesel and Gas Power Plant
L4		Layout of Hydel, MHD and Nuclear Power Plant
L5		Combined Power cycles – comparison and selection of the plant
L6		Load duration Curves
L7	Boilers	Steam boilers and cycles Fluidised Bed Boilers
L8		Fuel and ash handling
L9		Combustion Equipment for burning coal
L10		Mechanical Stokers.
L11		Description of stokers
L12		Pulveriser and Electrostatic Precipitator
L13		Various types of Draught
L14	Condensers	Different types of Surface condenser
L15		cooling Towers
L16		Pressurized water reactor and Boiling water reactor
L17		Waste disposal and safety
L18		Hydel Power plant- Essential elements
L19		Selection of turbines, governing of Turbines
L20	Diesel plants	Types of diesel plants, components, Selection of Engine type and applications
L21		Gas turbine power plant- Fuels- Gas turbine material
L22		Open and closed cycles, reheating – Regeneration and intercooling – combines' cycle
L23-25	Geo thermal energy	Geo thermal and Pumped storage hydel energy
L26-28		Solar central receiver system
L29-30		Cost of electric energy: Fixed and operating cost
L31-33		Introduction to tariff and energy rates
L34-36	Economics	Types of tariffs
L37-38		Impact of load power factor
L39		**Load duration curve**
L40		Economics of load sharing
L41		Minimization of cost of energy
L42		Tutorials-I
L43		Tutorials-II
L44		Discussions/Doubts, Display of Attendance

EN EM 1153 Energy Efficiency in Electrical Utilities

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Energy Efficient in Electrical Utilities		
Course code	EN EM 1153		
Core/ Elective/other	Elective Subject		

Prerequisite:	
1.	Basic Electrical Engineering
2.	Basic Mechanical Engineering
Course Outcomes:	
1.	**CO1:** Understand the Electrical load management and demand control.
2.	**CO2:** Evaluate the performance of Electrical Utilities like Electric motors, Refrigeration system, lighting system, pumping systems, etc. to improve efficiency.
3.	**CO3:**Assess and suggest methods to improve the overall efficiency for different energy intensive utilities.
4.	**CO4:**Impart knowledge on electrical utilities for evaluating energy saving potential.
5.	**CO5:** Do cost benefit analysis of various investment alternatives for meeting the energy needs of the organization.
Description of Contents in brief:	
1.	Introduction to Electrical system Electricity billing, Electrical load management and maximum demand control, Power factor improvement and its benefit
2.	Electric motors: Types, Losses in induction motors, Motor efficiency, Factors affecting motor performance, Energy saving opportunities with energy efficient motors.
3.	HVAC and Refrigeration System, Fans and blowers, Pumps and Pumping System,
4.	Lighting System: Light source, Choice of lighting, Luminance requirements, and Energy conservation avenues,
5.	Diesel Generating system: Factors affecting selection, Energy performance assessment of diesel conservation avenues
List of Text Books:	
1.	Guide Book 3.Energy Efficiency in Electrical Utilities, Fourth Edition, by Bureau of Energy Efficiency(BEE) Learning materials
List of Reference Books	
1.	Energy Efficiency, 1st Edition by **F Sioshansi**
URLs:	
1.	www. beeindia.gov.in

Lecture Plan (50 Lectures):

LECTURE NO.	TOPIC	Contents
L1-L8	Electrical System	Introduction to Electricity Distribution, Electricity Billing Electrical Load Management, DSM Power factor Improvement, numerical practice on tariff and Power factor improvement
L9-16	Electrical Motors	Motor Types, characteristics, Losses , Efficiency, Motor selection, Energy efficient motors, numerical practice
L16-22	HVAC and Refrigeration	Types of Refrigeration, Psychometric Chart, Air conditioning, Selection of suitable refrigeration

		system , types of AC, Proper selection of AC, performance analysis, Energy saving opportunities
L23-28	Fans and Blowers	Introduction, Fan Types, Fan performance evaluation, Fan design and selection criteria, Flow control strategies, Energy saving measures,
L29-34	Pumps and Pumping system	Pump types, Pump characteristics and curves, factors affecting pump performance, efficient pumping system operation, Muncipal water pumping system, Sewage water pumps, Agriculture water pumps, Flow control strategies, Conservation avenues
L35-39	Lighting Systems	Basic parameters and terms in Lighting systems, Light source and lamp types, Lighting design for interiors, Energy saving opportunities, Energy efficient lighting controls
L40-44	Diesel /Natural gas power generating system	Introduction, Selection and installation factors, operational factors, performance assessment and saving measures
L 45-46	Revision and numerical practice	Power factor, Electricity billing/ tariff
L47-48	Revision and numerical practice	DSM, Electric motors
L49-50	Revision and numerical practice	HVAC system , Lighting system

EN EM 1154 Alternative Fuels

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Alternative Fuels		
Course code	EN EM 1154		
Core/ Elective/other	Elective Subject		

Prerequisite:	
1.	Renewable Energy Sources
2.	Thermal Engineering
Course Outcomes:	
1.	**CO1:** Understand the importance of automotive fuels.
2.	**CO2:** Describe about Physio-chemical characteristics of Biofuel & Alcohol.
3.	**CO3:** Analyse the impact of alternative fuel on Engine.
4.	**CO4:** Evaluate the emission characteristics of automotive fuels
5.	**CO5:** Discuss the combustion methodology of automotive fuels.
Description of Contents in brief:	
1.	An introduction to hydrocarbon fuels–their availability and effect on environment, Gasoline and diesel self-ignition characteristics of the fuel, Octane number, Cetane number
2.	Alternative fuels - liquid and gaseous fuels, Physio-chemical characteristics, Alternative liquid fuels, Alcohol fuels - ethanol & methanol, Fuel composition, Fuel induction techniques, Fumigation, Emission of oxygenates, Applications to engines and automotive conversions,
3.	Biodiesel formulation techniques, Trans esterification, Application in diesel engines, DME (Dimethyl ether), properties fuel injection consideration general introduction to LPG and LNG, Compressed natural gas components, mixtures and kits
4.	Fuel supply system and emission studies and control, Hydrogen production methods, storage & its application,
5.	Biogas, Producer gas and their characteristics system development for engine application.
List of Text Books:	
1.	Alternative Fuels by S.S. Thipse
List of Reference Books	
1.	Alternative Transportation Fuels: An Environmental and Energy Solution by Daniel Sperling
2.	Alternative Transportation Fuels: Utilisation in Combustion Engines by M.K. Gajendra Babu and K.A. Subramanian

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Present Fuel Scenario	An introduction to hydrocarbon fuels–their availability and effect on environment
L2-3	Conventional Fuel	Gasoline and diesel self-ignition characteristics of the fuel, Octane number, Cetane number
L4-6	Alternative fuels	liquid and gaseous fuels, Physio-chemical characteristics
L7-10	Alternative liquid fuels	Alcohol fuels - ethanol & methanol, Fuel composition, Fuel induction techniques, Fumigation, Emission of oxygenates
L11	Tutorial -1	Problem & Solution, Discussion
L12-15	Engine & Fuel	Applications to engines and automotive conversions

L16-17	Biodiesel Production	Biodiesel formulation techniques
L18	Biodiesel Production	Trans esterification
L19-20	Biodiesel Utilization	Application in diesel engines
L21	Tutorial -2	Problem & Solution, Discussion
L22-23	Other Fuels	DME (Dimethyl ether) & its properties, fuel injection system
L24-25	Other Fuels	General introduction to LPG and LNG
L26	Other Fuels	Compressed natural gas components, mixtures and kits
L27-28	Fuel supply system	Emission studies and control
L29	Tutorial -3	Problem & Solution, Discussion
L30-31	Hydrogen	Hydrogen production methods
L32	Hydrogen	Storage & its application
L33-35	Biogas	Biogas and their characteristics system
L36-40	Biogas	Producer gas and their characteristics system
L41-44	Biogas	Development for engine application using Biogas & Producer Gas
L45	Tutorial -4	Problem & Solution, Discussion
L46-48	Case Studies	Recent trends in Alternative Fuel
L49-50	Case Studies	Recent trends in Alternative Fuel

EN RE 1155 Operation Research and Optimization

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Operation Research and Optimization		
Course code	EN RE 1155		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Advanced Mathematics		
2.	Operation Research		
Course Outcomes:			
1.	**CO1:** Understand the fundamental mathematics and to solve optimization problems		
2.	**CO2:** Convert the problem-solving strategies for multivariable objective.		
3.	**CO3:** Demonstrate the model solving ability for various processes/unit operations		
4.	**CO4:** Demonstrate skills required for energy management technique.		
5.	**CO5:** Suggest cost-effective measures towards improving energy management in various problems		
Description of Contents in brief:			
1.	Introduction to Operations Research ,Introduction, Historical Background, Scope of Operations Research, Features of Operations Research, Phases of Operations Research, Types of Operations Research Models, Operations Research Methodology, Operations Research Techniques and Tools		
2.	Linear Programming: Introduction, Linear Programming Problem, Requirements of LPP, Mathematical Formulation of LPP, Case Studies of LPP, Graphical Methods to Solve Linear Programming Problems, Applications, Advantages, Limitations		
3.	Graphical Analysis of Linear Programming Problems: Introduction, Graphical Analysis, Some Basic Definitions, Graphical Methods to Solve LPP, Some Exceptional Cases, Important Geometric Properties of LPP		
4.	Transportation Problem: Introduction, Formulation of Transportation Problem (TP), Transportation Algorithm (MODI Method), the Initial Basic Feasible Solution, Moving Towards Optimality Finite Queuing Models: Introduction, Finite Queuing Models		
5.	Assignment Problem: Introduction, Mathematical Formulation of the Problem, Hungarian Method Algorithm, Routing Problem, Travelling Salesman ProblemProject Scheduling and PERT-CPM: Introduction, Basic Difference between PERT and CPM, PERT/CPM Network Components and Precedence Relationship, Project Management – PERT, Game Theory: Introduction, Competitive Situations, Characteristics of Competitive Games, Maximin – Minimax Principle, Dominance		
List of Text Books:			
1.	Operation Research by Sharma, Gupta Chawla		
List of Reference Books			
1.	Operation Research by H.A Taha		
2.	Operation Research by Kanti Swarup.		

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Introduction to Operations Research	Introduction, Historical Background, Scope of Operations Research
L2-3	Introduction to Operations Research	Features of Operations Research, Phases of Operations Research,

L4-6	Introduction to Operations Research	Types of Operations Research Models, Operations Research Methodology,
L7-10	Linear Programming	Operations Research Techniques and Tools
L11	Linear Programming	Introduction, Linear Programming Problem, Requirements of LPP, Mathematical Formulation of LPP
L12-15	Linear Programming	Case Studies of LPP, Graphical Methods to Solve Linear Programming Problems, Applications, Advantages, Limitations
L16-17	Graphical Analysis of Linear Programming Problems	Introduction, Graphical Analysis, Some Basic Definitions
L18	Graphical Analysis of Linear Programming Problems	Graphical Methods to Solve LPP
L19-20	Graphical Analysis of Linear Programming Problems	Some Exceptional Cases
L21	Graphical Analysis of Linear Programming Problems	Important Geometric Properties of LPP
L22-23	Transportation Problem	Introduction,
L24-25	Transportation Problem	Formulation of Transportation Problem (TP)
L26	Transportation Problem	VAM, Maxima Minima method, NWCM method
L27-28	Transportation Problem	Transportation Algorithm (MODI Method), the Initial Basic Feasible Solution
L29	Transportation Problem	Moving Towards Optimality Finite Queuing Models: Introduction, Finite Queuing Models
L30-31	Assignment Problem	Mathematical Formulation of the Problem
L32	Assignment Problem	Hungarian Method Algorithm, Routing Problem
L33-35	Assignment Problem	Travelling Salesman Problem
L36-40	Project Management	Project Scheduling
L41-44	Project Management	Basic Difference between PERT and CPM, PERT/CPM Network Components and Precedence Relationship
L45	Project Management	Project Management – PERT
L46-48	Project Management	Game Theory: Introduction, Competitive Situations
L49-50	Project Management	Characteristics of Competitive Games, Maximin – Minimax Principle, Dominance

Departmental Electives-2

EN RE 1161 Hydrogen and fuel cells.

Name of Program	M.Tech Renewable Energy		Session 25-26
Name of Course	Hydrogen and fuel cells.		
Course Code	EN RE 1161		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Basic Engineering all disciplines		
COURSE OUTCOMES:			
1.	**CO1:** Understand the fundamentals of hydrogen as an energy carrier and the basic principles of fuel cell operation, including electrochemical reactions, thermodynamics, and kinetics.		
2.	**CO2:** Analyze various hydrogen production methods, both conventional and renewable, and evaluate fuel processing and purification techniques for efficient utilization.		
3.	**CO3:** Demonstrate knowledge of hydrogen storage and distribution systems, including gaseous, liquid, and solid-state methods, along with safety considerations.		
4.	**CO4:** Examine fuel cell materials, components, and system design; assess performance characteristics; and explore applications in power generation, industry, and transportation.		
5.	**CO5:** Evaluate the economic, environmental, and future perspectives of hydrogen and fuel cells, including techno-economic feasibility, policies, and research trends.		
Description of Contents in brief:			
1.	Introduction to Hydrogen and Fuel Cells Hydrogen as an energy carrier and its role in sustainable development,Principles of electrochemical energy conversion, Fundamentals of fuel cell operation: anode, cathode, overall cell reactions, Thermodynamics and kinetics of fuel cell processes,Types of fuel cells: PEMFC, SOFC, AFC, MCFC, PAFC, DMFC		
2.	Hydrogen Production and Processing Conventional hydrogen production: steam methane reforming, coal gasification, Water electrolysis for hydrogen generation, Renewable hydrogen production: solar, wind, biomass routes, Hydrogen purification and processing for fuel cells, Challenges and advancements in large-scale hydrogen production		
3.	Hydrogen Storage and Distribution Storage methods: gaseous (compressed), liquid (cryogenic), solid-state (metal hydrides, LOHCs), Hydrogen carriers and infrastructure for distribution, Pipelines, cylinders, and		

	refueling networks, Safety considerations in storage, transport, and handling, Recent developments in hydrogen storage technologies
4.	Fuel Cell Materials, Design, and Applications Fuel cell components: electrodes, catalysts, electrolytes, membranes, bipolar plates, Gas diffusion layers, seals, and durability issues, Stack configuration and Balance of Plant (BoP): humidification, cooling, controls, Applications: stationary power, portable devices, transportation, Performance characteristics: polarization curves, efficiency, degradation
5.	Economics, Future Trends, and Research Techno-economic analysis of hydrogen and fuel cell projects, Life cycle assessment and environmental impacts, Policy, social acceptance, and commercialization challenges, Future trends: green hydrogen, ammonia economy, synthetic fuels, Research directions, global hydrogen economy prospects, and innovations
List of Text Books:	
1.	"Hydrogen Energy: Economic and Social Challenges" by E. S. Kikoin
2.	"Hydrogen Production and Remediation of Carbon and Pollutants" by Devarajan Thangadurai and Geetha Baskar
3	"Introduction to Hydrogen Technology" by Roman J. Press
4	"Fuel Cells: Principles, Design, and Analysis" by Mitra Dutta and Shriram Ramanathan
5	"Fuel Cell Systems Explained" by James Larminie and Andrew Dicks

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	**TOPIC**	**Contents**
L1	Energy transition and the importance of hydrogen	• Role of hydrogen in sustainable development • Environmental benefits and challenges
L2-3	Basics of electrochemical energy conversion	• Electrochemical reactions, anode and cathode processes • Difference between fuel cells and batteries
L4-6	Fundamentals of fuel cell operation	• Thermodynamics of fuel cell reactions • Kinetics and efficiency considerations
L7-10	Types of fuel cells	• PEMFC, SOFC, AFC, MCFC, PAFC, DMFC • Operating conditions, advantages, and limitations
L11-14	Conventional hydrogen production	• Steam methane reforming, coal gasification • Hydrogen separation and purification
L15-16	Water electrolysis methods	• Alkaline electrolysis, PEM electrolysis, solid oxide electrolysis • Efficiency and cost aspects

L17-18	Renewable hydrogen production	• Biomass gasification, solar-driven thermochemical processes • Wind-solar powered electrolysis
L19-20	Hydrogen processing and challenges	• Purification requirements for fuel cells • Cost, scalability, and emerging advancements
L21-23	Gaseous hydrogen storage	• Compressed hydrogen tanks, high-pressure vessels • Design and efficiency
L24-26	Liquid hydrogen storage	• Cryogenic techniques, liquefaction process • Energy penalty and challenges,
L27-29	Solid-state hydrogen storage	• Metal hydrides, chemical hydrides, and LOHCs • Safety and material issues
L30-34	Distribution and safety	• Pipelines, cylinders, refueling stations • Transportation challenges and safety protocols
L35-40	Policy and social acceptance	• Government incentives, global hydrogen strategies • Public perception and commercialization challenges

EN RE 1162 Small Hydro Power

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Small Hydro Power		
Course code	EN RE 1162		
Core/ Elective/other	Elective Subject		

Prerequisite:	
1.	Fluid Machinery
2.	Fluid Mechanics
Course Outcomes:	
1.	**CO1:** Analyse the energy scenario of our country
2.	**CO2:** Describe the working principles of small hydropower plant and its component.
3.	**CO3:** Estimate the performance parameters of Hydro turbine
4.	**CO4:** Design structural & electro-mechanical subsystems of Small hydropower plant.
5.	**CO5:** Assess environmental impact of Small Hydropower Plant
Description of Contents in brief:	
1.	Hydro Power Plant- types, classification, construction, Micro-hydro Power-Introduction, site-Assessment
2.	Plant layout; Diversion weir and channel, de-silting tank, Forebay, penstock, tailrace, speed governor
3.	Turbine; classifications- Impulse turbine (Pelton turbine, Turgo turbine, crossflow turbine), Reaction turbines(Francis turbine, The propeller turbine and Kaplan, reverse pumps or pumps as turbines PATs)
4.	Turbine characteristics and selection, Generators, Hydroelectric Plant equipment ,Head and flow measurement, Regulation and incentives from the Government
5.	Economics of using micro-hydro power, Advantages and disadvantages of micro-hydro schemes
List of Text Books:	
1.	Water Power Engineering by M.M. Dandekar, K. N.Sharma, S Chand
List of Reference Books	
1.	Harvey A, Hettiarachi P, Iversin AR. Micro Hydro Design Manual. ITDG, UK; 1993 Jan 1.
2.	Harvey A, Inversin A. Micro-Hydro Design Manual: A guide to small-scale water power schemes. InNatural Resources Forum 1994 (Vol.18, No. 1, p. 69). London: Butterworths

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Hydro Power Plant	Types of Hydropower
L2	Hydro Power Plant	Classification of Hydropower
L3	Hydro Power Plant	Construction of Hydropower
L4	Hydro Power Plant	Micro-hydro Power-Introduction
L5-6	Hydro Power Plant	Site-Assessment
L7	Tutorial -1	Problem & Solution, Discussion
L8-10	Plant layout	Diversion weir and channel
L11	Plant layout	de-silting tank
L12	Plant layout	Forebay
L13-14	Plant layout	Penstock, tailrace
L15	Plant layout	Speed governor
L16	Tutorial -1	Problem & Solution, Discussion

L17-22	Turbine characteristics and selection	Impulse turbine (Pelton turbine, Turgo turbine, crossflow turbine)
L23-25	Turbine characteristics and selection	Reaction turbines (Francis turbine)
L26-30	Turbine characteristics and selection	Kaplan Turbine & its charcterstics
L31-33	Turbine characteristics and selection	Reverse pumps or pumps as turbines PATs)
L34	Tutorial -2	Problem & Solution, Discussion
L35-38	Economics of using small-hydro power	Cost component of SHP
L39-43	Economics of using small-hydro power	Economic analysis of SHP
L44	Tutorial -3	Problem & Solution, Discussion
L45-48	SWOT of SHP	Advantages and disadvantages of micro-hydro schemes
L49	Tutorial -4	Problem & Solution, Discussion
L50	Case Study	Small hydropower in India

EN RE 1163 Power Controllers for Energy Systems

Name of Program	M. Tech. Renewable Energy	-	Session 25-26
Name of Course	Power Controllers for Energy Systems		
Course code	EN RE 1163		
Core/ Elective/other	Elective		
Prerequisite:			
1.	Renewable Energy Sources		
2.	Basics in Electrical Engineering		
Course Outcomes:			
1.	**CO1:** Acquire knowledge about various power semiconductor devices.		
2.	**CO2:** To make students to analyze and design different power converter circuits.		
3.	**CO3:** To understand various power conversion techniques.		
4.	**CO4:** To understand controlling of high power sources.		
5.	**CO5:** To understand the power controller applications in energy systems.		
Description of Contents in brief:			
1.	Introduction to power electronic devices: SCRs, Triacs, GTOs, Power-MOSFETS, IGBT and other devices, their V-I characteristics, ratings, protection etc		
2.	Typical gate and triggering circuits, Opto-couplers. Various commutation techniques, parallel operation of power devices		
3.	Converters: A.C. to D.C. convertors- single phase & three phase, controlled and semicontrolled.		
4.	Choppers- type of operation and classification based on various quadrant operation, analysis and design of commutation parameters		
5.	Inverters: single phase and three phase bridge inverters. Voltage control, frequency control, PWM inverter.		
6.	Application of power controller in grid connected and stand-alone renewable energy systems		
List of Text Books:			
1.	Power Electronics by MD Singh		
List of Reference Books			
1.	Power Electronics by CY Lander		

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	**TOPIC**	**Contents**
L1	Introduction to Power controllers	Various power controllers and their applications
L2-8	Introduction to power electronic devices	SCRs, Triacs, GTOs, Power-MOSFETS, IGBT and other devices.
L9-11	Typical gate and triggering circuits	Various Gate firing circuits, merits, demerits and applications. Opto-couplers.
L12-16	Various commutation techniques to turn OFF SCRs	Natural Commutation Forced commutation: Class-A, Class-B, Class-C, Class-D and Class-E commutation circuits
L17-18	Tutorial -1	Problem & Solution, Discussion
L19-28	Converters: A.C. to D.C. convertors- single phase & three phase.	Classification, Single pulse, two pulse, three pulse and six pulse converters. Uncontrolled, Fully controlled and semi controlled converters. Mid-point and bridge converters and their applications
L29-30	Tutorial -2	Problem & Solution, Discussion

L31-34	Choppers- types and application	Introduction, types of choppers and their applications. Quadrant operations of choppers
L35-36	Tutorial -3	Problem & Solution, Discussion
L37-40	Inverters: single phase and three phase bridge inverters.	Introduction, Single phase half bridge and full bridge inverters. Three phase half bridge and full bridge inverters.
L41-43	Voltage control, frequency control, PWM inverter.	Voltage and frequency control through inverters and PWM inverters.
L44-45	Tutorial -4	Problem & Solution, Discussion
L46-49	Application of power controller in grid connected and stand-alone renewable energy systems	Stand-alone solar PV system, grid connected solar PV system, Stand-alone wind energy system and grid connected wind energy system.
L50	Tutorial -5	Problem & Solution, Discussion

EN RE 1164 Biomass and Waste Management

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Biomass and Waste Management		
Course code	EN RE 1164		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Basic Environmental engineering		
Course Outcomes:			
1.	**C01:** Understand the concept of waste its sources and classification		
2.	**C02:** To provide comprehensive overview of solid, biomedical, hazardous waste and liquid waste		
3.	**C03**: To understand Environmental legislation for solid ,hazardous waste and waste water disposal and transport		
4.	**C04:** To understand Technology for waste management		
5.	**C05:** To provide holistic solutions to waste management and energy generation challenges and establishing of zero waste society		
Description of Contents in brief:			
1.	Introduction to Concept of waste, sources and engineering classification,		
2.	Transport - collection systems, collection equipment, transfer stations, collection route optimization		
3.	Treatment methods - various methods of refuse processing, recovery, recycle and reuse, composting – aerobic and anaerobic, incineration, pyrolysis and energy recovery Need for waste conversion to energy and overview of waste to energy plant		
4.	Biomedical and hazardous waste management		
5.	Waste water management		
6.	Importance and steps of integrated solid waste e management system and energy from waste and zero waste society		
List of Text Books:			
1.	Solid Waste Engineering - Principles and Management Issues", Tchobanoglous G., Theissen H., and EIiassen R.(1991), "McGraw Hill, New York.		
2.	Waste Management Practices John Pichtel CRC Press		
List of Reference Books:			
1.	CPHEEO, Manual on Municipal Solid waste management, Central Public Health and Environmental Engineering Organisation, Government of India, New Delhi, 2000.		
2.	Handbook of Solid Waste Management and Waste Minimization Technologies by Nicholas P. Cheremisinoff		
Lecture Plan (about 40-50 Lectures			

):

LECTURE NO.	TOPIC	Contents
L1-2	Concept of waste, sources problems and classification	Concept of Waste solid, hazardous, liquid waste, Agricultural Residues, Industrial Wastes
L3-5	Integrated waste management system and energy from waste	Concept, principle, procedures and evolution Integrated waste management, hierarchy
L6-8	Relevant Regulations	Municipal solid waste (management and handling) rules; hazardous waste (management and handling) rules; biomedical waste handling rules; fly-ash rules; recycled plastics usage rules; batteries (management and handling) rules
L9-11	Agencies and government schemes	Swach-bharat mission, pollution control boards etc.
L12-13	Generation, collection and transportation	Collection systems, collection equipment, transfer stations, collection route optimization
L14-16	Municipal Solid Waste Management Fundamentals	Sources; composition; generation rates; collection of waste; separation,
L17-19	Hazardous waste	Characterization of waste; compatibility and flammability of chemicals; fate and transport of chemicals; health effects
L20-22	Landfill	Landfill design for solid and hazardous wastes; leachate collection and removal; landfill covers; problems and solution tutorial questions
L23-24	Waste to energy conversion overview	Energy Recovery from waste.
L25-26	Thermochemical process incineration gasification pyrolysis	Chemistry involved, Types , problems and end products
L27-30	Materials obtained from thermochemical process and utilisation	Solid. Liquid and gaseous production… their properties and utilisation tutorial questions
L31-32	Biological Treatment of Solid and Hazardous Waste	Composting; bioreactors; anaerobic decomposition of solid waste; principles of biodegradation of toxic waste; inhibition; co-metabolism in-situ remediation

L33-37	Waste water Management	Characteristics, treatment and disposal.
L38-39	Radioactive Waste Management	Fundamentals Sources, measures and health effects; nuclear power plants and fuel production; waste generation from nuclear power plants; disposal options
L40-41	Biomedical Waste Management	Fundamentals Sources, measures and health Effects. Treatment and disposal
L42-43	Energy production from waste plastics e-waste, batteries etc.	Scope, technology and products
L44-45	waste to energy plants-environmental implications	Environmental hazards, health effects and solutions
L46-47	Issues and challenges in India and the road ahead	Analysis of various waste to energy plants in terms of environmental implications. tutorial questions
L48-50	Case studies and visit to waste management facility	waste to energy thermal plants waste to energy biogas plants 3Rs facility

EN EM 2151 Climate Change and Carbon Sequestration

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Climate Change and Carbon Sequestration		
Course code	EN EM 2151		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Basic environmental science		
Course Outcomes:			
1.	**C01:** Understand the concept of climate change, science and identify the anthropogenic drivers of climate change		
2.	**C02:** To comprehend observed and projected trends and impacts in the climate change and analyse different climate change scenarios and their implications and interactions		
3.	**C03:** Identify the main organizations and bodies that operate under the UNFCCC and its Kyoto Protocol, and analysing key points relevant for a post-2020 climate change regime.		
4.	**C04:** understanding reduction and mitigation strategies including cdm and low carbon development methods		
5.	**C05:** comprehending various aspects of carbon sequestration and providing solutions		
Description of Contents in brief:			
1.	Introduction to Climate Change Science, greenhouse effect natural and anthropogenic drivers of climate change		
2.	Observed and projected Trends and Impacts of Climate Change –implication and interaction with population, agriculture, energy mix		
3.	Climate change policy and legal framework, UNFCC, Kyoto protocol and their importance. Indian policy and perspective		
4	Climate Change Mitigation ,adaptation and Low Carbon Development		
5	Carbon sequestration, concept, types, technology and suitability		
5.	Climate change and India- challenges and solutions ,innovative strategies		
List of Text Books:			
1.	Carbon Capture and storage: R&D Technology for Sustainable Energy future By Malti Goel ,TERI publications		
2	climate change by Joseph Romm OXFORD UNIVERSITY PRESS 2016		
3	IPCC (Intergovernmental for Climate Change). Climate Change: Mitigation. Contribution of Working Group III to the sixth Assessment Report of the Intergovernmental Panel on Climate Change		
List of Reference Books			
1.	Smart solutions to climate change -Bjorn Lomberg Cambridge university press		
2.	UNFCC –HANDBOOK		
3	Green, Reliable and Viable: Perspectives on India's shift towards low-carbon energy –TERI publications		
URLs:			
1 2. 3	https://www https://www.uncclearn.org https://unfccc.int/resource/docs/publications/handbook.pdf https://www.ipcc.ch/reports		

Lecture Plan (about 40-50 Lectures):		
LECTURE NO.	**TOPIC**	**Contents**
L1	Introduction to climate change	Overview of key concepts such as climate, weather and the greenhouse gas effect.
L2-6	Greenhouse emissions and effect	greenhouse gases sources and their interaction physical basis of the natural greenhouse effect .Greenhouse emissions components
L7-10	Global warming	Global warming, Global warming potential interaction, measurement and evidences Natural and anthropogenic drivers Calculation of GWP and numerical practice
L11-14	Aanthropogenic drivers of climate change	Historical evaluation industrial , transportation, agriculture and energy consumption .tutorial questions
L15-20	Observed and projected Trends and Impacts of Climate Change	Observed changes in the climate since the industrial revolution. projected future trends and impacts of climate change on surface temperature, precipitation, ocean pH, sea-level and Arctic sea-ice extent Climate change effects-local and global impact and effect of population, settlement, agriculture , construction , energy mix etc.
L21-24	International Legal and Policy Framework to Address Climate Change	brief history of international climate change negotiations United Nations Kyoto Protocol and its associated bodies, key issues relevant for a future climate change regime
L25--28	Adaptation strategy.	Local and global adaption strategies, technical aspects and challenges. Different adaptation measures that can be implemented for various vulnerable sectors..
L29-34	Mitigation strategies and and low carbon development	Introduction to Climate Change Mitigation and Low Carbon Development, CDM And clean coal technologies in various sector tutorial questions
L35-36	Mitigation and adaptation strategies in Inia	The Indian perspective and tutorials
L37-38	Carbon sequestration-	Natural carbon sinks.. terrestrial,aquatic and biological sinks
L41-44	Artificial methods – Pre-combustion and post combustion carbon capture	Industry and power sector Pre combustion and post combustion Absorption, adsorbent, oxyfuel etc
L45-46	Transportation and storage	transportaion and storage and associated problems different methods geological, oil wells marine sequestration etc
	Technology, policy and planning The Indian perspective	
L47-50	Case studies	Climate change and global warming Effect of climate change on various activities Adaptation strategies; Mitigation strategies Policy planning

Departmental Electives-3

EN EM 1251 Energy Efficiency in Thermal Utilities

Name of Program	M.Tech Renewable Energy		Session 25-26
Name of Course	Energy Efficiency In Thermal Utilities		
Course Code	EN EM 1251		
Core/ Elective/other	Elective		
Prerequisite:			
1.	Basic Engineering all disciplines		
COURSE OUTCOMES:			
1.	**CO1**: Effectively conduct energy audits in thermal systems, identifying key areas where energy savings can be realized, and suggesting appropriate measures to improve efficiency.		
2.	**CO2:** Demonstrate the ability to optimize thermal energy systems, implement best practices, and utilize advanced technologies to enhance energy performance.		
3.	**CO3:** Apply the fundamental principles of energy efficiency in the context of thermal utilities, demonstrating a clear understanding of energy forms, conversion processes, and efficiency metrics.		
4.	**CO4:** Perform economic evaluations of energy efficiency projects, calculating potential savings, payback periods, and justifying investments based on financial analysis.		
Description of Contents in brief:			
1.	Fuels and Fuel Properties Introduction to fuels and their classification. Properties of fuel oil, coal, and gas Fuel storage systems: handling, preparation, and safety aspects. Fuel blending, pulverization, and environmental considerations		
2.	Combustion and Boilers Principles of combustion: stoichiometry, flame characteristics, excess air requirements. Combustion of oil, coal, and gas. Boiler types: fire tube, water tube, package boilers, and modern designs. Boiler combustion process, heat balance, and performance evaluation of thermal devices.		
3.	Energy Losses and Steam Systems Analysis of thermal losses: stack, radiation, convection, and unburnt losses. Feed water treatment: softening, demineralization, blowdown methods. Energy conservation opportunities in thermal utilities. Steam system: properties, distribution, traps, condensate recovery. Furnaces: types and classification		

4.	Furnace Operations and Efficiency General fuel economy and efficiency factors. Furnace safety measures and operational best practices. Control of excess air and its impact on performance. Heat distribution and utilization techniques. Temperature and draft control: instrumentation, forced and induced draft fans
5.	Waste Heat Recovery and Advanced Technologies Principles and applications of waste heat recovery. Heat exchangers, economizers, recuperators, regenerators. Insulation: materials, selection criteria, and applications. Refractories: types, properties, and usage in thermal utilities. Fluidized bed combustion boilers: mechanisms, design, and advantages
List of Text Books:	
1.	Energy Efficiency in Thermal Utilities by Bureau of Energy Efficiency, India
2.	Energy Performance Assessment for Equipment and Utility Systems by Bureau of Energy Efficiency, India

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1-2	Introduction to Fuels	Types of fuels, characteristics, calorific value, proximate and ultimate analysis
L3-4	Properties of Fuel Oil	Viscosity, flash point, pour point, density, handling and storage issues
L5-6	Coal and Gas Properties	Types of coal, grading, natural gas properties, fuel handling systems
L7-8	Fuel Storage and Preparation	Storage methods, pulverization, fuel blending, safety aspects
L9-10	Principles of Combustion	Combustion chemistry, stoichiometric ratios, excess air requirements
L11-12	Combustion of Oil, Coal and Gas	Burner design, flame characteristics, emission aspects
L13-14	Boilers: Types	Fire tube, water tube, package boilers, modern designs
L15-16	Boiler Combustion & Performance	Heat balance, efficiency, equivalent evaporation, boiler trial
L17-18	Analysis of Losses	Stack losses, radiation/convection losses, heat balance study
L19-20	Feed Water Treatment & Blow Down	Hardness, demineralization, softening, blow down methods
L21-22	Energy Conservation Opportunities	Efficiency improvements in boilers and auxiliaries
L23-24	Steam System	Properties, steam distribution, steam traps, condensate recovery

L25-26	Furnaces: Classification	Reverberatory, rotary, cupola, electric furnaces
L27-28	Fuel Economy & Furnace Safety	Factors affecting efficiency, safety measures
L29-30	Excess Air & Heat Distribution	Measurement and control of excess air, heat recovery systems
L31-32	Temperature & Draft Control	Instrumentation, draft systems, induced & forced draft fans
L33-34	Waste Heat Recovery	Heat exchangers, economizers, recuperators, regenerators
L35-36	Insulation and Refractories	Types, selection criteria, applications in thermal utilities
L37-38	Fluidized Bed Combustion Boilers	Principle, advantages, design and applications
L39-40	Case Studies & Energy Audit	Industrial case studies, best practices, energy audit methodology

EN RE 1252 Energy from Waste

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Energy from Waste		
Course code	EN RE 1252		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Basic Environmental engineering		
Course Outcomes:			
1.	C01: Comprehend the current and futuristic trend in energy requirement and waste generation.		
2	C02: Understand the quantitative and qualitative aspect of waste		
3	C03: Understand the importance of integrated solid waste management. and analyse various waste to energy routes		
4	C04: Understand various processes involved in waste to energy plants		
5.	C05: To provide holistic solutions to waste management and energy generation challenges		
Description of Contents in brief:			
1	Global energy scenario , waste generation data, problems and challenges , and importance of waste to energy conversion		
2	Introduction to waste sources and characterization of wastes		
3.	Energy production from organic wastes through biochemical methods		
4.	Energy production form wastes through thermochemical methods incineration, gasification, pyrolysis and fromwaste plastics		
5.	importance and steps of integrated solid waste e management system and energy from waste and zero waste society		
List of Text Books:			
1.	1. Handbook of Solid Waste Management and Waste Minimization Technologies by Nicholas P. Cheremisinoff. 2. Solid Waste Engineering by P. AarneVesilind, William A. Worrell and Debra R. Reinhart.		
	Environmental Pollution Control Engineering-CS Rao, Wiley Eastern Ltd.		
List of Reference Books			
1.	Waste-to-Energy Technologies and Project Implementation Marc Rogoff Francois Screv		
2.	Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons by Gary C. Young.WILEY online		
URLs:			
1.	https://www.energy.gov/sites/prod/files/2019/08/f66/BETO--Waste-to-Energy-Report-August--2019.pdf		
Lecture Plan (about 40-50 Lectures):			
LECTURE	**TOPIC**	**Contents**	

NO.		
L1	Global and national energy and waste scenario Concept of waste, sources problems and classification	Global and national energy and waste scenario Concept of waste, sources problems and classification
L2-3	Waste –an important resource	Waste as a Renewable Energy Source and overview of the process
L4-8	Characterisation of wastes.	Characterisation of solid wastes-physical,-density, moisture content and proximate analysis
L9-11	Heating value and tutorial questions on waste characterisation	Heating value importance , types and calculations .tutorial questions
L12-13	Waste to energy conversion overview	Energy Recovery from waste, Agricultural Residues, Animal Waste, Industrial Wastes, Forestry Residues, Municipal Solid Waste (MSW),Energy assessment
L14-16	Waste management system and energy from waste and zero waste society	Integrated waste management, hierarchy
L17-19	Energy production form wastes through combustion and incineration,	Chemistry involved, Types , problems and end products
L20-22	Energy production form wastes through gasification pyrolysis	Chemistry involved, Types of gasifiers and end products
L23-24	Materials obtained from thermochemical process and utilisation	Solid. Liquid and gaseous production… their properties and utilisation tutorial questions.
L25-26	Issues and challenges in Energy production through thermochemical methods	Process and importance Landfills and incineration Problems, emissions and acceptability.
L27-30	Energy production form wastes through biochemical conversion	feedstocks, anaerobic digestion, type of digesters', steps in anaerobic process .properties and cleaning of biogas , numerical practice
L31-32	Energy production form wastes through fermentation	Energy production form wastes through sugar conversion. Process, pre-treatment and end products .

L33-34	Energy production form wastes through transesterification	Energy production form wastes through transesterification. Process ,pre-treatment and end products
L35-37	Material properties and utilisation and	Comparative evaluation and utilisation of end products tutorial questions
L38-39	Overview of waste to energy plants and factors influencing its performance	Selection of site, Government policy , barriers and techno - economic evaluation
L40-41	Analysis of existing waste to energy plants	Analysis and efficiency improvement and tutorial questions
L42-43	Energy production from waste plastics	Scope, technology and products
L44	Algae harvesting and microbial fuel cell	Algae harvesting and microbial fuel cell
L45	waste to energy plants- environmental implications	Environmental hazards, health effects and solutions
L46-47	Issues and challenges in India and the road ahead	Analysis of various waste to energy plants in terms of environmental implications. tutorial questions
L48-50	Case studies and visit to waste to energy facility	waste to energy thermal plants waste to energy biogas plants 3Rs facility

EN RE 1253 Green Buildings

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Green Buildings		
Course code	EN RE 1253		
Core/ Elective/other	Elective Subject		

Prerequisite:	
1.	Basic Electrical Engineering
2.	Basic Civil Engineering
Course Outcomes:	
1.	**CO1:** Understand the principles for lowering environmental impact of buildings and effort developed in research of green building.
2.	**CO2:** Know the background and understand the reasons for a more sustainable development of the built environment.
3.	**CO3:** Learn about Building Configuration and basic principles of Day-lighting and embodied Energy of Building Materials.
4.	**CO4:**Learn about alternative energy systems that could be applied in different building typologies
5.	**CO5:** Develop alternative green building concepts and recognizing their qualities and limits in lowering environmental impact
Description of Contents in brief:	
1.	Need of energy in buildings. Role of building design and building services to evaluate the energy performance in buildings.
2.	Principles of energy conscious design of buildings, Building Envelope, Orientation, Building Configuration, Passive Heating and Cooling. Study of Thermal environment and visual environment of Buildings..
3.	Basic Principles of Day-lighting, Embodied Energy of Building Materials, design guidelines, Energy efficient construction Technologies , integration of emerging technologies. Renewable Energy applications for buildings.
4.	Study of Climate and its influence in building design for energy requirement.
5.	Energy rating of buildings- IGBC, LEEDS, ECBC, GRIHA and case studies of Commercial Buildings, Industrial buildings, Residential buildings.
List of Text Books:	
1.	Energy Efficient buildings in India by Mili Majumdar TERI publications
List of Reference Books	
1.	Handbook on Energy Conscious Buildings by J.K. Nayak & J.A. Prajapati
2.	Sustainable Construction: Green Building Design and Delivery by **Charles J. Kibert** published by John Wiley & Sons; 3rd edition
URLs:	
1.	MNRE website, TERI website

Lecture Plan (50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Need of Energy in Buildings	Green Buildings –Introduction, importance and need of green buildings
L2-4	Green Buildings overview	Features and benefits of green buildings,
L5-8	Building Sitting, Orientation and layout	Building Envelope design, study of sun path and its impact on buildings, orientation study of buildings
L9-13	Energy Embodied and Construction	Embodied Energy of Building Materials

L14-18	Renewable Energy Usage	Solar water heaters, Solar PV panels , BIPV systems case studies
L19-23	Recycle recharge and reuse of water	Recycling of water, bathroom fixtures study, innovative and water efficient design of toilets and Waste management
L24-29	Building operation and maintenance	Basic Principles of Day-lighting, Lighting design , energy efficient lighting fixtures
L30-33	Low cost Green Building Strategies-Energy , Water	Day lighting, Natural Ventilation, Recycling of water, Paving materials, Landscape design
L34-37	Low cost Green Building Strategies-Materials , Indoor Air Quality Green Building materials	Engineered wood use, low VOC paints, vent range-hood, solar chimney in kitchen
L38-40	Cost effective construction Technologies	Rat trap walls, filler slab, brick arches, Residential, commercial, Industrial buildings case study
L41-43	Role of construction industry in climate change	Green Building Materials, GHG emission study from buildings
L44-46	Study of Climate and its influence in building design for energy requirement	Building design as per different climatic zones Study of Thermal environment of buildings Study of visual environment of buildings
L47-50	Passive Cooling concepts, integration of emerging technologies and Review of Building Codes	Earth tunnel, solar passive design studies ventilated windows, GRIHA Rating concepts, IGBC, LEEDS rating systems ECBC codes

EN RE 1254 Ocean and Geothermal Energy

Name of Program	M.Tech Renewable Energy	Semester	Session 25-26
Name of Course	Ocean and Geothermal Energy		
Course code	EN RE 1254		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Basic Environmental engineering		
Course Outcomes:			
1.	**C01:** Understand the concept of ocean and geothermal energy as renewable and non-conventional form of energy.		
2.	**C02:** To understand the principle of energy generation and application of geothermal and ocean energy.		
3.	**C03**: To understand the technology and design suitable OTEC tidal and wave energy based power-plants.		
4.	**C04:** To analyse the various form of geothermal resources and technology to harness energy from it.		
5.	**C05:** To understand the environmental implications and come out with holistic		
Description of Contents in brief:			
1.	Introduction to Concept of Ocean energy, nature and type of ocean energy		
2.	Ocean thermal energy source , range ,technology involved and environmental implications on OTEC System		
3	Oaken wave and tidal energy technology involved and environmental implications		
4	Geothermal energy of earth , type of resource technology involved and environmental implications		
5	Applications, research and innovations in Ocean and geo-thermal Systems		
List of Text Books:			
1.	Harsh K. Gupta, Sukanta Roy, Elsevier, "Geothermal Energy: An Alternative Resource for the 21st Century, first edition, 2006		
2.			
List of Reference Books:			
1.	G.D. Rai "Non-Conventional Energy Sources" Khanna Publishers		
URLs:			
1.	https://www.uprm.edu/aret/docs/ https://www.irena.org/geothermal		

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	Ocean energy introduction	Introduction, type of ocean energy
L2-3	Ocean thermal energy	Origin and characteristics Principle, selection of sites
L4-8	OTEC technology and power plant	Anderson and Carnot cycle , Closed Cycle System, Open Cycle System, Hybrid system components and comparison .numerical practice and tutorial questions
L9-10	Environmental impacts and challenges	Applications and environmental implications

L11-12	Present status and Innovative technologies and research	OTEC in India and Global Resource of Ocean Energy and research scope in OTEC
L13	Ocean Mechanical Energy	Introduction and types
L14-16	Tidal energy	Origin and principle of energy in tide and numerical practice
L17-19	Tidal energy technology	Selection of sites, type of schemes and power calculation , components of tidal power plants ,numerical practice and tutorials
L20-21	Environmental impacts	Environmental impacts and challenges in tidal energy
L22-23	Present status and Innovative technologies and research	Sites and present status , tutorial questions
L24-26	Wave energy	Introduction , power in waves , favourable conditions, numerical practice
L27-31	Wave energy technology	Floating or Pitching Devices, Oscillating Water Columns, surges numerical practice
L 32	Environmental impacts and challenges	Environmental impacts and challenges in wave energy
L33-34	Present status and Innovative technologies and research	Present status and Innovative technologies and research In wave energy
L35	Geothermal energy introduction	Thermal structure of earth-Heat flow and temperature distribution-heat and storage- Heat conduction, radiation and convection –Geo thermal gradient Thermal conductivity
L36-38	Characteristics and categories of Geothermal sites:	Geothermal reservoirs, water-dominated (hot water field, wet steam field), vapour dominated, Underground water, Aquifer, Underground water Vs Aquifer, Classification of geothermal resources: Hot Dry Rock Systems, Geo pressured Reservoirs, Magma Energy, Hot Dry Rock Fracturing Technique, Estimation of Potential from Dry Rocks, and Estimation of potential Sites
L39-44	Geothermal resources power plants-	Hydro geothermal-Dry steam fields-Wet steam fields-Hot water fields-Geo pressure resources-Hot dry rocks-Magma resources, volcano Dry Steam Power Plants, Flash Steam Plants, Binary cycle power plants numerical practice and tutorials
L45	Hot Springs system	Warm spring-Flow rates-High flow hot springs Therapeutic uses Infections-Hot springs around the world
L46	Material Selection	Material Selection for Geothermal Power Plants,

L47	environmental implications	Environmental hazards, and solutions
L48	Applications of geothermal energy	Applications of geothermal energy in power generation, space heating etc.
L49	Present status and Innovative technologies and research	Present status and Innovative technologies and research in geothermal energy

EN EM 1255 Research Methodology

Name of Program	MTech in Renewable Energy	-	Session 25-26
Name of Course	Research Methodology		
Course Code	EN EM 1255		
Core/Elect ice/Other	Elective Subject		
Prerequisite:			
Basic Engineering all disciplines			
COURSE OUTCOMES:			
CO1: To familiarize participants with basic of research and the research process.			
CO2: To enable the participants in conducting research work and formulating research synopsis and report.			
CO3: To impart knowledge for enabling students to develop data analytics skills and meaningful interpretation to the data sets so as to solve the business/Research problem.			
CO4: Identify and discuss the concepts and procedures of sampling, data collection, analysis and reporting.			
Description of Contents in brief:			
1.	Meaning of Research; Objectives, Motivation and Types of Research; Research Approaches; Significance of Research; Research Methods versus Methodology; Research Process; Criteria of Good Research		
2.	Meaning of Research Design; Need for Research Design; Features of a Good Design; Important Concepts Relating to Research Design; Different types of Research Designs		
3.	Measurement in Research; Measurement Scales; Sources of Error in Measurement; scaling and types- Collection of Primary Data; Observation Method; Interview Method; Collection of Data through Questionnaires; Collection of Data through Schedules; Difference between Questionnaires and Schedules; Some Other Methods of Data Collection		
4.	Research Writing Methods and Processes – This module introduces key academic writing formats such as research papers, review papers, book chapters, conference papers, and presentations. It focuses on their structure, purpose, and writing process, including planning, referencing, and peer review		
5.	Population and sample; Objects of Sampling; Methods of Sampling- Random and Non-Random; Techniques of sampling under each method; Sampling error and non-sampling error; Sampling distribution of a Statistic		

LECTURE NO.	TOPIC	Contents
L1	Introduction to Research Methodology	• Meaning of Research • Objectives of Research, • Motivations in Research
L2	Research Methodology	• Types of Research • Research Approaches,

L3	Significance of Research	• Research Methods v/s Methodology, • Research and Scientific Methods,
L4	Research Process	• Research Process, • Criteria of Good Research.
L5	Defining the Research Problem	• Concept and need • Identification of Research problem, • Defining and delimiting Research problem
L6	Data Analysis	• Data Preparation
L7	Data Analysis	• Univariate analysis (frequency tables, bar charts, pie charts, percentages)
L8	Interpretation of Data and Paper Writing	• Layout of a Research Paper • Journals in Energy, • Impact factor of Journals, • When and where to publish
L9	Paper publishing	• Ethical issues related to publishing • Plagiarism and Self-Plagiarism
L10-12	Interpretation	• Meaning of Interpretation, • Technique of Interpretation, • Precaution in Interpretation,
L13-15	Significance of Report Writing	• Different Steps in Writing Report, • Layout of the Research Report, • Types of Reports, • Oral Presentation,
L16-20	Process of Report Writing	• Mechanics of Writing a Research Report, • Precautions for Writing Research Reports, • Conclusions.
L20-25	Techniques for Research	• methods to search required information effectively, • Reference Management Software like Zotero/Mendeley,
L26-30	Use of tools	• Software for paper formatting like LaTeX/MS Office, • Software for detection of Plagiarism

Departmental Electives-4

EN RE 1261 Smart and Micro Grid

Name of Program	M.Tech Renewable Energy		Session 25-26
Name of Course	Smart and Micro Grid		
Course Code	EN RE 1261		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Electrical, Electronics and Power Electronics Engineering		
2.	Basics of IT & Communication systems		
Course Outcomes:			
1.	**CO1:**The course provides detailed understanding of Smart Grid with IT, Renewable Energy penetration into the grid, Concept of micro-grid		
2.	**CO2:**To impart enough knowledge aboutAutomation in Transmission and Distribution, Micro Grid modelling		
3.	**CO3:**The student should be able to understand the Development of converters to comply with grid standards to obtain grid integration		
4.	**CO4:** To understand operation of PMUs , Smart Meters for monitoring		
5.	**CO5:** Its objective is to sensitize students to learn to apply Evolutionary Algorithms, MAS and IOT for Smart Micro Grid		
Description of Contents in brief:			
1.	Traditional Power Grid and Smart Grid, Smart Grid Concepts with associated IT and communication technologies, Distributed generation, features and operations, advantages and disadvantages of DG, Importance & Effects of Renewable Energy penetration into the grid, Concept of micro-grids, advantages and disadvantages of Micro Grid,. Indian Smart Grid, Key Challenges for Smart Grid, Environmental impact and Economic Issues of transition, Initiatives for Smart and Micro-Grids developments.		
2.	Components and Architecture of Smart Grid Design, Transmission and Distribution Automation, Distribution Generation and Renewable Energy Technologies, Integration Tools and Techniques for Hybrid energy systems Micro grids, Storage Technologies, Electric Vehicles and plug -in hybrids, Distributed versus Centralized Control, Types of micro-grids , AC,DC, and Hybrid, Grid Integration and Control of Diesel, PV, wind and fuel cell based generators, Sizing, Modeling & analysis of micro-grids, Case Studies and Test beds for Micro Grids.		
3.	Grid Interfacing requirements, IEEE & IEC standards for renewable energy grid integrations Optimized integrated systems, Control strategies for grid connected and off-grid systems, Islanding Operations of Micro grid. predictive controllers and adaptive controllers, Load Frequency Control (LFC) and Voltage Control in Micro Grid System Reactive Power Control in Smart Grid, Converters and Power controllers to comply with grid standards, fault-ride through capabilities, protection and stability issues.		
4.	Communication and Measurement Technologies for smart grid Monitoring, Synchro-Phasor Measurement Units PMUs, Smart Meters and other advanced measurements methods, Communication Technologies like Wide Area Measurement Systems (WAMS) etc. **Performance Analysis Tools for Smart Grid Design** Load Flow Studies, Contingency Studies for the Smart Grid.		
5.	Computational Intelligence Techniques, Static and Dynamic Optimization Techniques, Evolutionary Algorithms, Artificial Intelligence techniques, Multi-Agent Systems (MAS) Technology, Internet of things (IOT) for Smart Micro Grid Operation and Control, Case Studies and Test beds for Smart Grids.		
List of Text Books:			
1.	Stuart Borlase, Smart Grids, Infrastructure, Technology and Solutions, CRC Press, 1e, 2013		

2	Gil Masters, Renewable and Efficient Electric Power System, Wiley–IEEE Press, 2e, 2013
3	Ali Keyhani Mohammad Marwali and Min Dai, Integration and Control of Renewable Energy in Electric Power System, John Wiley publishing company, 2nd Edition, 2010
List of Reference Books	
1.	Quing-Chang Zhong: Control of Power Inverters in Renewable Energy and Smart Grid Integration, IEEE- John Wiley and Sons Ltd. Publishers, 1St Edition, 2013
2	Report on "Large Scale Grid Integration of Renewable Energy Sources - Way Forward" Central Electricity Authority, GoI, 2013
3	S. Chowdhury, S. P. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, IET Power Electronics Series, 2012. 3. Lecture Plan (about 40-50 Lectures):
URLs:	
1.	www.smartgrid.gov
2	Indiasmartgrid.org

LECTURE NO.	TOPIC	Contents
L1	Traditional Power Grid and Smart Grid	• Traditional Power Grid and Smart Grid • Smart Grid Concepts with associated IT and • communication technologies
L2-3	Features and operations of grid	• Distributed generation, features and operations, • Advantages and disadvantages of DG, • Importance & Effects of Renewable Energy penetration into the grid, • Concept of micro-grids, advantages and disadvantages of Micro Grid,.
L4-6	Indian Smart Grid	• Indian Smart Grid, Key Challenges for Smart Grid, • Environmental impact and • Economic Issues of transition, Initiatives for Smart and Micro-Grids developments.
L7-10	Architecture of Smart Grid Design	• Components and Architecture of Smart Grid Design, • Transmission and Distribution Automation, • Distribution Generation and Renewable Energy Technologies,
L11-14	Integration Tools and Techniques for Hybrid energy	• Integration Tools and Techniques for Hybrid energy systems Micro grids, • Storage Technologies, • Electric Vehicles and • plug -in hybrids, Distributed versus Centralized Control,
L15-16	Types of micro-grids	• Types of micro-grids , AC,DC, • Hybrid, Grid Integration • Control of Diesel, PV, wind and fuel cell based generators, • Sizing Modeling & analysis of micro-grids, Case Studies and Test beds for Micro Grids.
L17-18	Grid Interfacing requirements	• Grid Interfacing requirements • IEEE & IEC standards for renewable energy grid integrations Optimized integrated systems • Control strategies for grid connected and off-grid systems,

L19-20	Islanding Operations of Micro grid	• Islanding Operations of Micro grid. predictive controllers and adaptive controllers, • Load Frequency Control (LFC) and Voltage Control in Micro Grid System Reactive Power Control in Smart Grid, • Converters and Power controllers to comply with grid standards, • Fault-ride through capabilities, protection and stability issues.
L21-23	Communication and Measurement Technologies	• Communication and Measurement Technologies for smart grid Monitoring, • Synchro-Phasor Measurement Units PMUs, • Smart Meters and other advanced measurements methods
L24-26	Communication Technologies	• Communication Technologies like Wide Area Measurement Systems (WAMS) etc. • Performance Analysis Tools for Smart Grid Design Load Flow Studies, • Contingency Studies for the Smart Grid.
L27-29	Computational Intelligence Techniques,	• Computational Intelligence Techniques, Static • Dynamic Optimization Techniques, Evolutionary Algorithms, • Artificial Intelligence techniques,
L30-34	Multi-Agent Systems (MAS) Technology,	• Multi-Agent Systems (MAS) Technology, • Operation & Control of smart grid
L35-40	Internet of things (IOT)	• Internet of things (IOT) for l Smart Micro Grid Operation Control • Case Studies and Test beds for Smart Grids.

EN RE 1262 Integrated Energy Systems

Name of Program	M. Tech Renewable Energy	-	Session 25-26
Name of Course	Integrated Energy Systems		
Course code	EN RE 1262		
Core/ Elective/other	Elective Subject		

Prerequisite:	
1.	Renewable Energy Sources
2.	Power controllers
Course Outcomes:	
1.	CO1: To understand the need of the integration of renewable energy sources.
2.	CO2: To understand the smart controllers
3.	CO3: To understand the need of reliable power supply.
4.	CO4: To understand the grid connected hybrid energy system
5.	CO5: To understand the modelling of different energy system.
Description of Contents in brief:	
1.	Introduction : Integrated Energy system and Hybrid Energy systems-component, configuration smart controller.
2.	Renewable Energy Generation: Renewable Resources, Micro grid Architecture, Distributed Storage
3.	Stand Alone Systems: Network voltage and system efficiency, Case studies of standalone system. Grid connected Energy Systems – block diagram case studies and its economic evaluation.
4.	Mathematical modeling of Renewable Energy sources and Hybrid Systems
5.	Grid Integration :Aspects, challenges, sensing and feedback composite .
6.	Economic analysis of Hybrid Energy System design concept optimisation overview of softwares and case study.
List of Text Books:	
1.	Advances in Integrated Energy System : Design control and Optimisation by Josep M G and Amjad A M - Applied Sciences
2.	Renewable Energy Sources for fuels and Electricity by Laurie Barrtom.
List of Reference Books	
1.	Smart Grid: Integrating Renewable, Distributed and Efficient Energy by Fereidoon P. Sioshansi, Academic Press, Elsevier

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1-L5	Introduction	Introduction to IES and HES, Components, configurations, inputs of IES and Various smart controllers
L6-10	Renewable Energy Generation	Various advanced energy storage technologies Renewable Resources, Micro grid Architecture, Distributed Storage Distributed Storage
L11-12	Tutorial -1	Problem, Discussion
L13- 15	Power controller	Various power controllers of IES and HES
L16- 18	Stand Alone Systems:	Network voltage and system efficiency, classification, block diagram
L 19-20	Tutorial -2	Case studies of standalone system. And discussion

L21-23	Grid connected Energy Systems	Block diagram case studies and its economic evaluation.
L24-25	Tutorial -2	Case studies of standalone system and discussion
L26-29	Mathematical modelling	Mathematical modelling of solar PV, wind, fuel cell etc.,
L30-34	MATLAB Simulation	Simulation of Solar PV, wind, fuel cell etc., Simulation of various combinations of IES.
L35-36	Tutorial -3	Simulation Problem & Solution, Discussion
L37-40	Grid Integration	Aspects, challenges, sensing and monitoring of outputs effect of variation in inputs
L41-42	Tutorial -4	Problem Discussion
L43-45	Economic analysis	Economic evaluation of Hybrid Energy System , design of IES and HES
L 46-48	Optimisation	Optimisation of IES and HES overview of softwares and case study.
L 49-50	Tutorial -5	Problem & Solution, Discussion

EN RE 1263 Electric Vehicles.

Name of Program	M.Tech Renewable Energy		Session 25-26
Name of Course	Electric Vehicles.		
Course Code	EN RE 1263		
Core/ Elective/other	Elective		
Prerequisite:			
1.	Basic Engineering all disciplines		
COURSE OUTCOMES:			
1.	**CO1:** Understand the fundamentals of electric vehicles (EVs), including architecture, components, and energy requirements.		
2.	**CO2:** Analyze different types of batteries, charging technologies, and their performance parameters.		
3.	**CO3:** Evaluate electric motors, power electronics, and control strategies for EV propulsion systems.		
4.	**CO4:** Examine EV integration with renewable energy, charging infrastructure, and smart grid concepts.		
5.	**CO5:** Assess economic, environmental, and policy aspects of EV adoption, along with future trends in sustainable mobility.		
Description of Contents in brief:			
1.	Introduction to Electric Vehicles EV history, importance in sustainable transportation, comparison with IC engines, EV classifications.		
2.	EV Components and Architecture Batteries, motors, controllers, power electronics, drive train configurations.		
3.	Energy Storage and Charging Systems Battery chemistry, BMS, charging methods (slow, fast, wireless), standards and infrastructure.		
4.	Electric Propulsion and Control Electric motors (BLDC, PMSM, Induction), converters, inverters, regenerative braking, control strategies.		
5.	Policy, Economics, and Future Trends Government policies, incentives, EV-grid integration, environmental benefits, upcoming research directions.		
List of Text Books:			
1.	"Electric Vehicle Technology Explained" by James Larminie and John Lowry		

2.	"Modern Electric, Hybrid Electric, and Fuel Cell Vehicles" by Mehrdad Ehsani, Yimin Gao, and Ali Emadi
3	"Electric and Hybrid Vehicles: Technologies, Modeling and Control" by Amir Khajepour, M. Saber Fallah, and Avesta Goodarzi
4	"Battery Management Systems for Large Lithium-Ion Battery Packs" by Davide Andrea
5	"Electric Drives: Concepts and Applications" by Vedam Subrahmanyam

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	**TOPIC**	**Contents**
L1	Introduction to EVs	• History, evolution, and significance of EVs in sustainable transport
L2-3	EV vs. IC Engines	• Comparisons of efficiency, emissions, and energy usage
L4-5	EV Classification and Architectures	• Battery EVs, Hybrid EVs, Plug-in hybrids, Fuel cell EVs
L6-8	EV Components	• Battery pack, electric motor, power converter, controller, auxiliaries
L9-11	Battery Technologies	• Lithium-ion, NiMH, solid-state; energy density, performance, safety
L12-14	Battery Management Systems (BMS)	• State of charge (SOC), state of health (SOH), thermal management
L15-16	Charging Systems	• AC and DC charging, slow/fast charging, wireless charging
L17-18	Charging Infrastructure	• EVSE, standards (CHAdeMO, CCS, Bharat EV), smart charging
L19-21	Electric Motors	• BLDC, PMSM, Induction motors – characteristics and control
L22-23	Power Electronics	• Converters, inverters, motor drive circuits
L24-25	Regenerative Braking	• Energy recovery, braking strategies, efficiency gains
L26-28	EV Control Strategies	• Drive cycle analysis, torque/speed control, efficiency optimization
L29-30	Hybrid and Fuel Cell EVs	• Series, parallel, series-parallel hybrids; hydrogen-based EVs
L31-33	Integration with Renewable Energy	• Solar/wind-powered charging stations, V2G technology

L34-35	Environmental and Economic Aspects	• LCA of EVs, carbon footprint, total cost of ownership
L36-37	Policies and Incentives	• Global and Indian EV policies, subsidies, and adoption trends
L38-39	Future Trends in EVs	• Solid-state batteries, wireless power transfer, autonomous EVs
L40	Research Directions and Case Studies	• EV innovations, case studies of Tesla, Tata, BYD

EN RE 1264 Energy policies

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Energy policies		
Course Code	EN RE 1264		
Core/ Elective/other	Elective Subject		
Prerequisite:			
1.	Renewable Energy Systems		
2.	Ecology and Environment		
COURSE OUTCOMES:			
1.	**CO1:** The course aims to provide root cause understanding of Environmental degradation, Global Climate Change issues and initiatives		
2.	**CO2:** To educate students about the EEELinkages,Environment Impact Assessment EIA, Environmental Acts and Treaties, , Environmental Policy Integration EPI		
3.	**CO3:** To impart enough knowledge about the Energy Policy purpose and action for energy intense industries		
4.	**CO4:** Its objectives is to sensitize students to the core competencies and skills required for formulating Strategies of Energy policy and its Implementation agencies of India		
5.	**CO5:** To train students to interpret different policies, Policy Assessment and Policy Relevance, Policies & Planning from Urban and Rural perspectives		
Description of Contents in brief:			
1.	Energy and Environment Basic Issues, Environmental degradation Global Climate Change issues and initiatives Kyoto Protocol, Emissions Inventories, Carbon Trading, Clean development mechanism, Relevant Case Studies		
2.	Criteria for Economic Growth, Energy-Economy-Environment Linkages,Environment Impact Assessment EIA, Indian environmental degradation, Effluent sewage, noise pollution standards and ambient air, water quality standards, The environmental protection act 1986 - Environmental laws prevention & control of pollution act 1974, Wild life protection act, Forest Conservation Acts, Environmental Acts and Treaties, , Environmental Policy Integration EPI		
3.	Energy policy purpose, perspective, Contents, Formulation, Ratification, Energy Policy basic Features and Typical Format, Energy Policy Statements of energy intense industries, Energy Management Principles, responsibilities of energy manager, Energy Action Planning Key elements and Force Field Analysis Tool		
4.	Functions of various ministries and organizations regarding Energy Policy and Planning, drivers and strategies of Energy policy of India, National Energy Policy features, Other Indian national Energy Acts and Treaties, Implementation agencies like IREDA, BEE, MPUVN, SECI etc. and organizations like CEA,NHPC, PNGRB,CERC etc.		
5.	Policy Analysis Concept and various approaches, Dimensions or factors for analyzing various policies, Policy Assessment and Policy Relevance, Planning Issues for Developing Countries, Policies & Planning from Urban and Rural perspectives Energy Planning Decision support systems, energy policy simulation and aanalysis methodologies.		
List of Text Books:			
1.	Energy Sources & Policies in India by Rishi Muni Dwivedi		
2	Energy Planning Reports of CMIE, State Governments & Govt. of India		
List of Reference Books			

1.	INTERNATIONAL ENERGY AGENCY, India 2020, Energy policy review report
2	The Handbook of Global Energy Policy byAndreas Goldthau © 2013 John Wiley & Sons, Ltd
URLs:	
1.	https://beeindia.gov.in
2	www.Ireda.in
3.	iced.cag.gov.in
4.	https://niti.gov.in
5.	www.iea.org

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1	About Energy and their types	• Energy and Environment Basic Issues, • Renewable energy
L2-3	Environmental degradation	• Environmental degradation • Global Climate Change issues and initiatives Kyoto Protocol,
L4-6	Greenhouse Gas Emissions	• Greenhouse Gas Emissions Inventories, • Carbon Trading, • Clean development mechanism
L7-10	Environment Impact Assessment and Environmental Degradation	• Criteria for Economic Growth, Energy-Economy-Environment Linkages, • Environment Impact Assessment EIA, • Indian environmental degradation,
L11-14	Environmental Pollution	• Effluent sewage, • noise pollution standards • ambient air, water quality standards,
L15-16	Legal Framework related to environment	• The environmental protection act 1986 • Environmental laws prevention & control of pollution act 1974,
L17-18	Legal Framework related to environment	• Wild life protection act, Forest Conservation Acts, • Other international Environmental Acts and Treaties,
L19-20	Objective of Energy policy	• Energy policy purpose, perspective, Contents, • Formulation, Ratification of Energy Policy basic
L21-23	Energy policy Management	• Features and Typical Format, • Energy Policy Statements of energy intense industries,
L24-26	Energy Action Planning	• Energy Management Principles, responsibilities of energy manager, • Energy Action Planning Key elements and Force Field Analysis Tool

L27-29	Functions of ministries and organizations	• Functions of various ministries and organizations regarding Energy Policy and Planning, • Drivers and strategies of Energy policy of India, National Energy Policy features, • Other Indian national Energy Acts and Treaties, Implementation agencies like IREDA, BEE, MPUVN, SECI etc. and organizations like CEA,NHPC, PNGRB,CERC etc.
L30-34	Environmental Policy Analysis	• Policy Analysis Concept and various approaches, • Dimensions or factors for analyzing various policies, • Policy Assessment and Policy Relevance,
L35-40	Energy Planning Decision and Stimulation	• Planning Issues for Developing Countries, • Policies & Planning from Urban and Rural perspectives • Energy Planning Decision support systems, • Energy policy simulation and aanalysis methodologies.

EN RE 1265 Pollution Control Technologies

Name of Program	M.Tech Renewable Energy	-	Session 25-26
Name of Course	Pollution Control Technologies		
Course code	EN RE 1265		
Core/ Elective/other	Elective Subject		

Prerequisite:	
1.	Basic Environmental engineering
Course Outcomes:	
1.	**C01:** Understand the various types of air pollutants and control technology
2.	**C02:** Analyse major water pollutants, their impact and provide solutions.
3.	**C03:** Provide suitable solutions to air, water, and noise pollution
4.	**C04:** Understand the importance of solid waste management and provide suitable remedies
5.	**C05:** To provide holistic solutions to pollution issue in the country
Description of Contents in brief:	
1.	Introduction to pollution and its types and classification
2.	Primary and secondary pollutants, their interactions, effects and control
3.	Surface and ground water pollution, their control and treatment
4.	Noise pollution, Radioactive pollution, Thermal pollution and eWaste problem and their abetment measures
5.	Land and soil pollution and importance and planning of integrated solid waste management
List of Text Books:	
1.	Peavy, Rowe and Tchobanoglous: Environmental Engineering.
	Environmental Pollution Control Engineering-CS Rao, Wiley Eastern Ltd.
List of Reference Books	
1.	Metcalf and Eddy, Wastewater engineering, Treatment and Reuse, Tata McGraw Hill Publication, New Delhi, 2003
2.	Handbook of Environmental management and technology: Gwendolyn Homes, Ben Ramnarine Singh, Louis Theodore.
3	CPCB, “Pollution control acts, Rules and Notifications”
URLs:	
1.	https://www.cpcbenvis.nic.in

Lecture Plan (about 40-50 Lectures):

LECTURE NO.	TOPIC	Contents
L1-2	Introduction to pollution and its types and classification	Concept , type, scope and relevance in present energy scenario
L3-4	Air pollution pollutants and effects and concept of Air Quality index[AQI]	Primary and secondary pollutants and their interactions

L5-7	Air pollution phenomena	Ozone depletion, photo chemical smog, London smog etc. Tutorial questions.
L8	Rules and Regulations for air pollution in India	Rules and Regulations for air pollution in India
L9-11	Air pollution control devices	Natural phenomena , absorption, adsorption height of stack , numerical practice
L12--16	Air pollution control devices	Removal of SPM and harmful gases , design and tutorial questions
L17-19	Indoor air pollution	Indoor air pollution, pollution due to smoking, sick building syndrome and solutions
L20-22	Issues, challenges and solutions to current air pollution issues	Air pollution in rural and urban areas , vulnerability and solutions and tutorial questions
L23-24	Noise pollution control	Noise pollution effects and control methods
L25-L26	Water pollution sources and classification	Water pollutants and sources Water quality assessment Effects of oxygen demanding wastewaters Dissolved oxygen and self-purification numerical practice
L27-29	Municipal Wastewater Treatment Technologies	Municipal wastewater treatment overview Pre-treatment Primary treatment Secondary treatment Advanced treatments
L30-31	Industrial Wastewater Treatment Technologies	Industrial Wastewater Treatment Technologies Classification of industrial effluents Specific treatment. Tutorial questions ,
L32	Ground water pollution	Causes and effects Treatment methods
L33	Marine pollution	Causes and effects Treatment methods
	Rules and Regulations for water pollution in India	Study of various standards, quality indices and rules and regulations
L34-35	Issues and challenges in India	River pollution, Water shortage etc
L36-37	Land and soil pollution	Sources and classification Effect of urbanisation
L39-40	Land and soil conservation	Drivers of land degradation like deforestation, desertification etc.
L41 -42	Solid waste management	Process and importance Landfills and incineration
L43 -44	Control strategies for land pollution	Bioremediation Proper solid waste management
L45-46	Radioactive and Thermal pollution. e-*waste*	Problems and control technology of thermal and radioactive pollution.
L47-50	Case studies	Bhopal Gas tragedy Chernobyl incident Pollution of ganga and Yamuna rivers Pollution in metro cities of India