# GUJARAT TECHNOLOGICAL UNIVERSITY

**Program Name: Diploma Engineering**

**Level: Diploma**

**Branch: Renewable Energy**

**Subject Code: DI04064021**

**Subject Name: Bio Fuels and Bio Mass**

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|---|---|
| **w. e. f. Academic Year:** | 2025-26 |
| **Semester:** | 4th |
| **Category of the Course:** | Professional Elective - I |

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|---|---|
| **Prerequisite:** | Fundamental knowledge of Electrical Engineering and Renewable energy sources. |
| **Rationale:** | The global energy landscape is undergoing a profound transformation, shifting from conventional fossil fuels toward sustainable and renewable sources. Among these, biomass and biofuels have emerged as highly promising alternatives due to their abundant availability, carbon neutrality, and potential for decentralized power generation. For diploma-level Electrical Engineering students, understanding how biomass and biofuels can be harnessed for electricity generation, grid integration, and energy conservation is essential, as they play a pivotal role in the design, control, operation, and protection of modern power plants. |

**Course Outcome:**

After Completion of the Course, Student will able to:

| No | Course Outcomes | RBT Level |
|---|---|---|
| 1 | Describe biomass resources, biofuels and their energy potential. | R |
| 2 | Explain biochemical conversion processes. | U |
| 3 | Explain thermochemical conversion processes. | U |
| 4 | Operate and maintain biomass power plants. | U/A |
| 5 | Evaluate energy efficiency, safety and environmental-policy aspects of biomass power plant. | U/A |

**Revised Bloom's Taxonomy (RBT)*

**Teaching and Examination Scheme:**

| Teaching Scheme (in Hours) | | | Total Credits L+T+ (PR/2) | Assessment Pattern and Marks | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|
| | | | | Theory | | Tutorial / Practical | | |
| L | T | PR | C | ESE(E) | PA(M) | PA(I) | ESE (V) | |
| 3 | 0 | 2 | 4 | 70 | 30 | 20 | 30 | 150 |

**Course Content:**

| Unit No. | Content | No. of Hours | % of Weightage |
|---|---|---|---|
| 1. | **Introduction to Biofuels & Biomass**<br>Contents:<br>(1) Renewable vs conventional fuels<br>(2) Biomass sources: Agricultural residues, Forestry residues, Municipal Solid Waste (MSW), Agro-industrial waste<br>(3) Properties of biomass fuels: Proximate analysis, Ultimate analysis, Calorific value, Gross Calorific Value (GCV), Net Calorific Value (NCV), bomb calorimeter<br>(4) Relevance to electrical power generation and rural electrification: Decentralized Power Generation, Co-generation Applications (Combined heat and power (CHP) systems in sugar, paper and agro-processing industries) | 08 | 16% |
| 2. | **Biochemical Conversion Processes**<br>Contents:<br>(1) Anaerobic Digestion: Principles of microbial decomposition of organic matter,<br>(2) Types of digester: batch, continuous, fixed dome, floating drum<br>(3) Biogas composition ($CH_4$, $CO_2$, $H_2S$) and calorific value.<br>(4) Ethanol Production**:** Fermentation of sugar/starch crops, distillation, fuel-grade ethanol<br>(5) Biodiesel Production**:** Transesterification of vegetable oils and waste cooking oil<br>(6) Characteristics of biodiesel: viscosity, cetane number, flashes point and use in diesel engines and generators.<br>(7) Biogas DG sets in rural electrification<br>(8) Biodiesel-powered gensets for small-scale industries | 08 | 17% |
| 3. | **Thermochemical Conversion Processes**<br>Contents:<br>(1) Biomass Combustion: Combustion mechanisms<br>(2) Types of Boilers used in Biomass Power Plants: Water Tube Boiler, Fire Tube Boiler<br>(3) Types of Furnaces used in Biomass Power Plants: Grate Furnaces, Pulverized Fuel Furnace<br>(4) Gasification: updraft/downdraft gasifiers, syngas quality, applications in IC engines and gas turbines electricity generation.<br>(5) Pyrolysis process and by-products.<br>(6) Electrical integration of gasifiers with IC engines and alternators. | 08 | 17% |

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|---|---|---|---|
| 4. | **Electrical Systems in Biomass Power Plants**<br>(1) Prime movers: biogas engines, steam turbines, dual-fuel engines.<br>(2) Generators & alternators: sizing, excitation, AVR.<br>(3) Grid interfacing: inverters, synchronisation, load sharing, islanded vs grid-tied operation.<br>(4) Electrical protection: fuses, relays, breakers for biomass plants.<br>(5) Control & instrumentation: sensors, SCADA/PLC monitoring.<br>(6) Mini/microgrid design using biomass-based sources.<br>(7) Preventive maintenance steps, breakdown maintenance procedures.<br>(8) Safety standards, troubleshooting practices. | 12 | 30% |
| 5. | **Energy Audit, Safety & Policy**<br>Contents:<br>(1) Energy losses in biomass systems: Combustion losses, Heat losses in boilers, Mechanical losses in turbines, engines and generators, Electrical losses: transformer, transmission and auxiliary consumption<br>(2) Efficiency calculation: Boiler efficiency (direct and indirect methods), Turbine efficiency (isentropic and mechanical efficiency), Overall plant efficiency<br>(3) Energy audit procedure (as per BEE guidelines)<br>(4) Safety aspects: handling biogas, biodiesel, fire/explosion risks.<br>(5) Environmental benefits: GHG reduction, carbon credits.<br>(6) Indian scenario: National Bio-Energy Mission, SATAT scheme, E20 blending, waste-to-energy plants, State and central support schemes<br>(7) Future of biomass-based electrical power. | 09 | 20% |
| | **Total** | **45** | **100** |

**Suggested Specification Table with Marks (Theory):**

| **Distribution of Theory Marks (in %)** | | | | | |
|---|---|---|---|---|---|
| **R Level** | **U Level** | **A Level** | **N Level** | **E Level** | **C Level** |
| 20 % | 50 % | 30% | - | - | - |

*Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)*

**References/Suggested Learning Resources:**
**(a) Books:**

| S.No. | Book Title | Author(s) | Publisher | ISBN |
|---|---|---|---|---|
| 1 | Non-Conventional Energy Resources | B.H. Khan | McGraw Hill Education | 9352601882 |
| 2 | Non-Conventional Energy Sources | G.D. Rai | Khanna Publishers | 8174090738 |
| 3 | Biomass Conversion and Technology | C.Y. Wereko-Brobby & Essel B. Hagan | Wiley (UNESCO Energy Engineering Series) | 0471962465 |
| 4 | Biomass for Renewable Energy, Fuels, and Chemicals | Donald L. Klass | Academic Press | 0124109500 |
| 5 | Biomass Processing, Conversion and Biorefinery | Bo Zhang & Yong Wang | Nova Science Publishers | 1626183465 |
| 6 | Bioenergy: Principles and Applications | Yebo Li & Samir Kumar Khanal | Wiley-Blackwell | 1118568311 |
| 7 | Energy Efficiency in Electrical Utilities | Bureau of Energy Efficiency | Bureau of Energy Efficiency, India | - |

**(b) Open-source software and website:**
1. MNRE – Ministry of New and Renewable Energy: https://mnre.gov.in/
2. BEE – Bureau of Energy Efficiency: https://beeindia.gov.in
3. FAO – Biomass and Bioenergy Resources: http:// fao.org/energy/en
4. NREL – National Renewable Energy Laboratory: http:// nrel.gov
5. https://task33.ieabioenergy.com/wp-content/uploads/sites/33/2022/06/India_2021.pdf?utm_source
6. https://www.canr.msu.edu/uploads/files/biodiesel_production.pdf?utm_source
7. https://www.sciencedirect.com/science/article/pii/S2772783125000032?utm_source
8. https://docs.nrel.gov/docs/legosti/old/3022.pdf?utm_source

**Suggested Course Practical List:**

| Sr. No. | Practical Outcome/Title of experiment | CO1 | CO2 | CO3 | CO4 | CO5 |
|---|---|---|---|---|---|---|
| 1 | Proximate analysis of biomass (moisture, ash, volatile matter). | ✓ | | | | |
| 2 | Ultimate analysis of biomass sample (C, H, O, N, S content – demo). | ✓ | | | | |

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|---|---|---|---|---|---|---|
| 3 | Calorific value measurement using bomb calorimeter. | ✓ | | | | |
| 4 | Preparation of biodiesel (transesterification) and testing viscosity & flash point. | | ✓ | | | |
| 5 | Performance test of a small biogas-fueled IC engine. | | ✓ | | | |
| 6 | Measurement of biogas composition ($CH_4$, $CO_2$) using gas analyzer kit. | | ✓ | | | |
| 7 | Demonstration of biomass gasifier and testing quality of producer gas. | | | ✓ | | |
| 8 | Emission testing (CO, $CO_2$, NOx) from a biodiesel/biogas engine. | | | ✓ | | |
| 9 | Load test on alternator driven by biofuel engine. | | | | ✓ | |
| 10 | Synchronization of biomass-based generator with grid using synchroscope. | | | | ✓ | |
| 11 | Study of inverter & load sharing in a biomass microgrid setup. | | | | ✓ | |
| 12 | Protection system demo – overcurrent relay, MCB/ELCB in biomass power plant. | | | | ✓ | |
| 13 | SCADA/PLC demonstration for process monitoring in bioenergy plant. | | | | ✓ | |
| 14 | Energy audit exercise – calculate efficiency of a biomass-based power system. | | | | | ✓ |
| 15 | Field visit & case study of a biomass/biogas/biodiesel power plant with report. | | | | | ✓ |

Subject In-charge can add experiments considering course content.

**List of Laboratory/Learning Resources Required:**

| Sr. No. | Equipment Name with Broad Specifications |
|---|---|
| 1 | CHNS elemental analyzer |
| 2 | Bomb calorimeter setup |
| 3 | Viscosity measurement kit |

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| 4 | Flash point tester |
| 5 | Small IC engine (single cylinder or dual-fuel) |
| 6 | Pressure gauge, tachometer, thermometer |
| 7 | Biogas analyzer |
| 8 | Small-scale updraft or downdraft gasifier |
| 9 | Gas analyzers |
| 10 | Voltmeter, ammeter, wattmeter, synchroscope |
| 11 | Overcurrent relay, MCB, ELCB |
| 12 | PLC system, SCADA software |
| 13 | Power analyzer |

**Suggested Projects List:**

1. Prepare comparative study of calorific value of different biomass samples (agro-waste, forestry residues, MSW).
2. Small-scale biodiesel production from waste cooking oil and performance testing in diesel engines.
3. Performance evaluation of a mini biogas plant for rural electrification.
4. Performance evaluation of updraft/downdraft biomass gasifier for IC engine applications.
5. Electrical protection and fault analysis in a mini biomass power system.
6. Energy audit of a small biomass/biogas/biodiesel power plant and calculation of overall efficiency.

**Suggested Activities for Students:**

Beyond classroom and laboratory learning, the following co-curricular activities are recommended to enhance the achievement levels of various outcomes in this course. Students are encouraged to undertake these activities either individually or in groups and prepare comprehensive reports of approximately five pages for each activity.

a) Collect and classify locally available biomass (agricultural residues, forestry waste, MSW) and prepare a biomass sample database.
b) Prepare a poster or chart showing renewable vs conventional fuels, highlighting environmental and economic impacts.
c) Prepare a report or presentation on ethanol blending in small engines

d) Demonstrate operation of an updraft or downdraft gasifier and test the quality of producer gas
e) Compare syngas calorific values from different feedstocks and discuss applications.
f) Conduct a mini energy audit of a lab-scale biomass system and calculate efficiency.
g) Conduct a case study or virtual tour of an Indian biomass/biogas/biodiesel power plant and present findings.

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