GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021(COGC-2021)
Semester-V

Course Title: Waste to Energy Conversion Technology
(Course Code: 4350502)

Diploma Programme in which this course is offered	Semester in which offered
Chemical Engineering	5th Semester

1. RATIONALE

The objective of the course is to provide insights into waste management options by reducing the waste destined for disposal and encouraging the use of waste as a resource for alternate energy production. This course is designed to provide an understanding of the various aspects of Waste to Energy. The various sources of waste generation are analyzed with a focus on its potential for energy production. The need for characterization of wastes will be discussed along with the existing norms for waste utilization for alternate energy source. Various Technological options available for the production of energy form waste.

2. COMPETENCY

The course should be taught and curriculum should be implemented with the aim to develop required skills so that students are able to acquire following competency:

- **To Supervise operation and to Optimize energy and Other Inventories**

3. COURSE OUTCOMES(COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a) Identify different wastes as a energy source
b) Apply concept of Thermo-chemical process for energy conversion
c) Apply concept of Biochemical process for energy conversion
d) Utilize algal biomass as source of energy production

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	-	-	3	30*	70	-	-	**100**

(*):Out of 30 marks under the theory CA,10 marks are for assessment of the micro-project to facilitate the integration of COs, and the remaining 20 marks are the average of 2 tests to be taken during the semester for assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *- Practical;* ***C*** *– Credit,* ***CA*** *-Continuous Assessment;* ***ESE****-End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. *Some of the* ***PrOs*** *marked* ***'*'*** *(in approx. Hrs column) are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'*.

Sr. No.	Practical/Exercise (Course Outcomes in Psychomotor Domain according to NBA Terminology)	Unit No.	Approx. Hrs Required
Not Applicable			

Note

i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list**.**

ii. The following are some **sample** 'Process' and '#Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.

Sr. No.	Sample Performance Indicators for the PrOs	Weight age in %
1	Question answer or Writing steps exercise (Assignment)	30
2	Executing of exercise	30
3	Result	40
Total		**100**

6. MAJOR EQUIPMENT/INSTRUMENTS AND SOFTWARE REQUIRED

These major equipment/instruments and Software required to develop PrOs are given below with broad specifications to facilitate procurement to them by the administrators/management to the institutes. This will ensure the conduction of practice in all institutions across the state in a proper ways other the desired skills are developing in students.

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
Not Applicable		

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow ethical practices
c) Observe safety measures

d) Good house keeping
e) Time management
f) Practice environmentally friendly methods and processes.

The ADOs are best developed through laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such higher-level UOs could be included by the course teacher to focus on the attainment of COs and competency.

Unit	Major Learning Outcomes(Course Outcomes in Cognitive Domain according to NBA terminology)	Topics and Sub-topics
Unit:1 Characterization of waste	1a. Classification of waste as energy	1.1 Definition of wastes and their classification 1.2 Important quality parameters of different types of wastes 1.3 Wastes suitable for energy production
	1c. Characterization of wastes	1.4 Characterization of solid wastes and waste water
	1d. Explain Technologies for Waste to Energy Conversion	1.5 Energy from wastes, some scenario 1.6 Routes for energy production from wastes 1.7 Define Biochemical Conversion and Thermo-chemical Conversion
	1b. Explain Status of wastes	1.8 Status of waste to Energy conversion in India.
	1d. Solve simple numerical	1.9 Numerical based on Characterization of wastes
Unit:2 Thermo-chemical Conversion	2a. Explain Mechanism of combustion	2.1 Definition and scope of combustion/incineration 2.2 Environmental and health impacts of incineration 2.3 Advantages and Disadvantages of combustion 2.4 Air requirement for combustion
	2b. Classification of combustors	2.5 Type of combustor 2.6 Energy production from wastes through incineration
	2c. Explain Basic chemistry of gasification	2.7 Concept and Advantages of gasification
	2d. Classification of Gasifier	2.8 Types of Gasifier 2.9 Energy production through gasification of wastes
	2e. Comparison Combustion and gasification	2.10 Comparison between incineration and gasification

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	2f. Classification of pyrolysis	2.11 Definition and mechanism of pyrolysis 2.12 Types of pyrolysis 2.13 Operating conditions and end product distribution
	2g Explain Properties of Pyrolysis products	2.14 Use of pyrolysis products 2.15 Properties of bio oil and need of its upgradation 2.16 Utilization of pyro char and gases
	2h. Solve simple numerical	2.17 Numerical based on combustion, gasification and Pyrolysis
Unit:3 Biochemical Conversion	3a. Outline Properties of biogas	3.1 Properties of biogas (Calorific value and composition) 3.2 Factors affecting biogas yield
	3b. Explain and Classify Anaerobic digestion	3.3 Feedstock's and primary products of Anaerobic digestion 3.3 Mechanism of anaerobic digestion 3.5 Flow sheet for anaerobic digestion of wastes 3.6 Types of anaerobic digesters and their operation
	3c. Energy production from wastes through fermentation	3.7 Different energy sources from biomass / wastes through fermentation 3.8 Production of ethanol from starchy crops (corn), lingo cellulosic biomass (LCB) and through gasification route 3.9 Butanol production from LCB
	3d. Energy production from wastes through transesterification	3.10 Transesterification process and Organic wastes for transesterification 3.11 Production of bio oil from oil seeds and its major composition 3.12 Up gradation of bio oil to bio diesel
	3e. Solve simple numerical	3.13 Numerical based on biochemical conversion process
Unit:4 Cultivation of algal Biomass	4a. Explain algal cultivation	4.1 Why algal cultivation? 4.2 Algal metabolism and synthesis of fat and protein
	4b. Classify algae	4.3 Classification of microalgae phyla 4.4 Lipid content in algal cell
	4c Show growth of microalgae	4.5 Reactor systems for cultivation/ growth of microalgae
	4b. Energy production from algal Biomass	4.6 Important energy production routes for algal biomass 4.7 Conversion of algal oil to biodiesel 4.8 Types of conversion process, mechanisms and comparison 4.9 Factors affecting biodiesel yield

		4.10 Upgradation of algal oil to bio diesel using homogenous and heterogeneous catalysts

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Characterization of waste	6	2	4	2	8
II	Thermo-chemical Conversion	14	5	10	10	25
III	Biochemical Conversion	14	5	10	10	25
IV	Cultivation of algal	8	6	6	0	12
	Total	**42**	**18**	**30**	**22**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should perform following activities in group and prepare reports of about 5 pages for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews:

Following is the list of proposed student activities like:

1. Assignments
2. Technical Quiz/MCQ Test
3. Presentation on some course topic
4. I-net based assignments
5. Undertake micro-Project in team/individually

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (*MOOCs*) may be used to teach various topics/subtopics.
b) Guide student(s) in undertaking micro-projects/activities.
c) Different types of teaching methods i.e. video demonstration, activity based learning, case study, m-learning need to be employed by teachers to develop the outcomes.
d) Some *of the topics/sub-topics* which is relatively simpler or descriptive is to be given to the students for *self-learning* but to be assessed using different assessment methods.
e) Teachers need to ensure to create opportunities and provisions for *co-curricular activities*.

f) Guide students to address issues on environment and sustainability with reference to using the knowledge of this course
g) OERs, Vlab, and Olabs may be used to teach for the teaching of different concepts.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her at the beginning of the semester. In the first four semesters, the micro-project is group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be industry application-based, internet-based, workshop-based, laboratory-based, or field-based. Each micro-project should encompass two or more COs which are the integration of PrOs, UOs, and ADOs. Each student will have to maintain dated work diary consist in go find individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students ought to submit micro-project by the end of the semester (so that they develop industry-oriented COs).

A suggestive list of micro-projects is given here. This should relate highly to the competency of the course and the COs. Similar micro-projects could be added by the concerned course teacher.

1	Prepare chart/model of Classification of waste along with their Mechanism and applications
2	Prepare chart of Status of waste to Energy conversion in India
3	Prepare chart/model types of Combustor
4	Draw suitable chart for various Combustor equipment
5	Prepare 15-20 slides power point presentation showing Classification of waste along with their examples
6	Prepare 15-20 slides power point presentation Characterization of wastes
7	Prepare 15-20 slides power point presentation on Waste to energy technology
8	Prepare a demonstrative model of any Gasifier reactor
9	Prepare a demonstrative model of any waste to energy conversion technology equipment
10	Prepare Working model of any waste to energy conversion technology equipment
11	Prepare 15-20 slides power point presentation on energy crisis in India and its solution
12	Prepare a model on pyrolysis system that can convert plastic into gas or oil.
13	Prepare chart/model of Incineration.
14	Prepare 15-20 slides power point presentation on comparison of seven different countries best practices for waste energy recovery with India.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Books	Author	Publication with place, year and ISBN
1	Waste-to-Energy: Technologies and Project Implementation	Marc J Rogoff Dr and Francois Screve	William Andrew; 2nd edition (15 June 2011)

2	Biogas Technology	Khandelwal K. C. and Mahdi S. S	Vol. I & II Tata McGraw Hill Publishing Co. Ltd., 1983
3	Solid Waste Engineering	Vesilind P.A. and Worrell W. A	2nd Ed. Cengage India (2016)
4	Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power	Robert C. Brown,	John Wiley and Sons, USA (2019)
5	Municipal Solid Waste to Energy Conversion processes	Young G.C	John Wiley and Sons

14. SUGGESTED LEARNING WEBSITES

a) https://onlinecourses.nptel.ac.in/noc23_ch05/
b) https://www.teriin.org/projects/green/pdf/National-Waste.pdf
c) https://www.eai.in/ref/ae/wte/typ/clas/india_industrial_wastes.html
d) Ministry of New & Renewable Energy - Government of India (mnre.gov.in)
e) http://www.ottusa.com/synthetic_fuel/synthetic_fuel
f) OSHA Technical Manual (OTM) | Occupational Safety and Health Administration
g) https://youtu.be/jYry2xe-HqY
h) https://youtu.be/MuYdfxanAk8
i) https://youtu.be/uXU2Pcxokb4

15. PO-COMPETENCY-CO MAPPING

Semester V	Waste to energy conversion technology (4350502)						
	POs						
Competency & Course Outcomes	PO1 Basic & Discipline -specific knowledge	PO2 Problem Analysis	PO3 Design/development of solutions	PO4 Engineering Tools, Experimentation &Testing	PO5 Engineering practices for society, sustainability & environment	PO6 Project Management	PO7 Life-long learning
Competency	To Supervise operation and to Optimize energy and Other Inventories						
CO1: Identify different wastes as a energy source	2.00	3.00	1.00	-	1.00	1.00	3.00
CO2: Apply concept of Thermo-chemical Conversion for biogas production	1.00	3.00	3.00	1.00	2.00	1.00	2.00
CO3: Apply concept of Bio-chemical Conversion for biogas production	1.00	3.00	3.00	1.00	2.00	1.00	2.00
CO4: Utilize algal biomass as source of energy production	1.00	2.00	2.00	-	2.00	1.00	2.00

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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