GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2023 (COGC-2023)
Semester-VI

Course Title: Cleaner Production Engineering
(Course Code: **4361304**)

Diploma programme in which this course is offered	Semester in which offered
Environmental Engineering	Sixth

1. RATIONALE

This course aims to provide diploma engineering students with a comprehensive understanding of cleaner production principles, strategies, and techniques. Students will acquire knowledge about environmental, economic and technological aspects of Cleaner Production Methods. The student will be exposed to methodology of cleaner production projects, methods of their implementing into industrial establishment and process of pollution prevention and reduction along with operating costs reduction and increase in safety of operation with the help of various case studies. This will help them appreciate the significance of adopting sustainable practices in engineering and encourage them to implement cleaner production strategies in their future careers.

2. COMPETENCY

The course content should be taught and with the aim to develop required skills in students so that they are able to acquire following competencies.

- **Apply sustainable engineering practices to minimize waste, reduce environmental impacts, and optimize resource utilization in various industries for Cleaner Production**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

a) Understand the concepts and principles of cleaner production and its methodology.
b) Analyse industrial processes to identify opportunities for waste reduction and resource optimization.
c) Apply strategies and techniques for pollution prevention in different industrial settings.
d) Interpret the role of Carbon Capture and Sequestration in mitigating climate change

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T/2+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA*	ESE	CA	ESE	
3	0	2	4	30	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the 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 **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'*.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Selection of suitable industry: (Food Processing Industry, Automotive Manufacturing, Chemical Industry, Electronics Manufacturing)	I,II,III	02
2	Baseline Assessment: Conduct a detailed analysis of the selected process, considering inputs, outputs, energy consumption, and waste generation. Use tools such as material flow analysis, energy audits, and process mapping to identify inefficiencies and environmental impacts.	I,II,III	02
3	Identify Improvement Opportunities: Brainstorm and research cleaner production techniques applicable to the selected process. Consider options such as process modifications, technology upgrades, material substitution, or waste recycling.	I,II,III	04
4	Life Cycle Assessment (LCA): Perform a simplified LCA to assess the environmental impact of the current process and potential improvements. Evaluate the environmental benefits of proposed changes.	I,II,III	04
5	Feasibility Analysis: Assess the economic feasibility of implementing proposed improvements, considering initial costs, payback periods, and potential long-term savings.	I,II,III	04
6	Implementation Plan and Monitoring Measurement: Develop a step-by-step plan for implementing the identified improvements. Consider the practicality of the proposed changes and potential challenges. Implement the proposed changes in a controlled manner. Set up a monitoring system to track key performance indicators (KPIs) such as waste reduction, energy savings, and resource efficiency.	I,II,III	04

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
7	Presentation: Present the sustainable process improvement project to the class, detailing the chosen process, baseline assessment, improvement strategies, and the impact of implemented changes. Encourage discussion and feedback from peers.	I,II,III	08
			Total:28

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..*

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
	For PrOs 1 to 7	
1	Thoroughness of the baseline assessment.	10
2	Appropriateness and feasibility of proposed improvements.	10
3	Quality of the LCA and economic feasibility analysis.	20
4	Presentation	20
5	Submission for progressive assessment on time	30
6	Viva Voce	10
	Total	**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to usher in uniformity of practicals in all institutions across the state.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	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 team member/ individual.
b) Follow ethical practices.
c) Follow safe practice on site and in laboratory.
d) Practice of environmental friendly methods and processes.

The ADOs are best developed through the 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

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
Unit – I **Introduction to Cleaner Production and its methodology**	1a. Familiarize with the evolution of cleaner production. 1b. Understand the Principles and concepts of cleaner production. 1c. Identify Motivators and Barriers to Cleaner Production 1d. Explain six step methodology for Cleaner Production 1e. Describe Cleaner Production Options	1.1 Introduction to sustainability and environmental engineering 1.2 Historical perspective and evolution of cleaner production 1.3 Principles and concepts of cleaner production 1.4 The effect of Cleaner Production on industrial economy 1.5 Motivators and Barriers to Cleaner Production 1.6 Six step methodology for Cleaner Production 1.7 Cleaner Production Options
Unit – II **Waste Minimization Techniques and good housekeeping**	2a. Describe Source reduction and waste hierarchy 2b. Analyse Material and energy flow 2c. Understand 3R principles 2d. Interpret Check lists for good housekeeping	2.1 Source reduction and waste hierarchy 2.2 Material and energy flow analysis 2.3 3R (Reduce, Reuse, Recycle) principles 2.4 Check lists for good housekeeping
Unit– III **Pollution Prevention Strategies**	3a. Describe pollution prevention and Design for environment (DFE) principles 3b. Identify Best available technology (BAT) for pollution prevention. 3c. Describe Lean	3.1 Introduction to pollution prevention 3.2 Design for environment (DFE) principles 3.3 Best available technology (BAT) for pollution prevention 3.4 Lean manufacturing and just-in-time (JIT) concepts 3.5 Energy efficiency and process

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
	manufacturing and just-in-time (JIT) concepts, Energy efficiency and process optimization, Green chemistry and sustainable materials, concept of eco-design. 3d. Perform Life cycle analysis	optimization 3.6 Green chemistry and sustainable materials, concept of eco-design 3.7 Life cycle analysis (LCA): target setting, data collection and processing, final evaluation by virtue of criteria
Unit– IV **Carbon Capture and Sequestration (CCS)**	4a. Define CCS and its role in mitigating climate change. 4b. Identify major sources of CO2 emissions 4c. Describe Carbon Capture Technologies 4d. Explain transportation and storage of Captured CO2 4e. Describe Enhanced Oil Recovery 4f. Identify Potential environmental impacts of CCS	4.1 CCS and its role in mitigating climate change. 4.2 Identification of major sources of CO2 emissions (e.g., power plants, industrial processes, transportation) and its quantification. 4.3 Carbon Capture Technologies: Post-Combustion Capture, Pre-Combustion Capture, Oxyfuel Combustion 4.4 Transportation of Captured CO2 by pipelines/shipping 4.5 Carbon Storage: Geological Storage, Ocean storage 4.6 Enhanced Oil Recovery (EOR) 4.7 Potential environmental impacts of CCS

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A	Total Marks
I	Introduction to Cleaner Production and its methodology	06	04	07	03	14
II	Waste Minimization Techniques and good housekeeping	08	08	10	03	21
III	Pollution Prevention Strategies	08	08	10	03	21
IV	Carbon Capture and Sequestration (CCS)	06	04	07	03	14
Total		**42**	**24**	**34**	**12**	**70**

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

Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions 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 vary slightly 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 conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare a report after gathering information the values of water and air pollution in your town or city and compare the values with that of other cities.
b) Collect sample of water and air from the specific field location.
c) Prepare sketches for different types of Plume behavior.
d) Undertake micro-project.
e) Give seminar on any relevant topic.

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/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4*** means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed Six.***

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 in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

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

a) Analyze the waste streams generated in different stages of production process of a small scale Industry. Propose strategies to reduce, reuse, or recycle specific waste components.

b) Conduct an energy audit in your college to identify areas of energy waste. Propose energy-efficient solutions and estimate potential cost savings.
c) Select a common product (e.g., packaging, consumer goods).Redesign the product to be more eco-friendly, considering materials, production processes, and end-of-life disposal.
d) Evaluate water consumption practices for a local business (restaurant, car wash, etc.).Suggest water-saving technologies.
e) Calculate the carbon footprint of a small business or community event. Identify strategies to reduce or offset the carbon emissions.
f) Choose a product commonly used by students (e.g., a smartphone). Conduct a simplified life cycle assessment to identify environmental hotspots and propose improvements.
g) Design and implement a campaign to raise awareness about cleaner production practices within the local community. Use various mediums like social media, workshops, and pamphlets.
h) Investigate the feasibility of implementing a small-scale waste-to-energy project. Assess available waste streams and identify suitable technologies for energy conversion.
i) Develop a plan for the collection and responsible recycling of electronic waste in your city. Create awareness materials to educate the public about proper e-waste disposal.
j) Conduct an assessment of sustainability practices on the campus. Propose and implement improvements, such as waste reduction strategies, energy-saving initiatives, or green transportation options.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Cleaner Production: Environmental and Economic Perspectives	Misra Krishna B.	Springer; 1st ed. 1996 edition (28 February 2012) ISBN-13 : 978−3642799426
2	Sustainable Engineering: Concepts, Design and Case Studies	David T. Allen and Michael M. VandenBerg.	Pearson Education India; 1st edition (1 January 2015) ISBN-13 : 978−9332556577
3	Life Cycle Assessment: Principles, Practice and Prospects	Ralph E. Horne and Society of Environmental Engineers.	CSIRO PUBLISHING (20 March 2009) ASIN : B004YV7D6K
4	Carbon Capture and Sequestration Integrating	Elizabeth Wilson and David Gerard	Wiley–Blackwell (15 March 2007); CBS Publishers & Distributors Pvt. Ltd. -PH:

S. No.	Title of Book	Author	Publication with place, year and ISBN
	Technology, Monitoring, Regulation.		011-49344934, ISBN-13 : 978–0813802077

14. SOFTWARE/LEARNING WEBSITES

a) www.gpcb.gov.in

b) https://cpcb.nic.in/about-namp/www.neeri.res.in

c) www.Nptel.ac.in

d) https://www.indiacode.nic.in/

15. PO-COMPETENCY-CO MAPPING

Semester II	Cleaner Production Engineering (Course Code:4361300)									
	POs and PSOs									
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning	PSO 1 Environmental planning & deisgn	PSO 2 Environmental Impact Assessment	PSO 3 (If needed)
Competency	i. Apply sustainable engineering practices to minimize waste, reduce environmental impacts, and optimize resource utilization in various industries for Cleaner Production									
Course Outcomes										
a) Understand the concepts and principles of cleaner production and its methodology.	3	3	2	-	3	-	2	3	3	-
b) Analyse industrial processes to identify opportunities for waste reduction and resource optimization.	3	3	3	2	3	-	2	3	3	-
c) Apply strategies and techniques for pollution prevention in different industrial settings.	3	3	3	2	3	-	2	3	3	-
d) Interpret the role of Carbon Capture and Sequestration in mitigating climate change	3	3	3	2	3	-	2	3	3	-

Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
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