Course title: Renewable energy resource characteristics

Course code: ENR 122	**No. of credits:** 4	**L-T-P:** 49-11-0	**Learning hours:** 60
Pre-requisite course code and title (if any): Not required			
Department: Department of Energy and Environment			
Course coordinator: Dr. Som Mondal		**Course instructor(s):** Dr. Som Mondal / Dr. Naqui Anwer / Dr. Sapan Thapar	
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Course type: Core		**Course offered in:** Semester 1	

Course description

The course is designed to familiarize and train the student with the tools and techniques used to assess the various renewable energy resources and its potential at any location across the globe, so that a student is able analyse a case quantitatively at the end of the term.

Course objectives

The objective of the courses is to develop in-depth knowledge for the following:

- Various renewable energy resources available at a location and assessments of its potential, using tools and techniques.
- Solar energy radiation, its interactions, measurement and estimation
- Site selection for wind turbines, wind systems, measurements and instruments
- Develop and read hydrographs, estimate flow, head, and power
- Geothermal, wave, tidal and OTEC resources, site selection
- Properties critical for Bio-energy resource assessment, pathway selection, biomass supply

Course contents

Module	Topic	L	T	P
	SOLAR			
1	**Introduction** Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy, energy flow in ecosystem **Solar Energy Resources** Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extra-terrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution Sun-earth movement in different seasons, solar geometry, solar radiation on tilted surface, local apparent time, irradiance, insolation Attenuation of solar radiation by the atmosphere, albedo, beam and diffuse components of hourly and daily radiation, GHI and DNI, clearness index, Radiation augmentation Different climatic zones and their impact on site selection	1 2 2 2 1	1	0
2	**Measurement of solar radiation** Instruments: sunshine recorder, Pyranometer, Pyrheliometer, Albedometer. Radiation measurement stations in India (NIWE, IMD etc.), Hands-on measurement of beam, diffuse and total radiation Solar radiation data, graphs, Meteonorm, NASA-SSE and other databases, Daily, monthly and annul average radiation data analysis using annual and TMY data	3	2	0
3	**Prediction of available solar radiation** Solar mapping using satellite data, Typical Meteorological Year	2	2	0

	Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components			
	WIND			
4	**Introduction** Introduction to Atmospheric Boundary Layer Theory, Wind gradient and geographical importance, Wind energy database-Wind atlas	3	0	0
5	**Physics of Wind** Wind Systems in India as Case, Potential sites, diurnal and seasonal variations	6	0	0
6	**Basic Introduction to Wind Energy** Introduction to wind power, Worldwide Developments	2	1	0
7	Instruments used and measurement process wind data	4	2	0
	BIOMASS			
8	**Basics** Biomass resources: plant derived, residues, aquatic and marine biomass, various wastes, photosynthesis. **Biomass resource assessment** Estimation of woody biomass, non woody biomass and wastes, ASTM standards.	2 2	0	0
9	**Bulk chemical properties** Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids.	2	1	0
10	**Chemical composition of biomass** Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD.	2	1	0
11	**Structural properties** Physical structure, particle size and size distribution, permeability. Physical properties: Bulk density, angle of repose, thermal analysis (thermogravimetric, differential thermal and differential scanning calorimetry).Properties of microbial biomass: Protein estimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.	5	1	0
	SMALL HYDRO RESOURCES, GEOTHERMAL AND OCEAN RESOURCES			
12	**Basics** Indian resource potential and exploitation, power potential estimation, hydrographs. **Resource Assessment** Methods for determining head and flow, head and flow measurements, site evaluation, cartography, geotechnical studies.	2 2	0	0
	GEOTHERMAL AND OCEAN ENERGY			
13	Heat mining, potential sites, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks, estimation of wave power, tidal power sites, scatter diagram of wave heights, OTEC resource map.	4	0	0
		49	**11**	**0**

Evaluation criteria

- Quizzes/Assignments: 30% (During module 1-13)
- Written Test 1: 15% (after Module 1, 4, 8 and 9)

- Written Test 2: 15% (after Module 2,3, 5, 6,10)
- Written Test 3: 40% (after Module 7,11, 12, 13)

Learning outcomes

At the end of the course the student will be able to:

- Identify a Renewable Energy Resource at a given location [Test 1 and assignments]
- Assess/quantify the potential of the renewable-energy resources at a given location [Test 2, 3]
- Develop understanding for case studies [assignments and Test 3]

Pedagogical approach

A combination of class-room interactions, group discussion and presentations, tutorials and assignments

Materials

Text Books

Renewable Energy Engineering and Technology – A Knowledge Compendium, ed. VVN Kishore (TERI Press, 2008).

Reference Books

Donald Klass, "Biomass for Renewable Energy, Fuels, and Chemicals", Entech International Inc., USA
JA Duffie and WA Beckman, "Solar Engineering of Thermal Processes", Third Edition (John Wiley & Sons)
S Sukhatme and J Nayak, "Solar Energy: Principles of Thermal Collection and Storage", Third Edition (Tata McGraw Hill, 2008)
TERI Energy Data Directory (TEDDY) 2016 (TERI Press, 2016)

Websites

Ministry of new and renewable energy
Planning commission

Additional information (if any)

There will bes test before and after the completion of the course

Student responsibilities

Attendance, timely feedback, discipline: as per university rules, adopt peer learning and knowledge sharing within the class

Course reviewers

1. Prof. R N Singh, Professor, School of Energy and Environmental Studies, Devi Ahilya Vishwavidyalaya, Indore
2. Prof. J S Saini, Professor Emeritus, Department of Mechanical and Industrial Engineering, IIT Roorkee
3. Dr. R.L. Sawhney, Former Professor, TERI Unievrsity, Delhi; School of Energy and Environmental Studies, Devi Ahilya Vishwavidyalaya, Indore