GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Renewable and Green Energy
(Course Code: 4351907)

Diploma program in which this course is offered	Semester in which offered
Mechanical Engineering	5th Semester

1. RATIONALE

Renewable & Green Energy technologies are emerging as Energy Sources and technologies of the Future. The Energy Sector has been identified as a sector having maximum impact on global warming and Climate Change. More than 70% of environment related issues are caused by our energy demand and utilization which is mostly 'hydrocarbons' based. 'Decarbonization of Economy' is the modern mantra for saving Planet Earth from a potential environmental disaster. Promoting and facilitating rapid development of these 'hydrocarbon-free' technologies has become a priority worldwide. Deployment of Renewable Energy Sources for meeting our present and future energy demand is an immediate need for any nation. There is going to be huge demand of engineers/ technical professionals / manpower with in-depth knowledge, exposure and understanding about Renewable and Green Energy technologies. This course will provide the basic knowledge of prospective RE technologies, viz. solar energy, wind energy, bio energy, ocean energy, geothermal energy etc. This course would develop skills related to proper designing, constructing, operating, and monitoring RE systems. This course is concerning "Energy" which is subject for all disciplines of engineering and mechanical engineers will have an important role to play in effective deployment of RE Systems in the Industries.

2. COMPETENCY

The course content should be taught and implemented to develop different skills so that students can acquire the following competency.

- Basic understanding of new Renewable Energy (RE) technologies and relate to the concepts, laws, and principles to design, deployment, operation, and maintenance of these new & renewable technologies.

3. COURSE OUTCOMES (COs)

The underpinning knowledge about rapidly depleting energy resources of the world and its environmental impacts and the relevance of advancements in the renewable & green energy sector in the country and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs: -

CO-1	Understand the Energy Scenario of the India and evaluate Renewable energy potential in India.
CO-2	Demonstrate the importance of solar energy collection & storage and evaluate the performance of various solar conversion systems.

CO-3	Determine the principle of wind energy and evaluate the potential of wind energy conversion system.
CO-4	Illustrate the biomass energy and its application.
CO-5	Illustrate the geothermal, tidal, ocean, wave energy and its application

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Total Credits	Examination Scheme				
				Theory Marks		Practical Marks		
L	T	P	C	CA	ESE	CA	ESE	Total
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

Following Practical activities will be included in the course to provide valuable insight to the immense potential renewable energy sources have to supplement the conventional energy in coming times. Practical activities will help in understanding RE in the same context as conventional energy sources, and in establishing a better understanding of REs which have greater advantages for a sustainable future:

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
01	Introduction of various Renewable energy sources.	1	02
02	Introduction to Instrumentation for measuring technical parameters of Solar, Wind and Bio Energy Sources. Viz. Solari Meter, Anemometer, Lux Meter, Digital Temperature Meter with different types of probes for different measurements.	2, 3	06
03	Demonstration on Working of different Solar Thermal Devices & their construction – Box Solar Cooker, Dish Solar Cooker, Solar Water Heater – FPC/ETC, insulated piping, and Hot Water Storage Tank.	2	06
04	Demonstration on Working of Solar Photovoltaic Devices & their components, viz, Solar PV Panel, Solar Inverter, Storage Battery and Charge Controller and their technical specifications.	2	04

05	To study the various types of wind mill and evaluate the performance parameter of wind mill Measurement of Wind Velocity (Power) and direction at a Site, using anemometer.	3	04
06	To study the various types of biomasses and biogas plant	4	04
07	To study about different green energy viz, tidal, geothermal, MHD, OTEC, wave, ocean	5	02
08	Field Visits / Virtual Visits of different RE installations	-	-
Total (Hours)		**-**	**28**

Note:

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

The following are some **sample 'Technology**' 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	Weightage in %
For Demonstration type PrOs (PrOs Number: 1,2,3,4,6,7)		
1	Knowledge	30
2	Quality of Report	30
3	Participation	20
4	Punctuality	20
Total		**100**
Experimentation/performance type PrOs (PrOs Number: 5)		
1	Knowledge	20
2	Procedure follows	15
3	Observation Skill	20
4	Analysis	10
5	Quality of Report	20
6	Punctuality	15
Total		**100**

Sample rubrics Performance Indicators for the PrOs

Demonstration type PrOs (PrOs Number: 1,2,3,4,6,7)					
Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30%	Students give the correct answers 90% or	Students give the correct answers between 70-89%.	Students give the correct answers between 50-69%.	Student give the correct answers less than 50%.

		more.			
Quality of Report	30%	Neat Handwriting, figure, and table. Complete labeling of figure and table.	Only formatting is improper (Location of figures/tables, use of pencil and scale).	A few required elements (labeling/ notations) are missing.	Several elements are missing (content in paragraph, labels, figures, tables).
Participation	25%	Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Participation is minimum.
Punctuality	15%	Timely Submission.	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.

Experimentation/performance type PrOs (PrOs number: 5)

Criteria	%	10	9-8	7-6	5
Knowledge	20%	Student give the correct answers 90% or more.	Student give the correct answers between 70-89%.	Student give the correct answers between 50-69%.	Student give the correct answers less than 50%.
Procedure follows	15%	Students follow all the procedures with precaution in a logical order.	Students follow all the procedures with some precautions in a logical order.	Students follow all the procedures without precaution in a logical order.	Students follow all the procedures without precaution in an illogical order.
Observation Skill	20%	Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Participation is minimum.
Analysis	10%	Student understand the data and analyze correctly the obtained test results.	Student understand most of the data and analyze the obtained test results with help or support.	Student need help to understand some of the data and also in analyzing the obtained test results.	Student always need help to understand the data and also in analyzing the obtained test results.

Quality of Report	20%	Neat Handwriting, figure, and table. Complete labeling of figure and table.	Only formatting is improper (Location of figures/tables , use of pencil and scale).	A few required elements (labeling/ notations) are missing.	Several elements are missing (content in paragraph, labels, figures, tables).
Punctuality	15%	Timely Submission.	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name	PrO. No.
1.	Measuring Instruments: - • Soleri Meter (Pyranometer), • Multimeter, • Anemometer, • Sunshine recorder, • Digital Thermometer with different probes (surface, air, liquid)	2
2.	Models of various solar energy collectors • Flat plate Collector (FPC) • Cylindrical Parabolic Collectors • Evacuated Tube Collector (ETC) • Solar Photo Voltaic (SPV)	2
3.	Box type solar cooker, Solar Air Heater	3
4.	Various of models of Wind mill • HAWT • VAWT	3
5.	Various of model hydro turbine using running tap	5

7. AFFECTIVE DOMAIN OUTCOMES

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

a. Work as a leader/ team member.

b. Follow safety practices.

c. Follow ethical practices

d. Maintain tools and equipment

e. Practice environment-friendly methods and processes. (Environment related)

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

Based on the higher-level UOs of Revised Bloom's taxonomy formulated for developing COs and competency, the primary underpinning theory is given below. If required, more such UOs could be included by the course teacher to focus on attaining COs and competency.

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
Unit – I Energy and Environment Scenario	1.a Understand the Energy as a vital resource of development and know the current energy scenario of the World vis-à-vis India 1.b Relevance of Renewable Energy and Green Energy in current day context of energy scarcity and environmental impacts of 'energy use'	1.1 Energy and Energy Sources 1.2 Energy Scenario of the World 1.3 Impact of Energy Use on global environment and the need to reduce these impacts. 1.4 Introduction of REs and its potential as energy sources of the future, importance, Classification of REs, comparison with Conventional & Non-conventional energy sources. 1.5 Need of RE, advantages & limitations of RE, Present Energy scenario of conventional and RE sources
Unit – II Solar Energy Technology	2.a Knowledge about Solar Energy Science and Potential of Solar Energy and understanding different conversion methods for producing green-clean and long-lasting energy for meeting future needs.	2.1 Solar Physics / Science – understanding different terminologies, like Solar Spectrum, Solar Irradiance, Insolation, Solar Constant, etc. related to energy flowing from the Sun and its conversion to different useable forms for meeting energy requirements of different category consumers – domestic to industrial. 2.2 Solar Thermal Systems – solar heaters, Solar PV (Electrical) Systems, Solar cell, modules & arrays, Solar cell types, Solar Concentrators, Solar Collectors, Solar ponds, Solar cookers, Solar distillation & drying, Solar energy thermal storage, Solar space heating, Central Power tower – system configuration and basics of sizing system and system components. 2.3 Installation, operation & maintenance of and troubleshooting in solar

		systems.
Unit-III Wind Energy Technology	3.a Understanding Wind Energy as a potential source of green power and the different conversion techniques for producing electricity on large scale.	3.1 Physics of Wind Energy – Energy available from wind, defining Wind Energy, like wind power density, wind speed, turbine power, tip speed ratio, etc. 3.2 Types of Wind Turbines – Horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT), on-shore & off-shore WTG 3.3 WTG construction and configuration 3.4 Estimation of Wind Power, Turbine Power, Annual Generation, Wind energy potential & site selection 3.5 Wind energy potential & installation in India
Unit-IV Bio Energy Technologies	4.a Introduction to different bio energy sources and conversion technologies and their potential to provide clean energy.	4.1 Type of biomass and their properties and the conversion technologies, sources of biomass 4.2 Types of Biogas Plant and different types 4.3 Biomass Gasification Process, pyrolysis, factors affecting on biogas generation, advantages & limitations 4.4 Biocoal: - Introduction, briquetting machines 4.5 Biofuels, Biodiesel
Unit V: Green Energy Technology	5.a Introduction to immerging clean energy technology	5.1 Tidal: - energy from tidal power, tidal power plant, single & double basin plant 5.2 Wave energy conversion devices, advantage, and disadvantage 5.2 Geothermal energy: - Vapour & liquid dominated systems, binary cycle, hot dry rock resources, magma resources, applications 5.3 Ocean thermal energy, OTEC (Open, Closed) 5.4 Fuel Cell Technology and their present status and future prospects 5.5 MHD Power generation: - Concept & working principle

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Energy and Environment Scenario	04	4	4	-	08
II	Solar Energy Technology	14	10	10	4	24
III	Wind Energy Technology	08	4	8	2	14
IV	Bio Energy Technologies	06	4	6	0	10
V	Green Energy Technology	10	6	8	-	14
Total		**42**	**28**	**36**	**06**	**70**

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

10. SUGGESTED STUDENT ACTIVITIES

Sr. No.	Activity
1.	Make an easy solar oven at home for cookies. (for instructions: - Click here)
2.	Prepare a display chart of Solar PV System
3.	Prepare a display chart of different types of Solar Collectors (FPC, ETC)
4.	Prepare a chart/presentation of HAWT power generation
5.	Prepare a chart/presentation of VAWT power generation
6.	Make a Power Point presentation on the MHD
7.	Prepare display chart of Ocean Thermal Energy Conversion (OTEC)
8.	Identify the potential of RE in India and total RE installed capacity (MW) of India

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies that the course teacher can use to accelerate the attainment of the various outcomes in this course.

Unit	Unit Title	Strategies
I	Energy and Environment Scenario	• Real-life examples, Demonstration of RE systems, Movies/Animations. • Numerical, Massive Open Online Courses (MOOCs)
II	Solar Energy Technology	
III	Wind Energy Technology	
IV	Bio Energy Technologies	
V	Green Technology Technology	

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. 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 with in integration of PrOs, UOs, and ADOs. Each student must maintain a dated work diary (Logbook) consisting of individual contributions to the project work and give a seminar presentation 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 a micro-project by the end of the semester to develop the industry-oriented COs.

A representative 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 or using suggested student activity.

A representative **list of micro-projects** is given here. The concerned faculty can add similar micro-projects based on student activities (chart/presentation/report/model):

1. Collect information about present energy scenario of Conventional & RE sources and prepare a display chart.
2. Prepare a model of the Solar roof top system & wind mill (reference: - Click here)
3. Prepare a model of the clean energy model (reference: - Click here)
4. Prepare a display chart of Solar PV System
5. Prepare a display chart of different types of Solar Collectors (FPC, ETC)
6. Prepare a tabulated summary of the Wind energy potential India and installed capacity in India (Summary includes potential and installed capacity in MW) Reference- Click here
7. Make an easy solar oven at home for cookies. (For instructions: - Click here)
8. Prepare a display chart of Horizontal Axis Wind Turbine (HAWT)
9. Prepare a display chart of Vertical Axis Wind Turbine (VAWT)
10. Prepare a display model of Biogas Plant (Reference- Click here)
11. Make a Power Point presentation on the MHD
12. Prepare a display model of Tidal energy (Reference- Click here)
13. Prepare display chart of Ocean Thermal Energy Conversion (OTEC)
14. Arrange a visit at Solar Park, Charanka, Gujarat and prepare a Report on Solar Power Plant.
15. Undertake 2 to 5 days of training in Solar Park, Charanka, Gujarat

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication
1.	Solar Energy – Principles of Thermal Collection and Storage	Sukhatme S.P. and J. K. Nayak	McGraw Hill Education
2.	Principles of Solar Engineering	D. Yogi Goswami, Frank Krieth & John F Kreider	Taylor & Francis
3.	Non-Conventional Energy Sources	G.D. Rai	Khanna Publication

4.	Renewable Energy Technologies	R. Ramesh & Narosa	Narosa publishing house
5.	Non- Conventional Energy Resources	B. H. Khan	Tata McGraw Hill
6.	Non- Conventional Resources of Energy	G.S. Sawhney	PHI
7.	Non- Conventional Energy Resources	Shobh nath singh	Person India
8.	Solar Energy Engineering	Soteris Kalogirou	Elsevier/Academic Press
9.	Renewable Energy, power for a sustainable future	Godfrey Boyle, 2004	Oxford

14. SOFTWARE/LEARNING WEBSITES

1. http://vlab.amrita.edu/
2. https://nptel.ac.in/courses/112/105/112105051/
3. https://nptel.ac.in/courses/108/105/108105058/
4. https://nptel.ac.in/courses/121/106/121106014/
5. http://ocw.mit.edu/courses/energy-courses/
6. National Renewable Energy Laboratory (NREL), USA
7. Solar Energy Corporation of India Limited (SECI)
8. US Department of Energy, Energy efficiency & Renewable Energy
9. Ministry of New and Renewable Energy , New Delhi
10. Bureau of Energy Efficiency
11. Centre for Wind Energy Technology
12. The Energy Resource Institute

15. PO-COMPETENCY-CO MAPPING

Semester IV	Thermal Engineering-I (4341905)						
Semester IV	POs						
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
Competency & Course Outcomes	Basic & Discipline-specific knowledge	Problem Analysis	Design/ development of solutions	Engineering Tools, Experimentation& Testing	Engineering practices for society, sustainability & environment	Project Management	Life-longLearning
Competency	Basic understanding of new technologies and relate to the concepts, laws, and principles to design, deployment, operation, and maintenance of these new & renewable						

	technologies

CO-1: Understand the Energy Scenario of the India and evaluate Renewable energy potential in India	2	-	-	-	1	2	3
CO-2: Demonstrate the importance of solar energy collection & storage and evaluate the performance of various solar conversion systems	2	2	2	2	3	-	2
CO-3: Determine the principle of wind energy and evaluate the potential of wind energy conversion system	2	-	2	-	3	-	2
CO-4: Illustrate the biomass energy and its application	2	-	2	-	2	-	2
CO-5: Illustrate the geothermal, tidal, ocean, wave energy and its application	2	-	-	3	1	-	2

Legend: '3' for high, '2' for medium, '1' for low, and '-' for no correlation of each CO with PO.

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE (GTU Resource Persons)

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Mr. Rajendra Pandya – Sr Project Executive	Gujarat Energy Development Agency	9909922451	rnpandya58@gmail.com
2.	Mr. Shivam R Modi – Lecturer Mechanical	K. D. Polytechnic Patan	9724717421	ershivammodi69@gmail.com

17. BOS Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1	Dr. S. H. Sundarani, BOS Chairman & HOD Mechanical	Government Polytechnic, Ahmadabad	9227200147	**gpasiraj@gmail.com**
2	Dr. Rakesh D. Patel, BOS Member & HOD Mechanical	B. & B. Institute of Technology, V. V. Nagar	9825523982	**rakeshgtu@gmail.com**
3.	Dr. Atul S. Shah, BOS Member & Principal	B. V. Patel Institute of Technology, Bardoli	7567421337	**asshah97@yahoo.in**