REVISED SYLLABUS

2019-2020

M. Tech. (Energy Sciences)

Department of Applied Sciences and Humanities
Jamia Millia Islamia
New Delhi

Modern civilization is completely depending on power and energy to move ahead. Every single electrical device that we use in our daily life, as well as the production of such machine, is not able to function without power. Initially, coal was the main fuel of eighteenth and nineteenth centuries. However, the birth of electricity, automobiles and airplanes saw oil, which is termed as a fossil fuel, comes into the picture as the dominant fuel in twentieth century. Till now, the main contributors in power generation have been fossil fuels like oil and natural gas, coal, and nuclear resources, accounting for 86.2%. Other energy resources like hydro, solar, wind, geothermal, and wood have contributed an infinitesimal 0.9% of global energy production. In the last few years, the world energy consumption has been increased. This results in raising the price of oil from about $15 a barrel to above $100 a barrel, which has made everybody to start thinking about the possibility of alternative energies. On the other hand, burning of fossil fuels causes environmental degradation. The planet is getting hotter day by day. The ice on the mountains is melting and the existence of the planet is getting into danger zone. The time has come to think about these serious issues in our country also and we may need dedicated manpower for both academics as well as energy based industries to carry out research and development as well as to work as the experts in the commercial units in the energy sector. To fulfill the future demands of the experts in energy sector, we have stared Master of Technology program in the field of Energy Sciences. The aim of **M. Tech. in Energy Sciences** is to provide advanced understanding of energy production, conversion, utilization and conservation from conventional as well as non-conventional sources with the special emphasis on the Renewable Energy. The focus is being drawn on economic, environmental and policy impact of sustainable energy practice so that the Students will develop the research and communication abilities to be effective leaders in the energy industry.

Program Objectives :

The objectives of M. Tech. program (Energy Sciences) is to empower and enable students to develop advanced knowledge and skills in order to become leaders and managers in the energy sector. Specifically,

- ✓ Students will have a solid understanding of the sciences and technology related to energy production, conversion, utilization and conservation.
- ✓ Students will understand the economic, environmental and policy impact of a sustainable energy practice for a sustainable society.
- ✓ Student will learn basic to advanced aspects of Renewable Energy systems to be prepared for paradigm shift from fossil fuels to renewable sources.
- ✓ Students will develop the research and communication abilities to be effective leaders in the energy industry.

Total Intake: 20

COURSE STRUCTURE

M. Tech. (Energy Sciences)
Semester-I

S. NO.	Paper	PAPER TITLE	CREDIT	PERIOD PER WEEK		DISTRIBUTION OF MARKS			
				L	P	MID SEMESTER EVALUATION		END SEMESTER EXAM	TOTAL
						CWS	MST		
FIRST SEMESTER									
THEORY									
01	EST-101	Fundamentals of Energy Sciences	4	4	-	-	40	60	100
02	EST-102	Physics and Chemistry of Energy Materials	4	4	-	-	40	60	100
03	EST-103	Introduction to Nanotechnology	4	4	-	-	40	60	100
04	EST-104	Energy Resources I : Concepts and Technologies	4	4	-	-	40	60	100
05	EST-105	Energy Resources II : Concepts and Technologies	4	4			40	60	100
06	EST-106	Lab-I	2		4	-	30	20	50
07	EST -107	Seminar	2		4		30	20	50
		TOTAL CREDITS	**24**			**TOTAL MARKS**			**600**

Paper Code	Paper Title	Credit	Total Lectures
EST-101	**Fundamental of Energy Sciences**	**04**	**40**

Course Objectives :

1. To understand the fundamental concepts of Solar Energy.
2. To provide the knowledge of the basics of energy conversion.
3. To learn the energy conversion techniques and its benefits,
4. To provide an understanding of energy demand and utilization.
5. To study impact of energy on environment.

Unit-1 **10 Lecture**

Basics of Solar Energy

Energy and development, Units and measurements, Solar spectrum – Electromagnetic spectrum. Energy balance of the earth, solar constant for earth, specialty and potential – Sun – Earth – Solar Radiation, beam and diffuse – measurement – estimation of average solar radiation on horizontal and tilted surfaces – problems – applications. Measurement of solar radiation – Pyranometer, Pyrheliometer, Sunshine recorder. Solar time - Local apparent time (LAT), equation of time (E), Solar radiation geometry - Earth-Sun angles – Solar angles. Calculation of angle of incidence - Surface facing due south, horizontal, inclined surface and vertical surface. Solar day length – Sun path diagram – Shadow determination. Estimation of Sunshine hours at different places in India. Calculation of total solar radiation on horizontal and tilted surfaces. Prediction of solar radiation availability, Capturing solar radiation – physical principles of collection – types – liquid flat plate collectors – construction details – performance analysis – concentrating collection – flat plate collectors with plane reflectors – cylindrical parabolic collectors – Orientation and tracking.

Unit-2 **06 Lecture**

Basics of Energy Conversion

Energy Conversion routes, Direct and Indirect way of Energy Conversion, Principles of heat and mass transfer, Thermodynamics, Fluid statics and dynamics, Electricity generation and distribution

Unit-3 **10 Lecture**

Energy Conversion

Introduction to Energy conservation, Approach and modem techniques, Benefits, Trend, Energy conservation technology (Thermal Energy), Energy conservation in Energy Intensive Industries, collection, Limitation and heat and its potential applications, Waste heat survey and measurements Data collection, Limitation and heat affecting

factors Heat recovery equipment and systems, Heat Exchangers, Incinerators Regenerators and Recuperates.
Need and importance of Energy storage in conventional and non-conventional Energy systems. Technical aspects (Measurements, Quantify), Various forms of Energy storage: thermal, chemical Mechanical, Electrical and Nuclear

Unit-4 **08 Lecture**

Energy Demand and Utilization
Introduction and Historical Demand, Understanding Current Demand, Energy Markets, Energy and the rebound Effect, Residential Energy, Commercial Energy, Transportation

Unit-5 **06 Lecture**

Energy and Environment
Impact of Energy on Environment, Flow of Energy in Ecological system, Environment Degradation due to Energy, Control of pollution from Energy.

References:

1. The Science of Energy, Roger G Newton, World Scientific
2. Energy Recourses and Systems (Volume 1), Tushar Ghosh, Mark Prelas, Springer.
3. Energy Technology, O. P. Gupta, Khanna Publishing

Paper Code	Paper Title	Credit	Total Lectures
EST-102	Physics and Chemistry of Energy Materials	04	40

Course Objectives :

1. To understand the fundamentals and basics of material science.
2. To provide the knowledge of the basics and properties of materials.
3. To know the concepts and models of semiconductor physics.
4. To provide an understanding of organic semiconductors.
5. To study the basics of polymers and their application in energy systems and devices.

Unit-1 **08 Lectures**

Elements of Materials Science

Types of crystal systems, Bravais lattices, atomic packing factor, planner atomic density, Miller indices, crystal defects, solid solutions, dispersion in solids, stress and strain diagram of brittle and ductile materials, Plastic Deformation strain hardening in single crystals and polycrystalline materials, Slip of Planes perfect lattices, force on dislocation line

Unit-2 **08 Lectures**

Properties of Materials

Electronic and Electric Properties: free electron theory, fermi energy density of states, elements of band theory, dielectric, piezoelectric, pyroelectric and ferroelectric effect.
Magnetic properties: origin of magnetism, para-, dia-, ferro and ferri-magnetisms.
Thermal Properties: specific heat, thermal conductivity and thermal expansion, thermoelectricity.
Optical and optoelectronic properties. Superconductivity.

Unit-3 **08 Lectures**

Elements of Semiconductor Physics

Introduction to Semiconductors, Types of Semiconductors; Crystalline and Amorphous Semiconductors; Direct and Indirect Bandgap Semiconductors; Intrinsic and Extrinsic Semiconductors; Compound Semiconductors
Behavior of the Chemical Potential, Metal–Semiconductor Junction – Rectifying Contact, Metal–Semiconductor Junction – Ohmic Contact, The p–n Junction, Bipolar Transistor, Field Effect Transistor, Metal Oxide Semiconductor Field Effect Transistor (MOSFET), CMOS, Processing of Semiconductor Devices

Unit-4 **08 Lectures**

Organic Semiconductors

Electronic Configuration and Concept of Atomic Orbital, Hybridization and Overlapping of orbitals, Molecular Orbital, LCAO theory, Bonding and Antibonding orbitals, Sigma Bonding and pi-bonding, Material Origin of bandgap in organic semiconductors, Charge transport in organic semiconductors, Types of organic semiconductors, Optical and Electrical Properties of Organic Semiconductors

Organic Semiconductor Devices: Principal and Concepts

Processing of Organic Semiconducting Materials and Devices.

Unit-5 **08 Lectures**

Polymer Chemistry

Introduction, Formation of polymers, classification of polymers, Mechanism of polymerization, Degree of polymerization, Crystallization of polymer, cross linking, vulcanization of rubber, deformation of polymer, Factor affecting the properties of polymer, Advance polymers for engineering applications i.e. vinyl copolymer, composites and nanocomposites, polymer -clay Nano composite, PTFE, electro active polymers, Biodegradable polymers, High Temperature Polymers.

References:

1. Introduction to Solid State Physics, 8th Ed., C. Kittel, J. Wiley & Sons
2. Physics of Functional Materials, Hasse Fredriksson and Ulla Åkerlind, J. Wiley & Sons
3. Textbook of polymer science, Fred W Billmeyer, J. Wiley & Sons
4. Materials Chemistry, Fahlman, Bradley, Sp

Paper Code	Paper Title	Credit	Total Lectures
EST-103	Introduction to Nanotechnology	04	40

Course Objectives :

1. To understand the fundamentals and basics of nanotechnology.
2. To provide the knowledge of the basics and properties of semiconductor nanostructures.
3. To know the concepts, types and properties of carbon nanotubes.
4. To provide an understanding of the multidisciplinary applications of nanotechnology.
5. To study the applications of nanomaterials for energy systems and devices.

Unit-1 **08 Lectures**

Introduction to Nanotechnology

Historical Background of Nanotechnology, Quantum phenomena, Size effect, Electronic confinement in 1D,2D and 3D structures, Nanomaterials, Molecular Nanotechnology, Top-down and Bottom up approaches, Green Nanotechnology, Applications of Nanotechnology.

Unit-2 **08 Lectures**

Semiconducting Nanostructures

Metal oxide nanostructures: Background, Synthesis, Properties and Applications
Nanochalcogenides: Background, Synthesis, Properties and Applications
Organic Semiconductor Nanostructures: Background, Synthesis, Properties and Applications

Unit-3 **10 Lectures**

Carbon Nanomaterials

Introduction to Carbon allotropes and Carbon nanomaterials
Fullerenes: Background, Synthesis, Properties and Applications
CNTs (SWNTs and MWCNTs,): Background, Synthesis, Properties and Applications
Nano-diamonds: Background, Synthesis, Properties and Applications
Graphene: Background, Synthesis, Properties and Applications
Carbon Nano-fibers and Carbon nano-yarns: Background, Synthesis, Properties and Applications

Unit-4 **08 Lectures**

Nanotechnology: A Multidisciplinary Approach

Nanobiotechnology; Introduction and applications, Nanomedicine; Introduction and applications. Nanotechnology for clean environment, Nanorobotics; future of robotics and applications, Nanotechnology in water desalination technologies.

Unit-5 **06 Lectures**

Nanomaterials for Energy Applications

Introduction, Nanomaterials for Photovoltaic Devices, Nanomaterials for Energy Storage Devices, Nanomaterials for Thermo-electric Devices, Nanomaterials for Hydrogen Storage, Nanogenerators

References:

1. A Handbook of Nanotechnology, U. Kumar, AGROBIOS
2. Springer Handbook of Nanotechnology, B. Bhooshan, Springer
3. Advances in Nanomaterials, Zishan Husain Khan & M. Husain, Springer
4. Recent Trends in Nanomaterials: Synthesis and Properties (Advanced Structured Materials), Zishan Husain Khan, Springer
5. Nanomaterials and Their Applications, Zishan Husain Khan, Springer

Paper Code	Paper Title	Credit	Total Lectures
EST-104	Energy Resources I : Concepts and Technologies	04	40

Course Objectives :

1. To understand the concepts of energy technologies.
2. To provide the deep knowledge of hydro-power plants.
3. To know the concepts, types and design of thermal power plants.
4. To provide an understanding of the concepts, design and project planning of nuclear power plants.
5. To study the of the techno-economic aspects of power projects.

Unit-1 **06 Lectures**

Introduction & Orientation
Conventional and Non-Conventional Energy, Sources of Conventional energy, Historical, economic and Environmental Perspective, Need of Non-conventional Energy Sources, Types of Non-conventional Energy Sources, Global and National scenario, Basics of Non-conventional Energy Sources, their distribution and limitations.

Unit-2 **09 Lectures**

Hydro Power
Types of hydropower plants and schemes, hydrology: runoff studies, flood estimation studies, assessment of hydropower potential of a basin, storage and pondage, load studies, elements of hydropower plants and their hydraulic design: dams, intakes, conveyance system, types of power house, hydraulic turbines and pumps, Components and design of hydraulic turbines, Standardization and selection of turbine, Components and design of hydraulic Pumps, Hydropower scenario; Global and Indian perspective, Policies, Environmental concerns, Sub classification of Hydropower projects, Conceptualization, Techno-commercial studies, Investigation & Planning, Design Principles, Project Management, Operational issues, Test cases of Hydropower Projects

Unit-3 **09 Lectures**

Thermal Power
Types of thermal power tubines, Gas turbines; Open and closed cycles, constant pressure and constant volume cycles, cycles with inter cooling, reheating and heat exchanger, compressor and turbine efficiencies, pressure losses, performance characteristics of various cycles, practical problems. Jet Propulsion: Calculation of thrust, Power, speed and efficiency, turbo - jet and turbo propulsion systems. Compressors, Combustion Systems, Steam turbines; Principle and working, type of turbines, stage to blade, speed ratio for optimum efficiency, diagram efficiency, steam s performance. Energy losses in steam turbine, turbine performance at various loads and governing of steam turbines. Constructional details and description of steam turbine, Thermal power scenario; Global and Indian perspective, Policies,

Environmental concerns, Sub classification, Techno-commercial studies, Investigation & Planning, Design Principles, Project Management, Operational issues, Test cases

Unit-4 **08 Lectures**

Nuclear Power

Introduction to Nuclear Energy, Nuclear power scenario; Global and Indian perspective, Nuclear Reactors and its Components, General Problems of Reactor Operation, Different Types of Reactors, Pressurised Water Reactors (PWR), Boiling Water Reactors (BWR), Heavy Water – cooled and Moderated CANDU (Canadian Deuterium Uranium) Type Reactors, Gas-cooled Reactors, Breeder Reactors, Reactor Containment Design, Location of Nuclear Power Plant, Nuclear Power Station in India, India's 3-stage Programme for Nuclear Power Development, Comparison Nuclear Plants with Thermal Plants, Nuclear Materials, Nuclear Waste and its disposal, Safety rules, , Policies, Environmental concerns, Sub classification, Techno-commercial studies, Investigation & Project Planning & Design, Project Management, Operational issues, Test cases.

Unit-5 **08 Lectures**

Techno-economic Aspects of Power Projects

Techno-commercial aspects of power projects, General scenario of health of power industry with changing times, Analysis of power projects under stress, Techno-economic viability of a power project, conceptualization of a project, Statuary compliances in approval of the report, Bankable project reports, Escalation of cost and interest cost during construction, Socio-economic impact studies, Environmental clearances, Process of determination of tariff of different types of projects.

References:

1. Handbook of Hydroelectric Engineering, P. S. Nigam, Nem Chand & Bros., Roorkee
2. Electricity generation using wind power, William Shepard & Li Zhang, World Scientific Singapore
3. Thermal Engineering, P. L. Ballany, Khanna Publishers
4. Nuclear Power Plants: Design, Operating, Experience and Economics, Robert L. Loftness, D Van Nostrand Company Inc, New Jersey

Paper Code	Paper Title	Credit	Total Lectures
EST-105	**Energy Resources II : Concepts and Technologies**	**04**	**40**

Course Objectives :

1. To understand the concepts of solar energy.
2. To provide the deep knowledge of solar photovoltaics.
3. To know the concepts, types and design of thermal power plants.
4. To provide an understanding of the concepts, design of solar thermal systems.
5. To study the of the concepts, design and applicability of fuel cell and tidal energy.

Unit-1 **08 Lectures**

Solar Photovoltaic

Photovoltaic effect - Principle of direct solar energy conversion into electricity in a solar cell. Fundamentals of solar cell, Types of solar cells, First generation solar cells: design, fabrication, performance and drawbacks, Second generation solar cells: design, performance and drawbacks, Third generation solar cells: design, performance and drawbacks, I-V characteristics of a PV module, maximum power point, cell efficiency, fill factor, effect of irradiation and temperature, Classification of PV systems and components - Central Power Station System, Distributed PV System, Stand alone PV system, Grid Interactive PV System, small system for consumer applications, Hybrid solar PV system, Concentrator solar photovoltaic. System components - PV arrays, inverters, batteries, charge controls, net power meters. PV array installation, operation, costs, reliability.Design of solar PV systems and cost estimation. Case study of design of solar PV lantern, stand alone PV system - Home lighting and other appliances, solar water pumping systems. Building-integrated photovoltaic units, solar cars, aircraft, space solar power satellites. Socio-economic and environmental merits of photovoltaic systems.

Unit-2 **08 Lectures**

Solar Thermal

Solar thermal Energy conversion, Solar Passive Heating and Cooling, Solar Liquid and Air Heating Systems, Solar Cooling and Dehumidification, Solar thermal power plants - Solar thermal electric power plants based on parabolic trough, solar central receiver, parabolic dish-Stirling engine. Concentrated solar power using Fresnel lenses. Fundamentals of design calculations and analysis of solar power plants. Economic analysis, Design of solar water heating system and layout, Power generation – Solar central receiver system – Heliostats and Receiver – Heat transport system – solar distributed receiver system – Power cycles, working fluids and prime movers, concentration ratio, Solar cooking – Performance and testing of solar cookers. Seawater

desalination – Methods, solar still and performance calculations. Solar pond - Solar greenhouse.

Unit-3 **08 Lectures**

Wind Energy

Introduction and status of Wind Energy Technology, Wind turbines; Working Principles, Components and Design, Aerodynamics of Wind Turbine, Wind Turbine Blade Manufacture, Role of Non-Crimp fabric in Blade Manufacturing, Drive Train Concepts of Wind Turbine, Wind Turbine Gear Box, Wind Turbine Generator, Control and Protection System in Wind Turbine, Wind Turbine Tower, Wind Turbine Foundation, Wind resource assessment, Wind testing and certification, Wind power scenario; Global and Indian perspective, Policies, Environmental concerns, Sub classification, Techno-commercial studies, Investigation & Planning, Wind Farms Project Management, Operational issues.

Unit-4 **08 Lectures**

Bio-gas and Bio-mass

Introduction to biomass and farm residue, management and briquetting, Biomass: Sources and Characteristics; Wet biogas plants ; Biomass gasifiers: Classification and Operating characteristics; Updraft and Downdraft gasifiers ; Gasifier based electricity generating systems ; Maintenance of gasifiers, Technology of biogas, Principles, feedstock, types and design of biogas plants, Comparison of plant designs, Main parts of biogas plants, digester, gas holder, pressure gauge, gas controlling cocks and meter, Selection of biogas model and size. Site selection of biogas plants, Appliances of biogas plant - burner, heating plate, lamps, Operation, trouble shooting and maintenance of biogas plant, Safety measures in biogas plants, Biomass Gasification, Different types of biomass gasifiers, Applications of the gasifier, Problems in the developments of Gasifiers, Biomass energy program in India, Case study of Hosahalli biomass gasifier engine generator system.

Unit-5 **08 Lectures**

Fuel Cell & Tidal Power

Introduction – working and types of fuel cell – low, medium and high temperature fuel cell, liquid and methanol types, proton exchange membrane fuel cell solid oxide, hydrogen fuel cells – thermodynamics and electrochemical kinetics of fuel cells, Fuel cell performance characteristics, Hydrogen storage technology – pressure cylinders, liquid hydrogen, metal hydrides, carbon fibers – reformer technology – steam reforming, partial oxidation, auto thermal reforming – CO removal, Introduction to Tidal Power Plants; single basin and two basis plants, Variation in generation level; Ocean Thermal Electricity Conversion (OTEC) ; Electricity generation from Waves : Shoreline and Floating wave systems, Factors affecting the suitability of the site for tidal power plant, Classification of tidal Power Plants, Working and Design of Different Tidal Power Plants, Advantages and disadvantages of Tidal Power Plants, Components of Tidal Power plants.

References

1. Solar Energy, by S P Sukhatme & J K Nayak, Mc Graw Hill Publishers
2. Non-Conventional Energy Resources, B. H. Khan, Mc Graw Hill Publishers
3. Bioenergy: Biomass to Biofuels, Anju Dahiya, Academic Press.
4. Fuel Cells for automotive applications – professional engineering publishing UK. ISBN 1- 86058 4233, 2004.
5. Fuel Cell Technology Handbook SAE International Gregor Hoogers CRC Press ISBN 0-8493-0877-1-2003.
6. Yogi Goswami .D, Frank Kreith, Jan F. Kreider, “Principles of Solar Engineering”, Second Edition, Taylor & Francis, 2003.
7. Kalogirou .S.A., “Solar Energy Engineering: Processes and Systems”, Academic Press, 2009. 2. Vogel. W, Kalb .H, “Large-Scale Solar Thermal Power Technologies”, WileyVCH, 2010.
8. Sukhatme .S.P, Nayak .J.K, “Solar Energy”, Tata McGraw Hill Education Private Limited, New Delhi, 2010.
9. G. N. Tiwari, Solar Energy, Narosa Publishing House

Paper Code	Paper Title	Credit	Total Lab. classes
EST-106	**Energy Sciences Lab. I**	**02**	**40**

Course Objectives :

1. To study the properties of semiconductor materials.
2. To study the characteristics of semiconductor devices.
3. To study the solar cell characteristics.
4. To study the energy generation from wind turbine.
5. To study the energy generation from biomass/biofuel.

List of Experiments

1. To calculate the Hall co-efficient (R_H), type of majority charge carriers and number of charge carriers per unit volume (n) in a sample material.
2. By using Four probe method calculate the resistivity of semiconductors.
3. Using PN junction kit, observe the variation of current with voltage and plot the I-V characteristics of PN junction diode at room temperature.
4. To determine the value of Planck's constant 'h' by using a photo cell.
5. To determine the Planck's constant by using LED.
6. To study the I-V characteristics of Zener diode and calculate the breakdown voltage of Zener diode.
7. Using solar cell kit, plot the I-V characteristics of solar cell and determine the efficiency of solar cell.
8. Using solar cell kit, study the current and voltage for different parallel and series combination of cells.
9. Using Wind Energy Kit, study the generation of energy from the given wind turbine.
10. Using Bio Energy Kit, study the generation of energy from the given biomass/biofuel.

COURSE STRUCTURE

M. Tech. (Energy Sciences)
Semester-II

S. NO.	Paper	PAPER TITLE	CREDIT	PERIOD PER WEEK		DISTRIBUTION OF MARKS			
				L	P	MID SEMESTER EVALUATION		END SEMESTER EXAM	TOTAL
						CWS	MST		
SECOND SEMESTER									
THEORY									
01	EST-201	Advanced Energy Materials	4	4	-	-	40	60	100
02	EST-202	Energy Economics and Energy Policy	4	4	-	-	40	60	100
03	EST-203	Energy Audit	4	4	-	-	40	60	100
04	EST-204	Energy Management Systems	4	4	-	-	40	60	100
05	EST-205	Embedded Control Systems	4	4	-	-	40	60	100
06	EST-206	Laboratory-II	2	-	4		30	20	50
07	EST-207	Seminar	2	-	4	-	30	20	50
TOTAL CREDITS : 26								**TOTAL MARKS: 600**	

Paper Code	Paper Title	Credit	Total Lectures
EST-201	Advanced Energy Materials	04	40

Course Objectives :

1. To understand the fundamentals and basics of materials for solar energy.
2. To provide the knowledge of the synthesis of materials.
3. To understand about the characterization of materials.
4. To provide an understanding of energy harvesting materials.
5. To provide an understanding of the energy storage materials

Unit 1 **08 Lectures**

Materials for photovoltaics

First generation solar cell materials; single and polycrystalline Silicon, amorphous silicon: growth and wafer processing, contact materials, materials for surface engineering. Second generation solar cell materials; CdSe, CdTe, Copper Indium Gallium Selenide (CIGS), Gallium Arsenide for applications in photovoltaics, Materials for thin film solar cells, Thin film processing, and properties. Contact materials for second generation solar cells. Third generation solar cell materials; Quantum Dots, Organic materials, Composites, Dyes, Perovskites and their synthesis, characterization and properties, Interface energetics, photoactive layers and their materials, role of electron transport, hole transport, electron blocking and hole blocking materials and their processing. Contact materials and processing of contact layers.

Unit 2 **08 Lectures**

Materials Synthesis Methods

Physical Methods ; Vacuum Evaporation, Electron beam evaporation Sputtering, Cathodic Arc Deposition, Chemical Vapour Deposition, Atomic Layer Deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy, Lithography and their types, Chemical Methods; Sol-Gel technique, self assembly, colloidal method, hydro-thermal method, co-precipitation method, solid state synthesis, microwave method, micro-emulsion method.

Unit 3 **08 Lectures**

Materials Characterization Methods

Electron beam instruments: Transmission electron and scanning electron microscopes, Auger electron spectroscope, x-ray spectrometers, scanning probe microscope. Interpretation of diffraction information: selected area and convergent beam Electron diffraction patterns. Analysis of micrographs in TEM, SEM, and HRTEM, Interpretation of analytical data: EDS, WDS, Auger, EELS, ESCA, SIMS. Bulk averaging techniques: Thermal analysis, DTA, DSC, TGA, resistivity/conductivity. Optical spectroscopy:

Atomic absorption spectroscopy, infrared spectroscopy and Raman spectroscopy. Scanning Tunneling and Atomic Force Microscopy.

Unit 4 **08 Lectures**

Materials for energy harvesting

Piezoelectric, Pyroelectric and Thermo-electrics materials, Electrostatic (capacitive) Energy Harvesting and materials, energy from Magnetic Induction, Metamaterial, energy from atmospheric pressure changes, electroactive polymers (EAPs), nanogenerators, Ambient radiation sources and nanoantenna, energy from noise.

Unit 5 **08 Lectures**

Materials for Energy Storage

Electrochemistry and electro-chemical Battery materials, Hydrogen Storage materials for fuel cells: Metal hybrids, Nanostructured metal hydrides, Non-metal hydrides, Carbohydrates, Synthesis of hydrocarbons, Aluminum, Liquid organic hydrogen carriers (LOHC), Ammonia, Amine borane complexes, Nano borohydrides and nano catalyst doping, imidazolium ionic liquids, phosphonium borate, Carbonite substances, Metal Organic frameworks, Activated Carbons, Carbon nanotubes, Clathrate hydrates, Glass capillary arrays.

References:

1. Advanced Energy Materials, Ashutosh Tiwari & Sergiy Valyukh, J. Wiley & Sons
2. Eco- and Renewable Energy Materials, Young Zho, Springer
3. Materials and Energy (Book Series), Leonard C Feldman (Ed. In Chief), World Scientific

Paper Code	Paper Title	Credit	Total Lectures
EST-202	**Energy Economics and Energy Audit**	**04**	**40**

Course Objectives :

1. To understand the global scenario of energy and its impact of GDP.
2. To provide the knowledge of Indian energy scenario; consumption and supply.
3. To know about the global and national energy policies.
4. To provide an understanding of energy policy planning.
5. To study the economics of energy.

Unit-1 **08 Lectures**

Global Energy Scenario

Role of energy in economic development and social transformation: Energy & GDP, GNP and its dynamics, Discovery of various energy sources: Energy Sources and Overall Energy demand and availability, Energy Consumption in various sectors and its changing pattern, Exponential increase in energy consumption and Projected future demands, Energy Security: Chemical and Nuclear: Non Proliferation, Energy Security, Energy Consumption and its impact on environmental climatic change, International Energy Policies of G-8 Countries, G-20 Countries, OPEC Countries, EU Countries. International Energy Treaties (Rio, Montreal, Kyoto), INDO-US Nuclear Deal.

Unit-2 **08 Lectures**

Indian Energy Scenario

Energy resources & Consumption: Commercial and noncommercial forms of energy, Fossil fuels, Renewable sources including Bio-fuels in India, their utilization pattern in the past, present and future projections of consumption pattern, Sector wise energy consumption, Impact of Energy on Economy, Development and Environment, Energy for Sustainable Development, Energy and Environmental policies, Need for use of new and renewable energy sources, Status of Nuclear and Renewable Energy: Present Status and future promise Energy Policy Issues: Fossil Fuels, Renewable Energy, Power sector reforms, restructuring of energy supply sector, energy strategy for future. Energy Conservation Act-2001 & its features, Electricity Act-2003 & its features. Framework of Central Electricity Authority (CEA), Central & States Electricity Regulatory Commissions (CERC & ERCs)

Unit-3 **08 Lectures**

Energy Policy

Global Energy Issues, National & State Level Energy Issues, National & State Energy Policy, Industrial Energy Policy, Energy Security, Energy Vision, Energy Pricing & Impact of Global Variations, Energy Productivity (National & Sector wise productivity).

Unit-4 **08 Lectures**

Energy Policy Planning

Key Elements of Energy Policy Planning: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation, Implementation of Energy Policy: Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability, Motivation of employees, Requirements for Energy Action Planning, Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning.

Unit-5 **08 Lectures**

Energy Economics

Energy economics: Basic concepts, energy data, energy cost, energy balance, Energy accounting framework; Economic theory of demand, production and cost market structure; National energy map of India, Energy subsidy – National and international perspectives, Concepts of economic attributes involving renewable energy, Calculation of unit cost of power generation from different sources with examples, different models and methods, Application of econometrics; input and output optimization; energy planning and forecasting different methods, Concepts of economic attributes involving renewable energy, Calculation of unit cost of power generation from different sources with examples, different models and methods, Application of econometrics; input and output optimization; energy planning and forecasting different methods

References:

1. Energy Economics, Concepts, Issues, Markets and Governance, Subhes C. Bhattacharyya, Springer
2. Energy Economics, Peter M. Schwarz, CRC Press
3. Energy Law And Policy, Nawneet Vibhaw, Lexis Nexis

Paper Code	Paper Title	Credit	Total Lectures
EST-203	Energy Audit	04	40

Course Objectives :

1. To understand the objectives of energy audit.
2. To provide the knowledge of procedures and techniques used in energy audit.
3. To study the energy balance and MIS.
4. To provide an understanding of evaluation and understanding of thermal systems.
5. To study the evaluation and understanding of mechanical systems.

Unit -1 **06 Lectures**

General Aspects

General Philosophy and need of Energy Audit, Definition and Objective of Energy Audit, General Principles of Energy Audit, Energy Audit Methodology, Energy Audit Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution.

Unit -2 **06 Lectures**

Procedures and Techniques-I

Basic measurements – Electrical measurements, Light, Pressure, Temperature and heat flux, Velocity and Flow rate, Vibrations, etc.

Instruments Used in Energy systems: Load and power factor measuring equipment, Wattmeter, flue gas analysis, Temperature and thermal loss measurements, air quality analysis etc.

Mathematical and statistical modelling and analysis.

Energy Measurement & Verification, Measurement & Verification (M & V) Protocol

Unit -3 **08 Lectures**

Procedures and Techniques-II

Data gathering: Level of responsibilities, energy sources, control of energy and uses of energy get Facts, figures and impression about energy /fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering.

Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation.

Evaluation of saving opportunities: Determining the savings in Rs, Noneconomic factors, Conservation opportunities, estimating cost of implementation.

Energy Audit Reporting: The plant energy study report- Importance, contents, effective organization, report writing and presentation,

Energy Balance & MIS: First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses, Improvements. Energy Balance sheet and Management Information System (MIS) Energy Modelling and Optimization.

Unit-4 **10 Lectures**

Thermal Systems-Evaluation and Assessment

Boilers- performance evaluation, Loss analysis, Water treatment and its impact on boiler losses, integration of different systems in boiler operation. Advances in boiler technologies, FBC and PFBC boilers, Heat recovery Boilers- it's limitations and constraints. Furnaces- Types and classifications, applications, economics and quality aspects, heat distributions, draft controls, waste heat recovering options, Furnaces refractories- types and sections. Thermic Fluid heaters need and applications, Heat recovery and its limitations. Insulators- Hot and Cold applications, Economic thickness of insulation, Heat saving and application criteria. Steam Utilization- Properties, steam distribution and losses, steam trapping, Condensate, Flash steam recovery. Integrated analysis of steam base co-gen system, Gas turbine combine cycle operation, IC engine base co-generation and tri-generation, extraction turbines and steam cycle of cogeneration.

Unit-5 **10 Lectures**

Mechanical Systems-Evaluation and Assessment

Pumps, types and application, unit's assessment, improvement option, parallel and series operating pump performance. Energy Saving in Pumps & Pumping Systems, Blomers (Blowers) types & application, its performance assessment, series & parallel operation applications & advantages. Energy Saving in Blowers Compressors, types & applications, specific power consumption, compressed air system, & economic of system changes. Energy Saving in Compressors & Compressed Air Systems Cooling towers, its types and performance assessment & limitations, water loss in cooling tower. Energy Saving in Cooling Towers HVPC & Psychometric, vapour compression cycles & comfort cooling, refrigerants new trends, COP, Capacity assessment, Vapor absorption refrigeration's – Li Br & Ammonia Cycles, working principle and system analysis, comparison of different cooling systems, heat pump off ions for HVPC systems improvements and its analysis. Energy Saving in HVAC Systems, Water system and water analysis for power generation, water audit and it utilization, Hydro-pneumatic applications for optimization of water pumping cost

References:

1. Handbook of Energy Audits, Albert, Terry Niehus, William J. Younger, Fairmont Press
2. Energy Audit: Thermal Power, Combined Cycle, and Cogeneration Plants, Y. P. Abbi, The Energy and Resources Institute, TERI

Paper Code	Paper Title	Credit	Total Lectures
EST-204	Energy Management Systems	04	40

Course Objectives :

1. To understand the definition and concept of energy efficiency.
2. To provide the knowledge of Indian transmission and distribution systems.
3. To study the SCADA and smart grids.
4. To provide an understanding of poer and energy inter-change.
5. To study different regulatory frameworks for Indian poer systems.

Unit-1 **08 Lectures**

Energy Efficiency

Energy Efficiency, Energy Efficient Buildings, Green Buildings, Intelligent Buildings, Energy Conservation Opportunities in Public and Private Buildings Various Energy Efficiency Rating Systems for Buildings- LEEDS, BEE & GRIHA Rating Systems, Energy Conservation Building Code

Energy Conservation Act 2001, Revisions and Present State of Implementation Standardization &Labelling, Electricity Act 2003, Revisions and Present Status of Implementation

Energy Efficiency Projects, Evaluation of Energy Efficient Projects, Various ways of Financing Energy Efficiency Projects, Role of Financial Institutions and Corporate Banks, Deferred Payment Financing,

Unit-2 **06 Lectures**

Indian Transmission and Distribution Systems

Architectures, Transmission and distribution systems Planning in India-Strategies, Planning Criteria: Philosophy and General Guidelines, T&D Losses, Power Factor Improvement, Harmonics and its improvement, Transformer Loss Reduction, Tr. Parallel Operation.

Unit-3 **10 Lectures**

SCADA and Smart Grid

Types of Supervisory Systems, Uses of SCADA, SCADA Hierarchy, Components of SCADA System, SCADA Functions, National Grid, Regional Grid, Energy Management System Function, Distribution Automation, Intelligent Electronics Devices (IEDs), Phasor Measurement Units (PMUs). Smart Grid Concept, components, characteristics and technologies; AMI, Demand Side Management (DSM), Demand Response etc.

Unit-4 **08 Lectures**

Interchange of Power and Energy

Interchange of power and energy, economy interchange between interconnected utilities. Interchange evaluation. capacity interchange, Diversity Interchange, Energy Banking, Emergency Power Interchange, Power pools, Energy Broker System, transmission effects and issues; Transfer limitations, Wheeling, Calculation of Rates for transmission services in multiple utilities transactions.

Unit-5 **08 Lectures**

Regulatory Framework for Indian Power Systems Management and Control

Restructuring and Deregulations of Electric Utilities, Indian Electricity Act; Guidelines and their impact, Traditional Central Utility Model, Reform Motivations, Separation of Ownership and Operation, Central Dispatch versus Market Solution, Independent System Operator (ISO).

Wholesale Electricity Market Characteristics: Central Auction, Bidding, Market Clearing and Pricing, Bilateral Trading, Scheduling, Gaming, Ancillary. Maximalist ISO, Minimalist ISO Model.

Trading Arrangements: The Pool, Pool and Bilateral Trades, Multilateral Trades, Congestion Management in Open-access Transmission Systems,

References:

1. Power generation Operation & Control, Allen J. Wood and Bruce Woollenberg, John Wiley
2. Mini S. Thomas and John Douglas McDonald, “Power System SCADA and Smart Grids” CRC Press-2015.
3.] Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press-2009.
4. Loi Lai Lai, “Power Systems Restructuring and Deregulation-Trading , Performance and Information Technologies”, John Wiley and Sons Ltd.

Paper Code	Paper Title	Credit	Total Lectures
EST-205	Embedded Control System Design	04	40

Course Objectives :

1. To understand the concepts of embedded systems.
2. To provide the knowledge of design of embedded systems.
3. To study the system identification and model structures.
4. To provide an understanding of control design.
5. To study the fundamentals of robust control systems.

Unit 1 **08 Lectures**

Embedded Systems – Basic Concepts

What Is an Embedded System? The Main Architecture of Embedded Control Systems, Electric Power Level, Signal Processing Level , Communication Networks in Embedded Systems , Main Features of a Controller Area Network (CAN) Communication, CAN Message Frames ,Error Detection and Signaling, CAN Controller Modes , CAN Implementations , Multi-tasking Embedded Control Systems , Planning Embedded System Development.

Unit 2 **08 Lectures**

Introduction into Embedded Control System Design

Requirements for Control System Design, Safety Requirements, Identification of the System to Be Controlled, Control Device Specification, Design, Installation and Maintenance, Mathematical Models for Control, Models from Science, Models from Experimental Data, Linearization of Nonlinear Models, Control System's Characteristics, Disturbance Attenuation, Tracking, Sensitivity to Parameter Variations ,Control System's Limitation. Stability and Relative Stability, Performance Specifications for Linear Systems

Unit 3 **08 Lectures**

System Identification and Model-Order Reduction

Model Building and Model Structures, Input Signal Design for System Identification Experiments, Model Validation in Time and Frequency Domain, Model-Order Reduction Methods, Nominal Plant and Plant Uncertainties, Identification of a Fuel Cell.

Unit 4 **08 Lectures**

Controller Design

Based on Pole-Zero Cancellation, The Influence of Controller Zero, Controller Design for Deadbeat Response , Controller Design Using the Root Locus Technique, PID Controller Design, Ziegler-Nichols Tuning Formula, Monte Carlo Simulation, Controller Design for

Systems with Time Delays, Systems with Time Delays – Smith Predictor, Controller Design for Disturbance Rejection, Disturbance Observers

Unit 5 **08 Lectures**

Fundamentals of Robust Control

Review of Norms for Signals and Systems, Internal Stability, Youla Parametrization, Unstructured Plant Uncertainties, Robust Stability for Different Uncertainty Models, Controller Design Using Youla Parametrization, Risk Assessment and Safety Levels, Fault Categories and Failure Rates.

References:

Applied Control Theory for Embedded Systems. A volume in Embedded Technology. Book • 2006. Authors: Tim Wescott; Elsevier

Paper Code	Paper Title	Credit	Total Labs.
EST-206	Energy Sciences Lab.-II	02	40

Course Objectives :

1. To study the Solar Photovoltaic system.
2. To study different elements of photovoltaics energy systems.
3. To study the characteristics of fuel cells and their applications.
4. To study Hydro Turbine Energy Generator.
5. To study SCADA system.

List of Experiments

1. Study of I-V characteristics of Solar Cell
2. Study of various modes of Constant Voltage Charging technique.
3. Study of Buck and Boost Converter.
4. Study of Bypass Diodes.
5. Study of Dusk to Dawn Switch.
6. Fuel Cell:
   - **(a)** Study of Current-Voltage Characteristic of Electrolyzer's function of Reversible PEM Fuel Cell.
   - **(b)** Study of the Application of Fuel Cell function of Reversible Fuel Cell of providing electrical energy to the loads such as buzzer, fan and bulb.
7. To study the generation of electricity by using Bio Energy & run the different applications using generated electricity.
8. Hydro Turbine Energy Generator:
   - **(a)** To study the Hydro Turbine (Pelton wheel Type) with Resistive Load.
   - **(b)** To study the Hydro Turbine (Pelton wheel Type) with Motor Load.
   - **(c)** To study the Hydro Turbine (Pelton wheel Type) with Bulb Load.
9. To demonstrate the I-V and P-V characteristics of different types of solar cells with varying radiation and temperature level.
10. To demonstrate the impact of partial shading on solar cell performance.
11. To demonstrate the impact of tilt angle on solar cell performance.
12. Construct and describe the Hardware architecture of the SCADA system for the given power system field pump in the SCADA laboratory of the Department of Electrical Engineering.
13. Demonstrate how to connect the FBD logic to the field signal through SCADA project. Describe the RTU architecture. List the functions of each of its subsystem.
14. Demonstrate how to test the communication between workstations and the controller. List
    different components needed for Ethernet LAN. Describe different classes of IP addresses and the use of subnet mask.

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Semester-III

S. NO.	PAPERS	PAPER TITLE	CREDIT	PERIOD PER WEEK		DISTRIBUTION OF MARKS			
				L	P	MID SEMESTER EVALUATION		END SEMESTER EXAM	TOTAL
						CWS	MST		
THIRD SEMESTER									
THEORY									
01	EST-301	Solar Photovoltaic Technology	4	4	-	-	40	60	100
02	EST-302	Energy Efficient Lighting and Displays	4	4	-	-	40	60	100
03	EST-303	Energy Storage Systems	4	4	-	-	40	60	100
04	EST-304	Innovation, Entrepreneurship and Start up Ecosystems	4	4			40	60	100
04	EST-304	Minor Project	4	-	-	-	-	100	100
TOTAL CREDITS			**20**	**-**		**TOTAL MARKS**			**500**

Paper Code	Paper Title	Credit	Total Lectures
EST-301	**Solar Photovoltaic Technology**	**04**	**40**

Course Objectives :

1. To study the concept of PV systems.
2. To study about PV devices, modules and arrays and their technical parameters.
3. To study the components and working of solar power plant.
4. To study the concepts of solar power management.
5. To learn Grid Codes and Standards.

Unit-1 **08 Lectures**

Introduction to photovoltaic (PV) systems

Historical development of PV systems, Overview of PV usage in the world, Solar energy potential for PV, irradiance, solar radiation and spectrum of sun, geometric and atmospheric effects on sunlight, Photovoltaic effect, conversion of solar energy into electrical energy, behavior of solar cells.

Unit-2 **08 Lectures**

Photovoltaic Devices & Array and Modules, Technical Parameters

Solar cells, basic structure and characteristics: Single-crystalline, multicrystalline, thin film silicon solar cells, emerging new technologies, Electrical characteristics of the solar cell, equivalent circuit, modeling of solar cells including the effects of temperature, irradiation and series/shunt resistances on the open-circuit voltage and short-circuit current. Solar cell arrays, PV modules, PV generators, shadow effects and bypass diodes, hot spot problem in a PV module and safe operating area. Terrestrial PV module modeling

Unit-3 **08 Lectures**

Solar Power Plant: Components and Working

Types of Solar Power Plant: Off grid, Grid Connected, Hybrid, Interfacing PV modules to loads, direct connection of loads to PV modules, connection of PV modules to a battery and load together, DC-DC Converters, Inverters.

Unit-4 **08 Lectures**

Solar Power Management

Power conditioning and maximum power point tracking (MPPT) algorithms based on buck- and boost-converter topologies, Maximum power point tracking (MPPT) algorithms, Inverter topologies for stand-alone and grid-connected operation. Analysis of inverter at fundamental frequency and at switching frequency.

Unit-5 **08 Lectures**

Grid Codes and Standards

Grid Codes, Anti Islanding protection, LVRT protection, HVRT Protection, Active and Reactive Power Control, Advance Control for Inverters, Feasible operating region of inverter at different power factor values for grid-connected systems

References:

1. Photovoltaics: Designs, Systems and Applications, Michael Stock, Larsen and Keller Education
2. Photovoltaics: Engineering and Technology for Solar Power, Catherine Waltz, Syrawood Publishing House
3. Principles of Solar Engineering, D. Goswami, CRC Press
4. Solanki S. Chetan. Solar Photovoltaics: Fundamentals, Technologies and Applications, New Delhi, PHI, 2012.

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Paper Code	Paper Title	Credit	Total Lectures
EST-302	**Energy Efficient Lighting and Displays**	**04**	**40**

Course Objectives :

1. To study the basics of lighting and lighting system elements.
2. To study solid state lighting.
3. To study organic light emitting diodes.
4. To study the concept of fiber optic lighting.
5. To study display technology.

Unit-1 **08 Lectures**

Introduction to Lighting and Lighting System Elements

Need for Energy Management, Illumination requirements for various tasks Activities/Locations; Basic Terms in Lighting System and Features, Light Sources, Luminaries, Ballasts; Lamp Types and their Features, Methodology of Lighting System, Day lighting, lighting system controls, system maintenance, operating schedule, psychology of changeover. Lighting energy management in buildings: Case Studies Some Good Practices in Lighting, History of Lighting

Unit-2 **08 Lectures**

Solid State Lighting

Florescence, Phosphorescence, Electroluminescence
Inorganic Luminescent Materials and Devices (Light Emitting Diodes and Light Emitting Transistors)
Blue and Ultraviolet LEDs, White LEDs, RGB system
Phosphor Based LEDs

Unit-3
08 Lectures

Organic Light Emitting Diodes

Introduction to Organic Semiconductors, Classification of Organic Semiconductors, Florescence, Phosphorescence, Thermally Active Delayed Fluorescence and Hyper-fluorescence in Organic Materials, Different generations of Organic Light Emitting Diodes and their processing, Blue OLEDs and White OLEDs, Technical aspects of OLEDs.

Unit-4 **04 Lectures**

Fiber Optic Lighting

Types of Fibers, fabrication technology, Materials development for fiber optic, Transmission losses, Use of fiber in lighting

Unit-5 **12 Lectures**

Display Technology

History of Display Technology, LCD display technologies and devices, thin-film transistor (TFT) technology for LCD. Back lighting technologies for LCDs, Field-emissive, electro-chromic, and photo-chromic displays, Plasma Display, Electronic-ink, electronic paper (e-paper) and flexible display technologies and their applications, Laser based projection displays, digital micromirror devices (DMD) and pico-projectors, Three-dimensional (3-D) display technologies, Microdisplays, STEREOSCOPIC 3D displays, integral imaging, polarization based 3Ddisplays, HOLOGRAPHIC 3-D displays and laser based 3D-TV.

References:

1. Fundamentals of Solid-State Lighting: LEDs, OLEDs, and Their Applications in Illumination and Displays, Vinod Kumar Khanna, CRC Press
2. Materials for Solid-State Lighting and Displays, Adrian Kitai, John Wiley & Sons Ltd.
3. Handbook of Display Technology, Joseph A. Castellano, Gulf Professional Publishing
4. Handbook of Visual Display Technology, Janglin Chen, Wayne Cranton, Mark Fihn, Springer

Paper Code	Paper Title	Credit	Total Lectures
EST-302	**Energy Storage**	**04**	**40**

Course Objectives :

1. To study the basics of energy storage systems.
2. To study the concept and design of electrochemical batteries.
3. To study the concept and design of electrochemical batteries.
4. To study Hydrogen production and storage.
5. Other Emerging Energy Storage Techniques.

Unit-1 **08 Lectures**

Introduction

Importance and need of energy storage, modes of energy storage, Energy transmission methods, Electrical energy characteristic's and basic load calculations, Performance characteristics of energy storage systems, Types of load curves, energy shift, Ragone plot. Importance of energy density and power density, Transmission Congestion - Demand for Portable Energy, Demand and scale requirements, Environmental and sustainability issues. Introduction to different energy storage mechanisms.

Unit-2 **08 Lectures**

Rechargeable Batteries

Primary and secondary batteries, battery potential, charge figure of merit, energy and power in battery, polarization losses, thermodynamics of battery materials, tortuosity and porosity of battery materials, reversible and irreversible interfacial reactions, battery architecture and design guidelines, Lead–acid battery, Nickel–cadmium battery (NiCd), Nickel–metal hydride battery (NiMH), Lithium-ion battery, Lithium-ion polymer battery.

Energy density, power density, price and market.

Battery Management systems and System Performance

Unit-3 **10 Lectures**

Super Capacitors

Basic components of supercapacitors like types of electrodes like high surface area activated carbons, metal oxide and conducting polymers, aqueous and organic electrolytes. The disadvantages and advantages of supercapacitors over battery systems and their applications in aspects of energy density, power density, price and market.

Unit-4 **08 Lectures**

Hydrogen Storage

Background and working of Fuel Cell, Hydrogen production processes, Hydrogen storage: Physical and chemical properties, general storage methods, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, Carbon based materials for hydrogen storage.

Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles.

Unit-5 **06 Lectures**

Other Emerging Energy Storage Techniques

Superconducting Magnetic Energy Storage, Hybrid Energy Storage: Bacitor (Battery + Fuel Cell) and Flow Batteries (Battery + Capacitor + Fuel Cell)

Applications: Storage for Hybrid Electric Vehicles, Regenerative Power, capturing methods.

References:

1. Detlef Stolten,"Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", Wiley, 2010.
2. Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, "Electrochemical Technologies for Energy Storage and Conversion", John Wiley and Sons, 2012.
3. Francois Beguin and Elzbieta Frackowiak ,"Super capacitors", Wiley, 2013.
4. Doughty Liaw, Narayan and Srinivasan, "Batteries for Renewable Energy Storage", The Electrochemical Society, New Jersy,2010.

Paper Code	Paper Title	Credit	Total Lectures
EST-303	Energy Storage	04	40

Course Objectives :

1. To learn the basics of Entrepreneurship & Innovation.
2. To learn the concepts and practices for Entrepreneurial Development.
3. To study start-up ecosystem.
4. To learn start-up project planning and analysis.
5. To learn Start-Up Project Scalability processes.

Unit – 1 **08 Lectures**

Entrepreneurship & Innovation – Definition, Objective and Features

Key terminology: Entrepreneurship& innovation; Difference between Entrepreneurship and Traditional Businesses; Entrepreneurs and Intrapreneurs; Technological Entrepreneurship: Characteristics and needs of Innovation

Unit – 2 **08 Lectures**

Entrepreneurial Development

Business Planning; Mid-career Dilemmas; Entrepreneurial Growth and Competitive Advantage; Changing Role of Entrepreneurs. Entrepreneurship Development Institute; Entrepreneurship development Programs.

Unit – 3 **08 Lectures**

Start-Up Ecosystem

General presentation about startup development phases (from formation, to validation to scaling) specifically from the support role's perspective; Key terminology: idea & innovation, entrepreneurship & start-ups; Innovation megatrends; Why startups?; Startup as a category; Understanding & mapping startup ecosystems; Public-private partnerships; Developing startup ecosystems; Maturity levels and measures for startup ecosystems; Measuring and Collecting valuable data; Use of startup data

Unit – 4 **08 Lectures**

Start-Up Project Planning and Analysis

Focus on the formation phase, which is the most crucial phase for co-founding team building; Preparing for the journey: what things to focus on and why?; Value of ideas & how to innovate more systematically; Building BIG visions; Measuring potential;

Success & failure factors; Mission, Vision & Strategy; Co-founder team building; Idea / team fit; Shareholder agreement (SHA); Confirming team commitment; Problem / solution fit; Market timing and journey; Planning in short & long term; Evaluating opportunities; Funding options and strategies at this stage; Additional tools & resources for self learning

Unit – 5 **08 Lectures**

Start-Up Project Scalability Report

Focus on scaling phase, which is the most crucial phase for getting serious about building a real and scalable business; What things to focus on and why?; Business planning; Go to market strategies; Born global & internationalization; Scaling metrics (KPI's); Recruiting; Building processes; Funding options; Working with big companies; Methods & tools; Additional tools & resources for self learning

Suggested Readings:

1. Innovation and Entrepreneurship by Peter F. Drucker (Special Indian Edition). Routledge
2. Entrepreneurship (11th Edn) by R. Hisrich, M. Peters and D. Shepherd. McGraw Hill
3. Business Model Innovation – The Organizational Dimension by Nicolai J. Foss & Tina Saebi. Oxford University Press
4. Guide to Start-Ups by Taxmann.
5. Entrepreneurship Development by S.S. Khanka. S. Chand Publishers

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Semester-IV

S. NO.	PAPER	PAPER TITLE	CREDITS	PERIOD PER WEEK		DISTRIBUTION OF MARKS			
				L	P	MID SEMESTER EVALUATION		END SEMESTER EXAM	TOTAL
						CWS	MST		
FOURTH SEMESTER									
01	EST-400	Major Project	12	-	-	-	-	300	300
TOTAL CREDITS			**12**	**-**		**TOTAL MARKS**			**300**