GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
VI – Semester
Course Title: Green Technology
(Course Code: 4360904)

Diploma programmer in which this course is offered	Semester in which offered
Electrical Engineering	Sixth

1. RATIONALE

India has declared the goal to achieve net zero emissions by 2070. As India's growth story unfold, its demand for energy and resources is set to rise. Energy use has doubled in the last 20 years and is likely to grow by least another 25% by 2030. India currently imports over 40% of its primary energy requirement, worth over USD 90 billion every year. Major sectors of Indian economy depend on imported fossil fuels. This necessitates shift towards technologies that enable enhanced share of renewable source and progressively reduce the reliance on fossil fuels

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Understanding renewable energy technologies, optimization, regulation and Policies**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

COs	Statement
CO1	Describe the different sources of renewable energy
CO2	Analyze PV system performance.
CO3	Understand the operation of wind turbine generators.
CO4	Understand government policies for renewable energy sources

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+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 are the sub-components of the Course Outcomes (COs).

Sr. No.	Practical Outcomes	Unit No.	Approx. Hrs. Required
1	To plot the I – V characteristics of solar cell and determine fill factor.	II	2
2	Perform P – V characteristics of solar cell.	II	2
3	To measure efficiency of solar cell	II	2
4	To study effect of irradiance on the I – V and P – V characteristics of solar cell	II	2
5	Analyze the performance of solar panel based on tilt angle of solar panel	II	2
6	Analyze the performance of solar cell based on azimuth angle of the solar panel.	II	2
7	Estimate size of solar panel for small residential load	II	2
8	Estimate AC energy output of small solar farm considering	II	2

	fixed array, one axis tracking and dual axis tracking.		
9	Estimate AC energy output of small solar farm, cost of power plant and payback period.	II	2
10	To measure sunshine hours by using sunshine recorder	II	2
11	Measure solar irradiance & record it during solar time of a place	II	2
12	Prepare technical report on small solar farm / solar plant visit	II/III	4
13	Estimate Bifacial gain by the albedo in the solar panel	II	2

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 Practical	Weightage in %
1	Prepare experimental setup	20
2	Operate the equipment setup or circuit	20
3	Follow safety practices.	10
4	Record observations correctly	20
5	Interpret the result and conclude	30
		100

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	Practical No.
1	Solar Tracker (Track solar energy, Applications in solar radiation network, meteorological)	--
2	ISO 9060 Pyranometer (Solar Radiation Measurement)	--

3	Pyrgeometer (Highest Quality Scientific Solar Radiation for all weather condition)	--
4	Pyrheliometer (Radiometer for the measurement of direct normal irradiance)	--
5	Albedometer Mounting Kit (To measure ratio of irradiance reflected to the irradiance received)	--
6	Sunshine Duration Sensor (Product Link)	--
7	Data Logger (Non-power radiometer to display and record measurement of solar irradiance)	--
8	Solar IV Tester (To check deterioration in the solar system)	--
9	Digital Anemometer (Wind speed meter)	--
10	Wind vane sensor (Measure wind direction)	--
11	Thermal Imager or Thermography Camera (Detect hotspot in PV Modules)	--

7. AFFECTIVE DOMAIN OUTCOMES

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

a) Work as a leader/a team member (while doing a micro-project)
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 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

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 UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit 1 Renewable Energy Resources	• Understand the energy scenario in India and advance non-conventional energy resources	• Energy resource in India, India's total installed capacity, India's generation capacity, energy demand – supply, impact on environment due to fossil fuel • Yearly generation growth, Renewable energy generation state-wise • Advance non – conventional energy sources • Hydrogen: Characteristics, advantages, and applications • Green hydrogen, Blue hydrogen & Grey hydrogen • Biofuels, Bioethanol, Biodiesel, Advance Biofuels, Drop in fuels, bio CNG, Di-Methyl Ether
Unit-II Solar Energy	• Knowledge of solar energy and its potential • Understand various terminology associated with solar energy • Estimate solar energy output for different tilt angle, azimuth angle and tracking system	• Solar energy potential in India, National institute of solar energy, Off grid solar PV Programme • Intensity of light, Electromagnetic radiation • DNI, DHI, GHI and relation between them, factors affecting global irradiance • Albedo, Factors affecting albedo • Working of solar cell, Monocrystalline, Polycrystalline, Thin film solar cell, Comparison • Series & Parallel Connection of Solar array • Solar cell, modules and array • I – V and P – V Characteristics of Solar Cell, Maximum power point, fill factor, effect of irradiance on characteristic of solar cell • Sun – Earth relation: Equinox, Summer solstice, Winter solstice

		• Tilt angle & its case study. Solar hour angle, Declination angle, Altitude angle, Zenith angle, Azimuth angle & its case study • Orientation of solar panel, case study • Solar inverter: Grid connected inverter, central inverter, string inverter, micro inverter, off grid inverter, hybrid inverter, Estimation of inverter size and battery size • Solar tracking: single axis tracking, dual axis tracking, Cosine effect in solar tracking • Shadow analysis: distance between two arrays • Solar Farm, Case Study
Unit-III Wind Energy	• Estimate the wind energy potential in India • Understand HAWT, VAWT and working of wind measuring instruments • Classify wind generators	• Wind energy potential in India, Wind energy potential at 120 m, 150 m and above 150 m level • Wind power equation • Wind power curve • HAWT, VAWT, Savonius & Darries wind turbine • Wind speed measure instrument: Cup type, pitot tube type, impeller type, ultrasonic type, LIDAR and SODAR anemometer • Construction and working of wind generator: squirrel cage, wound rotor, double fed, wound rotor permanent magnet and permanent magnet synchronous generator
Unit-IV Renewable Energy Policies	• Describe Government Incentive Schemes & Policies to promote renewable energy	• Grid connected solar roof top solar programme, objectives, CFA for different sectors • Grid connected solar power projects • PM KUSUM Scheme, component A, component B and component C, incentives, Feeder level solarization scheme • Solar park and Ultra mega solar power plant policy • Wind data sharing policy • National offshore wind energy

		policy, 2015, objective of policy, incentives • Wind solar hybrid policy 2018, objective of policy, incentives, waiver of charges • National green hydrogen mission: Objectives and Incentives for electrolyzer and green hydrogen production

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Renewable Energy Resources	6	4	6	0	10
II	Solar Energy	18	8	14	8	30
III	Wind Energy	12	8	10	2	20
IV	Renewable Energy Policies	6	4	6	0	10
Total		42	24	36	10	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

The following student related co-curricular activities are suggested other than laboratory learning which are helpful to attain various outcomes of the course. Students should perform following activities in group (or individual) and prepare reports of about 5 pages for each activity.

a) Present seminar on course related topics
b) Group discussion on course related topics
c) Estimate solar energy potential in India
d) Prepare a display chart of solar energy map
e) Prepare chart of wind energy potential in India

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

There are some of the sample strategies that course teacher can implement to accelerate the attainment of various course outcomes.

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-projects are 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 in fact, an integration of Pracaticals, 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 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 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) Series and parallel connection of solar cell
b) Trainer kit for I – V characteristics of solar cell
c) Prepare display chart for HAWT and VAWT
d) Renewable energy map of India
e) Solar power bank
f) Mini solar power station
g) Solar street light
h) Solar study lamp
i) Solar display board
j) Small wind power station

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, Year and ISBN
1	Renewable and Efficient	Gilbert M.	John Wiley & Sons Ltd

	Electric Power Systems	Masters	
2	Energy Harvesting	Alireza Khaligh & Omer C. Onar	CRC Press, Taylor and Francis Group
3	Wind Power in Power Systems	Thomas Ackerman	John Wiley & Sons Ltd
4	Wind Energy	J.F.Manwell, J.G.Mcgowan, A.L. Rogers	John Wiley & Sons Ltd
5	Fundamental of photovoltaic modules and their applications	G N Tiwari & Swapnil Dubey	RSC Publishing
6	Renewable energy resources & Emerging technology	Kothari D P	PHI publications

14. SOFTWARE/LEARNING WEBSITES

- www.mnre.gov.in
- https://solarrooftop.gov.in/rooftop_calculator
- Solar energy corporation of India limited
- National renewable energy laboratory
- US Department of Energy
- Bureau of Energy Efficiency
- NPTEL Online Course – Renewable Energy
- NPTEL Online Course – Wind Energy

15. PO-COMPETENCY-CO MAPPING:

Semester VI	**Green Energy (Course Code:4320901)**						
	POs						
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**
Competency & Course Outcomes	Basic & Discipline specific knowledge	Problem Analysis	Design/ development of solution	Engineering Tools, Experiments and Testing	Engineering practices for society, sustainability & environment	Project Management	Life-long learning
Competency	**Understanding renewable energy technologies, distribution**						

	grid, regulation, and policies.						
Describe the different sources of renewable energy	1	1	-	1	-	-	-
Analyze PV system performance	1	2	1	2	-	1	2
Understand the operation of wind turbine generators.	1	-	-	1	-	-	-
Understand government policies for renewable energy sources	1	-	-	1	1	-	-

*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.	R D Panchal Lecturer Electrical Engg.	A. V. Parekh Technical Institute, Rajkot	9825776648	rajup1178@gmail.com
2.	B B Chauhan Lecturer Electrical Engg.	Government Polytechnic, Jamnagar	9925210010	bbc.gpjam@gmail.com