Malaviya National Institute of Technology Jaipur

Centre for Energy and Environment

Minor specialisation in Sustainable Energy for BTech students of MNIT (all branches)

Program Structure

S.No.	Sem.	Course Title	Course Category	Credit	L	T	P
1.	V	Energy Economics and Policy	Core	3	3	0	0
2.		Elective - I	Elective	3	3	0	0
3.	VI	Energy Storage Technologies	Core	3	3	0	0
4.		Sustainable Energy Laboratory	Core	3	0	0	6
5.	VII	Elective - II	Elective	3	3	0	0
6.	VIII	Mini project	Core	3	--		
Total Credit Requirements				18			

List of Courses

S.No.	Course Code	Course Name	Core/Elective
1.		Energy Economics and Policy	Core
2.		Energy Storage Technologies	Core
3.		Sustainable Energy Laboratory	Core
4.		Energy management and audit	Elective
5.		Solar Energy Engineering	Elective
6.		Sustainable Buildings	Elective
7.		Energy and Data Science	Elective
8.		Hydrogen Energy	Elective
9.		Circular Economy	Elective
10.		Grid Integration of Renewable Energy	Elective
11.		Mini project	Mandatory

1. Sustainable Energy Laboratory				
Prerequisite: Nil	L	T	P	C
	0	0	6	3
List of Experiments				
• Solar cooker • Solar Thermal Training Kit • Thermal energy storage • Heat recovery wheel. • PV system characterization and performance analysis • Hybrid Smart Grid Solution • Solar PV Grid tied Training System • Wind energy training system. • Biogas production • Battery testing				

2. Energy Economics and Policy				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes
CO1: To comprehend regulations and policies in the energy and environment sector.
CO2: To learn the nexus between economic growth, energy, and climate policies
CO3: To analyse the impact and limitations of various policy measures.

Course Content	
Unit 1	International scenario: world energy outlook, governing and nodal national/international agencies and their role. Demand supply position, All India Energy Scenario, Energy Security - Concept, Trade-Off between Energy Security and Climate Change Introduction to Energy codes and policies: Energy Conservation act, Electricity Act and amendments.
Unit 2	Energy Economics - Time Value of Money Concept, Simple Payback Period, IRR, NPV, Life Cycle Costing, LCA, LCOE, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation, Energy Chain
Unit 3	Global Warming, International Environmental Policy Practices, Emissions Trading System (ETS), UNFCCC, Kyoto protocol, clean development mechanism (CDM), Joint implementation, Emission targets, COPs, NAPCC, INDC and latest national/international government policies. Waste Management Practices and policies.
Unit 4	Renewable Energy Policy: Incentives and subsidies, Foreign Investment, Role of MNRE, IREDA, Bio Energy Policy, Solar Policy, Hydro Policy, Wind policy, National Solar Mission, Renewable purchase obligations, Feed in Tariffs, Renewable Energy Certificates, Hydro Power Policy, Small/Large Scale National policy on Hydropower in India, India EV Policy, Other schemes – Saubhagya, UJALA, UDAY, RFMS, Smart Cities, etc.
References	1. SC Bhattacharyya. Energy Economics, Concepts, Issues, Markets and Governance, Springer Science & Business Media, (2011) ISBN 978-0-85729268-1. 2. RS Axelrod & SD VanDeveer (Eds.). The Global Environment: Institutions, Law, and Policy. CQ Press; Fifth edition (2019). ISBN 1544330146 3. TF Braun & MG Lisa. Understanding Energy and Energy Policy. Zed Books, (2014) ISBN 1780329342 4. Kandpal, Tara Chandra, and Hari Prakash Garg. Financial evaluation of renewable energy technologies. MacMillan India Limited, 2003. 5. Nersesian, Roy L. Energy economics: markets, history, and policy. Routledge, 2016, ISBN-13: 978-1138858374, ISBN-10: 1138858374. 6. P. Zweifel, A. Praktiknjo, and G. Erdmann. Energy economics: theory and applications. Springer, 2017, ISBN 978-3-662-53022-1.

3. Energy Storage Technologies				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3
Course Outcomes **CO1:** Gain understanding of basics and parameters of energy storage methods. **CO2:** Understand utilization, sizing and operation of energy storage systems. **CO3:** Analyse the integration of energy storage systems.				
Course Content				
Unit 1	Introduction: basics of energy storage, their requirements, current status of the technology, comparison of different energy storage methods, cost performance and maturity of storage technology, tools for evaluation of energy storage methods.			
Unit 2	Electrochemical energy storage: Ragone plot, basics of electrochemical cell, battery states, estimation of battery states, performance of batteries, cell reaction, failure modes, safety of battery, introduction of battery management system, standards and system sizing.			
Unit 3	Thermal energy storage: basics of Sensible, Latent and Thermochemical energy storage method, selection suitable materials for the thermal energy storage, parameters and components of thermal energy storage system, configuration and sizing of storage system.			
Unit 4	Mechanical energy storage systems: basics of flywheel energy storage (FES), pumped hydropower storage (PHS), and compressed-air energy storage (CAES). Comparison and application state-of-art including principle, function and deployments.			
References	1. US DOE Energy storage handbook (https://www.sandia.gov/ess-ssl/lab_pubs/doeepri-electricity-storage-handbook/) 2. Large Energy Storage Systems Handbook Edited by Edited by Frank S. Barnes Jonah G. Levine. Publisher CRC Press Taylor & Francis Group ISBN 978-1-4200-8601-0 3. Energy Storage: Fundamentals, Materials and Applications by Robert Huggins, 9783319212388, Edition 2nd ed. 2016 Publisher Springer Nature 4. Energy Storage Architecture (Elements in Grid Energy Storage) ISBN-10 : 1009013939, ISBN-13 : 978-1009013932, Publisher : Cambridge University Press 2022			

4. Energy Management and Audit				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes

CO1: To gain a comprehensive understanding of different energy systems and energy conversion processes

CO2: To understand the broader environmental and social implications of energy consumption and the importance of integrating sustainability principles into energy management practices.

CO3: To create ability to plan, implement, and monitor energy management projects effectively

Course Content	
Unit 1	General Aspects of Energy Management & Energy Audit: Basics of Energy and its various forms; Overview of Energy Conservation and related policies; Material and Energy Balance; Energy Action Planning; Energy Monitoring and Targeting. Financial Management; Carbon Footprint Calculation
Unit 2	Energy Efficiency in Thermal Utilities: Fuel and Combustion; Boiler; Steam system; Furnaces; Insulation and Refractories; Cogeneration; Waste Heat Recovery; Heat Exchangers; HVAC and refrigeration system; Compressed Air System
Unit 3	Energy Efficiency in Electrical Utilities: Electrical Systems; Electrical Motors and variable speed drives; Pump and pumping systems, Fan and Blowers, Lighting systems; Power generating system; Energy Conservation in buildings
Unit 4	Energy Performance Assistance: Steel industry; Cement Industry; Textile industry; Pulp and paper Industry; Fertilizer Industry; Buildings and commercial establishments Energy Audit: need, types, understanding the energy cost, audit instruments, details methodology, different phases, detailed audit report format,
References	1. Guide to Energy management, by Barney L. Capehart, Wayne C.Turner, and William J.Kennedy, The fairmont press, INC. Fourth edition 2. http://www.nptelvideos.in/2012/11/energy-resources-and-technology.html 3. Bhattacharyya, Subhes C. Energy economics: concepts, issues, markets and governance. Springer Science & Business Media, 2011, ISBN 978-0-85729-268-1. 4. Energy Demand – Analysis, Management and Conservation,Ashok V. Desai, Wiley Eastern Ltd., New Delhi.,1990, ISBN 9788122402025. 5. Handbook of Energy Audits by Albert Thumann.CRC press 9th ed. 6. BEE guide books for energy auditor and energy manager exam https://beeindia.gov.in/content/energy-auditors

5. Solar Energy Engineering				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes

CO1: To understand the principles and concepts underlying energy generation from photovoltaic systems and solar thermal technologies.

CO2: To design solar energy systems for power generation and storage.

CO3: To apply innovative solutions to challenges in solar energy implementation and integration.

Course Content	
Unit 1	Solar Radiation: Basics of Solar Radiation, instruments for measuring solar radiation, solar radiation geometry, empirical equations, solar radiation on tilted surfaces.
Unit 2	Fundamentals of solar PV cells and systems: P-N junction, I-V and QE curves of solar cells, recent advances in solar cell technologies, PERC, TOPCon solar cell, BOS for power plant: mounting and installation, battery storage, power condition unit, selection of cables and balance of systems, maintenance and schedule, sources of losses and prevention. Performance Analysis and Financial Analysis.
Unit 3	Solar PV power plant: Estimating power and energy demand, site selection, land requirements, choice of modules, economic comparison, the balance of systems, off-grid systems, grid interface, and Concentrator solar cells.
Unit 4	Liquid Flat plate Collector: Basic elements, performance analysis, transmissivity - absorptivity, heat transfer coefficients and correlations, collector efficiency, and heat removal factors, effect of various parameters, types of other liquid flat-plate collectors, introduction to transient analysis, Evacuated tube collectors Concentrating Collectors: Type of concentrating collectors and their general characteristics, geometry, heat transfer correlations, tracking requirements, performance analysis, effect of various parameters Solar thermal power systems, Energy storage in solar process systems
References	1. S. P. Sukhatme and J. K Nayak, Solar Energy, 4th Edition, McGraw-Hill Education Pvt., 2018, ISBN 978-93-5260-711-2. 2. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, 4th Edition, Wiley, 2013, ISBN 978-0-470-87366-3 3. D. Y. Goswami, Principles of Solar Engineering, 3rd Edition, CRC Press, 2015, ISBN 978-1-4665-6379-7. 4. R.K. Satpathy, Rabindra Kumar., V. Pamuru, Solar PV Power: Design, Manufacturing and Applications from Sand to Systems. Netherlands: Elsevier Science, 2020, ISBN 9780128176276 5. 5. P. Verlinden, v. S. Wilfried. Photovoltaic Solar Energy: From Fundamentals to Applications. United Kingdom: Wiley, 2017, ISBN 9781118927465

6. Sustainable Buildings				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes

CO1: To develop knowledge of contemporary issues pertaining to energy efficiency in buildings

CO2: To apply the knowledge of engineering in design of energy-efficient buildings

CO3: To apply standards, codes and ratings in the design of energy-efficient buildings

Course Content	
Unit 1	Energy Efficiency, Overview of energy efficiency (EE) in buildings and its benefits, Approach to EE in Buildings, Basics of energy systems in buildings interface of systems and envelope, overview on energy-consuming end uses, energy consumption patterns of different end-use for varying building typologies, energy consumption benchmarks in buildings. Concept of passive building design.
Unit 2	HVAC basics, types of HVAC systems, psychrometric analysis, Thermal comfort basics, Heating and cooling load of buildings: elements of heating and cooling load, load reduction approaches, comfort zone. Indoor Environment quality.
Unit 3	Building energy efficiency, Standards, codes and rating of buildings (international and national perspective) related to energy efficiency in commercial buildings. Calculation and documentation for compliance and rating. Envelope, HVAC, lighting, controls for code compliance.
References	1. Kubba, S, LEED Practices, Certification, and Accreditation Hand book, 1st ed. Elsevier, 2010. 2. Minsitry of Power, Energy Conservation Building Code 2018, Revised Version, Bureau of Energy Efficiency, 2018, 3. Architectural Energy Corporation, Building Envelope Stringency Analysis, International Institute for Energy Conservation, 2004 4. Indian Building Congress, Practical Handbook on Energy Conservation in Buildings, 1 st ed. Nabhi Publication, 2008. 5. McQuiston, F.C., and Parker, J.D. Heating, Ventilating, and Air Conditioning, Analysis and Design, Fourth Ed. John Wiley & Sons, Inc,1994. 6. Clarke, J.A., Energy Simulation in Building Design, Adam Hilger Ltd. 1985. 7. TERI-Griha's Green Design practices (www.teriin.org/bcsd/griha/griha.html)

7. Energy and Data Sciences				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes

CO1: Know and apply the basic concepts of data science.

CO2: Apply techniques of data processing, data interpretation and data visualisation for sustainable energy related problems.

CO3: Apply AI algorithms to address various challenges of the renewable energy (RE) sector.

Course Content	
Unit 1	Introduction: Probability basics, Descriptive statistics, Sampling and sampling distributions, Point estimation and interval estimation, Confidence intervals, Hypothesis testing, Confidence intervals, p-values and significance levels, Type I and Type II errors. t-tests (independent samples, paired samples), Analysis of variance (ANOVA), Chi-squared tests, Wilcoxon signed-rank test, Mann-Whitney U test, Kruskal-Wallis test, Kolmogorov-Smirnov test. Challenges in the renewable energy (RE) sector and Co-benefits of data science.
Unit 2	Basics of data preprocessing, Data cleaning, integration, selection, data transformation, outlier detection methods, data analysis, Bias-Variance Trade-Off, Overfitting and Underfitting, data visualization.
Unit 3	Basics of artificial intelligence, machine learning (ML) and deep learning (DL), Categories of machine learning: supervised, unsupervised and reinforced learning, Supervised learning, Unsupervised learning, Reinforcement learning, Parametric and Nonparametric Algorithms
Unit 4	Application of data science and AI: Renewable energy (RE) forecasting, predictive maintenance of RE system, application of regression and classification algorithms in RE system.
References	1. An Introduction to Artificial Intelligence in Education, By Shengquan Yu, Yu Lu 2. Introduction to Data Mining, Tan, Steinbach and Vipin Kumar, Pearson Education, 2016 3. Data Mining: Concepts and Techniques by Jiawei Han (Author), Micheline Kamber (Author), Jian Pei Professor (Author) ISBN-10 9780123814791, Morgan Kaufmann 2011

8. Hydrogen Energy				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes

CO1: To understand different hydrogen production pathways for sustainable development.

CO2: To get knowledge about fundamentals of hydrogen transportation, distribution and storage methods.

CO3: To perform Hazard and Operability Analysis (HAZOP) and evaluate hydrogen safety for mobile and stationary applications.

Course Content	
Unit 1	Basics of hydrogen energy, current and future hydrogen demand, various applications of hydrogen in industry, market challenges. Hydrogen production from renewable and non-renewable sources, Electrolysis of water: types of electrolysers, hydrogen related policy and regulation.
Unit 2	Hydrogen transportation, distribution and storage: Strategic Considerations, Distribution and Bulk Storage of Gaseous, Dewars for transport applications Gas Cylinders, Pipelines, Large-scale Storage, Metal Hydrides, Chemical and Related Storage, Simple Hydrogen-bearing Chemicals, Complex Chemical Hydrides, Nano- structured Materials, Hydrogen Storage in Road Vehicles, Industrial scale pressurised hydrogen storage.
Unit 3	Hydrogen as a fuel in heat engines: Stationary and powering vehicles in road transport and aviation industry, Hydrogen energy, Hydrogen as a fuel, Liquid and Gaseous Fuels. Physico-chemical characteristics.
Unit 4	Hydrogen safety: Hydrogen gas and Liquified hydrogen, properties and associated hazards - Safety regulations - Codes and Standards - Physiological, physical and chemical hazards of hydrogen, Safety of hydrogen storage facilities - Effects of Hydrogen on Materials of Construction - Hydrogen Embrittlement, blistering. Hazard and Operability Analysis (HAZOP), Case study.
References	1. Angelo Basile, Adolfo Iulianelli (Editors), Advances in hydrogen production, storage and distribution, ISBN 978-0-85709-768-2, 2014 Elsevier Ltd. 2. Broom, Darren P, Hydrogen Storage Materials: The Characterisation of Their Storage Properties, 2011, ISBN 978-0-85729-221-6, Springer 3. Arno A. Evers, 2010. The Hydrogen Society. Hydrogeit Verlag. ISBN 978-3- 937863-31-3. 4. Vladimir Molkov, Fundamentals of hydrogen safety engineering - I, Bookboon.com, ISBN 978-87-403-0226-4 5. Vladimir Molkov, Fundamentals of hydrogen safety engineering - II, Bookboon.com, ISBN 978-87-403-0279-0 Fotis Rigas and Paul Amyotte, Hydrogen Safety, CRC Press, ISBN 978-1-4398- 6231-5

9. Circular Economy				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes

CO1: To understand the concept of a circular economy based on its socio-technical, managerial and environmental characteristics

CO2: To Apply the principles of circularity and their application to sustainable development

CO3: To Apply complexity aspects of circular economy for sustainable development

Course Content	
Unit 1	Introduction to circular economy; Purpose of circular economy, Circular sustainability, Challenges for circular economy, Concept of sustainable development, Sustainable processes technologies and Critical assessment on current sustainable technologies. Circular economy towards zero waste: circular economy and waste sector, waste management in the context of circular economy
Unit 2	Circular Economy in Manufacturing: Sustainable Materials Selection and Sourcing, Closed-loop Manufacturing Processes, Remanufacturing and Refurbishment Techniques, Waste Minimization Strategies in Manufacturing, Lean and Green Manufacturing Practices, Blockchain and IoT Applications in Circular Supply Chain
Unit 3	Circular bioeconomy, Circular Business Models. Circular business models to create economic and social value. Extended Producer Responsibility (EPR) Programs, Pay-per-Use and Subscription-based Models, Circular Economy Revenue Streams and Financial Models
Unit 4	Circular economy policy framework, universal circular economy policy goals, role of governments and networks and how policies and sharing best practices can enable the circular economy, Challenges and Opportunities in Scaling Circular Economy Solutions, Ethical and Social Implications of Circular Economy Implementation
References	1. The Circular Economy A User's Guide by Walter R Stahel. CRC Press 2019. 2. The Circular Economy Handbook: Realizing The Circular Advantage by Peter Lacy, Jessica Long, Wesley Spindler. 2020. 3. Waste to Wealth: The Circular Economy Advantage Peter Lacy, Jakob Rutqvist, 2015. 4. Towards Zero Waste: Circular Economy Boost, Waste to Resources María-Laura 5. Franco-García, Jorge Carlos Carpio-Aguilar, Hans Bressers. Springer International Publishing 2019 6. Strategic Management and the Circular Economy Marcello Tonelli, Nicolo Cristoni, Routledge 2018.

10. Grid Integration of Renewable Energy				
Prerequisite: Nil	L	T	P	C
Total hours: 40	3	0	0	3

Course Outcomes

CO1: To identify grid integration challenges for renewable energy

CO2: To comprehend the concept of power quality and issues related to Large renewable energy integration to the grid.

CO3: To have an insight of grid integration devices, and protection

Course Content	
Unit 1	Grid integration of renewables at different grid levels, microgrids. Need of integrating large renewable energy sources, issues related to the integration of large renewable energy sources, RE intermittency, rooftop plants. Concept of VPP.
Unit 2	Types of generators: synchronous, induction. their synchronization/integration to the grid, operating stability, Power Electronics devices, their role in grid integration, converter, inverter, chopper, ac regulator and cyclo-converters for AC/DC conversion. Power quality issues: THD, voltage sag/swell, frequency variation and its effects, system protection
Unit 3	Power system scheduling and dispatch, system balancing, optimal power flow, reactive power and voltage control, frequency control, operating reserve, energy storage systems, electric vehicles, islanding and interconnection
Unit 4	Overview of Indian power sector, Indian power sector stakeholders and their roles, Indian grid operation hierarchy, Grid Code, Ancillary services and market provisions, Electricity markets
References	1. Integration of Alternative Sources of Energy, Felix A. Farret and M. Godoy Simoes, IEEE Press – Wiley-Interscience publication, 2006. 2. Grid integration of solar photovoltaic systems, Majid Jamil, M. Rizwan, D.P. Kothari, CRC Press (Taylor & Francis Group), 2017. 3. Renewable Energy Grid Integration, Marco H. Balderas, Nova Science Publishers, New York, 2009. 4. Wind Power Integration connection and system operational aspects, B. Fox, D. Flynn L. Bryans, N. Jenkins, M. O' Malley, R. Watson and D. Milborrow, IET Power and Energy Series 50 (IET digital library), 2007 5. Power Generation, Operation, and Control, Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheblé, John Wiley & Sons, New York, 2013 (3rd edition) 6. Power Electronics: Circuits, Devices, and Applications. M.H.Rashid, Pearson Education India, 2013

➢ **Intended Learning Outcomes of Minor specialisation in Sustainable Energy for B.Tech students of MNIT:**

1. **Diversification of Skills:** A minor in sustainable energy introduces B. Tech students to interdisciplinary concepts beyond their core engineering discipline, enhancing their skill set and making them more versatile professionals.
2. **Addressing Global Challenges:** Sustainable energy is critical for mitigating climate change and reducing reliance on finite fossil fuel resources. By gaining knowledge in different energy technologies, students can contribute to addressing pressing global challenges related to sustainability and energy security.
3. **Interdisciplinary Learning:** The minor exposes students to various engineering and science disciplines fostering a holistic understanding of renewable and sustainable energy systems and their socio-economic implications.
4. **Career Opportunities:** The energy sector offers diverse career opportunities in areas such as solar energy, bioenergy, energy policy, energy storage etc. A minor in sustainable energy enhances students' employability and opens doors to a wide range of job prospects in both the public and private sectors.
5. **Innovation and Entrepreneurship:** Students with a minor in sustainable energy are equipped to innovate and develop sustainable solutions to energy challenges. They can also explore entrepreneurship opportunities in the growing renewable energy market, driving innovation and contributing to the transition towards a clean energy future.
6. **Hands-on Experience:** Many sustainable energy programs incorporate practical, hands-on learning experiences such as laboratory experiments, field trips, and project-based learning, allowing students to apply theoretical knowledge in real-world contexts and develop valuable technical skills.
7. **Contribution to Sustainable Development:** Through their knowledge and skills in renewable energy, students can actively contribute to sustainable development goals by promoting the adoption of clean energy technologies, reducing greenhouse gas emissions, and fostering energy access and equity.
8. **Personal and Professional Growth:** Studying sustainable energy as a minor exposes student to emerging technologies, current research trends, and evolving policy landscapes, fostering intellectual curiosity and encouraging lifelong learning and growth in their chosen field.