



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering

Level: UG

Branch: Chemical Engineering

Subject Code: BE05000121

Subject Name: Energy Technology

w.e.f. Academic Year:	2024-25
Semester:	5
Category of the Course:	Professional Elective Courses - 2

Prerequisite:	Basic knowledge of Thermodynamics, Heat Transfer, and Environmental Studies.
Rationale:	This course aims to introduce students to modern energy technologies and sustainable energy systems in the context of global and Indian energy challenges. The course provides a system-level understanding of renewable energy, bioenergy, hydrogen, energy storage, and climate mitigation technologies aligned with Sustainable Development Goals. It also introduces the role of digitalization and artificial intelligence in energy systems for optimization, forecasting, and decision-making. Students will gain insight into energy transition pathways, net-zero concepts, and sustainability assessment of energy systems relevant to industrial and societal applications.

Course Outcome:

After Completion of the Course, Students will be able to:

No	Course Outcomes
CO-1	To Understand energy systems, resources, sustainability challenges, and Indian energy policy framework.
CO-2	To Analyze and evaluate renewable energy technologies and their integration challenges.
CO-3	To apply bioenergy and waste-to-energy concepts for design and evaluation of circular economy-based energy systems.
CO-4	To evaluate hydrogen, energy storage, and digital technologies for sustainable energy transition and decarbonization.

Teaching and Examination Scheme:

Teaching/Learning Scheme in hrs/semester					Total Credits	Assessment Pattern and Marks					Total Marks
L	T	P	PBL*	TH	TH/30	Theory		Practical			
						ESE (E)	PA (M)	PA (I)	PBL(I)	ESE (V)	
45	15	0	30	90	3	70	30	20	30	00	150

Where L = Lecture, T= Tutorial, P= Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, ESE = End-Semester Examination, PA = Progressive Assessment

Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.



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Course Content:

Sr. No.	Content	Total Hrs	% weightage
1	Energy Systems and Sustainable Development Framework: Introduction to Sustainable Development Goals related to energy systems. Overview of global and Indian energy consumption and future trends. Primary and secondary energy resources include conventional and renewable sources. Energy–environment interactions and energy needs of a developing economy. Energy security, import dependency, and long-term energy transition pathways. Energy policy framework in India including National Energy Policy, National Electricity Plan, and National Hydrogen Mission.	7	15
2	Renewable Energy Technologies for India: Solar photovoltaic and solar thermal energy systems. Onshore and offshore wind energy technologies and applications. Small and large hydropower systems. Biomass, biogas, compressed biogas, and biofuels. Hybrid renewable energy systems and integration challenges. Role of renewables in India's non-fossil energy capacity expansion. Solar PV manufacturing ecosystem and PLI scheme overview.	12	27
3	Bioenergy and Waste-to-Energy Systems: Bioenergy potential and resources in India. Utilization of agricultural residues and municipal solid waste. Anaerobic digestion and biogas production principles. Biogas upgrading and Bio-CNG production routes. Thermal conversion technologies including gasification and pyrolysis. Role of bioenergy in circular economy. Case studies of Indian waste to energy and bio CNG plants.	8	18
4	Hydrogen and Energy Storage Technologies: Green hydrogen production through electrolysis. Hydrogen safety, storage, transportation and industrial applications. Green ammonia, green methanol, and synthetic fuels. Battery energy storage systems. Pumped hydro, thermal, and hybrid energy storage technologies. Role of hydrogen in hard to abate sectors such as steel, cement, and refineries.	9	20
5	Global Energy Transition and Advanced Energy Systems: Net-zero energy systems and global transition timelines. Energy transition pathways and future scenarios. Electrification of transport and industrial sectors. Advanced and long-duration energy storage concepts. Critical energy materials, supply chains, and geopolitics. Digitalization and AI applications in energy systems. Smart grids and demand side management using AI.	9	20

Overall Course SDG Mapping:



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The course as a whole primarily addresses **SDG 7: Affordable and Clean Energy**, **SDG 9: Industry, Innovation and Infrastructure**, **SDG 11: Sustainable Cities and Communities**, **SDG 12: Responsible Consumption and Production**, and **SDG 13: Climate Action** through comprehensive coverage of clean energy technologies and climate mitigation strategies.

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	20	25	15	15	10

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Problem based learning can include the following:

Sr. No.	Description	No. Of hours	Total Hrs.
1	Energy Data Analysis: Analyze MNRE, CEA, or IEA datasets to identify energy trends and insights	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
2	Renewable Energy System Sizing: Design basic renewable systems using standard assumptions	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
3	Solar, Wind, Hydrogen Case Studies: Solve numerical case studies based on given data	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
4	Waste to Energy Calculations: Estimate energy recovery from biomass or MSW data	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
5	Carbon Footprint Estimation: Estimate emissions for given activities or systems	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5



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6	Energy Storage Sizing: Determine battery or storage capacity for a given load profile	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
7	Literature Based Case Study: Review research papers or technical reports on energy technologies	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
8	Simulation Using Open Source Tools: Perform simple simulations using tools like Python, PVLIB, or OpenModelica	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
9	Policy and Sustainability Evaluation: Evaluate energy policies and SDG impacts	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
10	Household or Campus Energy Assessment: Perform small energy audit or consumption analysis	Data collection and understanding – 2h Analysis and interpretation – 2 h Summary preparation – 1 h	5
Max. Hours to be allotted			30

Content:

Reference Books:

1. Singh, S. P. and Sharma, M. AI and Data Analytics for Smart Energy Systems. CRC Press India, New Delhi, 2024.
2. Dey, N., Ashour, A. S., and Balas, V. E. Smart Energy Systems: AI and Machine Learning in Renewable Energy Systems. Wiley India Publications, New Delhi, 2023.
3. Deshmukh, M. S. and Jadhav, S. R. Industrial Energy Efficiency and Digital Tools. 1st Edition. Notion Press Academic, Chennai, 2023.
4. Kreith, F. and Goswami, D. Y. Energy Management and Conservation Handbook. 2nd Edition Indian Reprint. CRC Press India, New Delhi, 2022.
5. Gupta, R. B. Hydrogen Fuel Production, Transport, and Storage. 2nd Edition Indian Reprint. CRC Press India, New Delhi, 2022.
6. Konno, T., and Shibata, E. Critical Materials for Clean Energy Technologies. Springer India Publications, New Delhi, 2022.
7. Rao, C. N. R., and Gopalakrishnan, J. Materials for Sustainable Energy Applications. Elsevier India Academic Press Edition, New Delhi, 2022.
8. Masters, G. M. Renewable and Efficient Electric Power Systems. 3rd Edition Indian Adaptation. Wiley India Publications, New Delhi, 2021.
9. Kothari, D. P., Singal, K. C., and Ranjan, R. Renewable Energy Sources and Emerging Technologies. 3rd Edition. PHI Learning Pvt. Ltd., New Delhi, 2021.
10. Kaltschmitt, M., Streicher, W., and Wiese, A. Renewable Energy Technology, Economics and Environment. 2nd Edition Indian Reprint. Springer India Publications, New Delhi, 2021.
11. Rai, G. D. Non-Conventional Energy Sources. 5th Edition. Khanna Publishers, New Delhi, 2020.



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12. Boyle, G. Renewable Energy Power for a Sustainable Future. 4th Edition Indian Reprint. Oxford University Press India, New Delhi, 2020.
13. Bejan, A., Tsatsaronis, G., and Moran, M. Thermal Design and Optimization. Indian Edition. Wiley India Publications, New Delhi, 2020.
14. Sukhatme, S. P., and Nayak, J. K. Solar Energy: Principles of Thermal Collection and Storage. 4th Edition Indian Reprint. Tata McGraw Hill Education Pvt. Ltd., New Delhi, 2017.
15. Khan, B. H. Non-Conventional Energy Resources. 3rd Edition. Tata McGraw Hill Education Pvt. Ltd., New Delhi, 2019.

List of Tutorials:

Unit 1 – Energy Systems and Sustainable Development			
Sr. No.	Tutorial Topic	Numerical Questions	Descriptive Questions
1	Indian Energy Scenario	From the given electricity demand data of last 10 years, calculate the average annual growth rate of electricity demand in India.	Explain present Indian energy mix and future challenges.
		Forecast electricity demand for the next 5 years using compound annual growth rate method.	Discuss importance of Sustainable Development Goals in energy planning.
Unit 2 – Renewable Energy Technologies			
2	Solar PV System Design	Design a solar PV system for a load of 5 kW operating 6 hours per day. Determining the Necessary Panel Capacity	Explain components of a solar PV system
		Calculate required battery size for 2-day autonomy.	Compare grid connected and standalone PV systems.
	Wind Energy Calculations	Calculate annual energy generation of a 2 MW wind turbine with 30 percent capacity factor.	Explain factors affecting wind energy generation.
		Determine power output of a wind turbine at wind speed of 10 m per second using given turbine data.	Describe onshore and offshore wind technology.
	Hybrid Renewable Systems	For a hybrid system of 3 kW solar and 2 kW wind, calculate daily energy output.	Explain advantages of hybrid renewable systems.



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		Estimate battery storage required for the hybrid system.	Discuss integration challenges of hybrid systems.
Unit 3 – Bioenergy and Waste to Energy			
3	Biogas Plant Design	Calculate biogas production from 600 kg cattle manure with 18 percent volatile solids	Explain anaerobic digestion process
		Estimate digester volume required for 30 days retention time	Describe components of a biogas plant.
	Bio CNG Upgrading	If raw biogas contains 60 percent methane and upgraded gas contains 96 percent methane, calculate upgrading efficiency.	Explain different biogas upgrading technologies
		Determine methane recovery rate for 120 m³ per hour raw biogas flow	Compare PSA and water scrubbing methods.
	Gasification Process	Calculate cold gas efficiency if input energy is 600 kW and Syngas energy is 380 kW	Explain gasification process with diagram
		Estimate calorific value of producer gas from given composition.	Discuss applications of gasification.
Unit 4 – Hydrogen and Energy Storage			
4	Green Hydrogen Production	Calculate electrical energy required to produce 1 kg hydrogen at 65 percent electrolyzer efficiency.	Explain methods of hydrogen production.
		Determine hydrogen production rate for a 1 MW electrolyzer plant.	Discuss safety issues in hydrogen storage.
	Battery Energy Storage	Size a battery system to supply 15 kWh for 3 hours at 80 percent depth of discharge.	Compare different battery technologies
		Calculate number of battery modules required for a 100 kWh storage system.	Explain role of storage in renewable integration.
	Pumped Hydro Storage	Calculate energy stored in a pumped hydro plant with head 120 m and water volume 40,000 m³.	Explain working of pumped hydro storage.
		Estimate power output for 5 hours discharge.	Discuss advantages and limitations.
Unit 5 – Digitalization and AI in Energy			
5	AI Based Forecasting	Calculate mean absolute error from given actual and predicted load data.	Explain role of AI in smart grids.



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		Determine percentage error in demand forecasting.	Discuss applications of machine learning in energy systems.
	Electrification of Transport	Calculate annual electricity demand if 50,000 cars are converted to EV with average use 12,000 km per year.	Explain impact of EVs on energy demand.
		Estimate CO ₂ reduction from EV adoption.	Discuss charging infrastructure requirements.
	Critical Materials	Estimate lithium requirement for 50 MWh battery storage.	Explain importance of critical materials in clean energy.
		Calculate material intensity for solar PV installation.	Discuss supply chain challenges.

List of Open Source Software/learning website:

Open source software tools

1. Python with Anaconda distribution
2. Jupyter Notebook
3. NumPy, Pandas, Matplotlib for data analysis and plotting
4. scikit learn for machine learning and AI modelling
5. TensorFlow or PyTorch for advanced AI applications
6. OpenModelica for energy system modelling and simulation
7. EnergyPlus for building energy and efficiency analysis
8. PVLIB Python for solar PV modelling
9. PyPSA for power system and renewable integration studies
10. pandapower for distribution and grid studies
11. OpenLCA community edition for life cycle assessment
12. Brightway2 for LCA modelling in Python
13. QGIS for energy resource mapping and spatial analysis

Learning websites and open course platforms

1. NPTEL
2. SWAYAM
3. IITBombayX
4. Spoken Tutorial IIT Bombay
5. MIT OpenCourseWare
6. OpenLearn by The Open University

Open data and technical learning resources for energy

1. Ministry of New and Renewable Energy (MNRE) portal
2. Central Electricity Authority (CEA) reports and data



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3. National Institute of Wind Energy (NIWE) resources
4. NITI Aayog energy and hydrogen reports
5. Global Solar Atlas
6. Global Wind Atlas
7. NASA POWER for solar and meteorological datasets
8. IPCC Assessment Reports for climate mitigation and pathways
9. International Energy Agency (IEA) data and reports
10. The following activities are recommended to enhance understanding, practical exposure, and analytical skills related to Energy Technology.

Suggested Activities for Students:

1. Industrial Visit

Students shall visit a solar power plant, wind farm, biogas plant, or waste-to-energy facility and prepare a technical visit report including process description, equipment details, and observations.

2. Mini Project

Each group shall prepare a small project such as solar dryer, solar water heater model, biogas digester model, or battery management system prototype.

3. Case Study Analysis

Students shall analyze real life energy projects such as rooftop solar installation, electric vehicle charging station, or hybrid renewable system and present findings.

4. Data Analysis Exercise

Students shall collect and analyze real energy data from MNRE, CEA, or IEA sources and prepare graphical interpretation using Excel or Python tools.

5. Seminar Presentation

Each student shall prepare and present a seminar on emerging topics such as green hydrogen, smart grids, carbon capture, or energy storage technologies.

6. Poster Preparation

Students shall prepare technical posters on renewable energy systems, energy transition pathways, or climate mitigation technologies and display them in departmental events.

7. Field Survey

Students shall conduct a small survey on household energy consumption, EV awareness, or renewable energy adoption and prepare an analytical report.

8. Software Learning Activity

Students shall learn basic tools such as OpenModelica, PVLIB, or OpenLCA and perform simple simulation or analysis related to energy systems.

9. Group Discussion

Group discussion sessions shall be organized on topics such as net-zero targets, carbon markets, critical materials, and sustainable energy policies.

10. Technical Report Writing

Students shall prepare a structured technical report on any selected topic from syllabus including diagrams, data tables, and references.



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11. Quiz and Debate

Subject related quizzes and debates shall be organized on topics like renewable versus fossil fuels, nuclear energy, or hydrogen economy.

12. Industry Expert Interaction

Students shall attend guest lecturers or webinars by industry experts and submit learning summary reports.

13. Energy Audit Activity

Students shall perform basic energy audit of a classroom, laboratory, or home and suggest energy saving measures.

14. Carbon Footprint Calculation

Students shall estimate carbon footprint of daily activities or institutional electricity use and propose reduction strategies.

15. Internship and Project Work

Students are encouraged to undertake internships or small research projects in energy companies, startups, or research institutes.
