COURSE SYLLABUS
for
M. Tech. (Agril. Engg.)
in
Renewable Energy Engineering

(Approved by Academic Council vide resolution No. 7644, dat. 07.12.2022)

ODISHA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR-751003

M.Tech.(Agril. Engg.) in Renewable Energy Engineering

Major Courses (Requirement: 20 Credits)

Sl. No.	Course Code	Name of the Course	Credit Hour
1.	REE 501*	Renewable Energy Technologies	2+1
2.	REE 502*	Solar Thermal Energy Conversion Technologies	2+1
3.	REE 503*	Biomass Energy Conversion Technologies	2+1
4.	REE 504	Energy Auditing, Conservation and Management	2+1
5.	REE 505	Wind Energy Conversion and Utilization	2+1
6.	REE 506	Solar Photovoltaic System Design and Analysis	1+1
7.	REE 507	Renewable Energy Policy, Planning and Economics	3+0
8.	REE 510	Energy, Ecology and Environment	3+0
9.	REE 513	Agro Energy Audit and Management	2+1
10.	REE 515	Energy Management in Food Processing Industries	1+1

*Compulsory Course

Minor Courses (Requirement: 08 Credits)

Sl. No.	Course Code	Name of the Course	Credit Hour
1.	FMPE 517	Machinery for Precision Agriculture	2+1
2.	ASCE 501	Dimensional Analysis and Similitude	2+1
3.	CSE 501	Big Data Analytics	2+0
4.	CSE 502	Artificial Intelligence	2+0
5.	MATH 501	Finite Element Methods	3+0
6.	FMPE-502	Testing and Evaluation of Agricultural Equipment	2+1
7.	ME 501	Mechatronics and Robotics in Agriculture	2+1

Any other course(s) of other department other than courses from major can be taken as per recommendations of the student's advisory committee.

Supporting Courses (Requirement: 06 Credits)

Sl. No.	Course Code	Name of the Course	Credit Hour
1.	*STAT 501	Statistical Methods for Research Works	2+1
2.	EE 501	Applied Instrumentation	2+1
3.		Courses from subject matter fields (Other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee	

*Compulsory Course

Common Courses (Requirement: 05 Credits)

Sl. No.	Course Code	Name of the Course	Credit Hour
1.	*PGS 501	Library and Information Services	1+0
2.	*PGS 502	Technical Writing and Communication Skills	0+1
3.	*PGS 503	Intellectual Property and its management in Agriculture	1+0
4.	*PGS 504	Basic Concepts in Laboratory Techniques	0+1
5.	*PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

*Detailed course outline to be developed by designated BSMA

List of Other Essential Requirements

Sl. No.	Course Code	Name of the Course	Credit Hour
1.	REE 591	Seminar	0+1
2.	REE 599	Research for Thesis	0+30

SEMESTER WISE COURSE DISTRIBUTION

M.Tech (Agril. Engg.) Renewable Energy Engineering

Sl. No.	Course Title	Course No.	Major	Minor	Supporting	Common courses
SEMESTER-I						
1	Applied Instrumentation	EE 501			2+1	
2	Renewable Energy Technologies	REE 501*	2+1			
3	Solar Thermal Energy Conversion Technologies	REE 502*	2+1			
3	Biomass Energy Conversion Technologies	REE 503*	2+1			
4	Energy Auditing, Conservation and Management	REE 504	2+1			
5	Statistical Methods for Research Works	STAT 501*		2+1		
6	Testing and Evaluation of Agricultural Equipment	FMPE 502		2+1		
7	Finite Element Methods	MATH 501		2+1		
8	Artificial Intelligence	CSE 502		2+0		
9	Library and Information Service	PGS 501*				1+0
10	Basic Concepts in Laboratory Techniques	PGS 504*				0+1
SEMESTER-II						
1	Wind Energy Conversion and Utilization	REE 505	2+1			
2	Solar Photovoltaic System Design and Analysis	REE506	1+1			
3	Agro Energy Audit and Management	REE 513	2+1			
4	Dimensional Analysis and Similitude	ASCE 501		2+1		
5	Numerical Methods for Engineers	MATH 502		2+1		
6	Big Data analysis	CSE 501		2+0		
7	Mechatronics and Robotics in Agriculture	ME 501		2+0		
8	Technical Writing and Communication Skills	PGS 502*				0+1
9	Agricultural Research, Research Ethics and Rural Development Programmes	PGS 505*				1+0
10	Thesis Research	REE599 (0+5)				
SEMESTER-III						
1	Renewable Energy Policy, Planning and Economics	REE 507	3+0			
2	Energy Management in Food Processing Industries	REE 515	1+1			
3	Computer Aided Design of Machinery	FMPE 515		0+2		
4	Soft Computing Techniques in Engineering	CSE 504		2+1		
5	Intellectual Property and its Management in Agriculture	PGS 503*				1+0
6	Thesis Research	REE599 (0+10)				
SEMESTER-IV						
1	Thesis Research	REE 599 (0+15)				
2	Seminar	REE 591 (0+1)				

The students of M. Tech (Ag. Engg.) course will have to take a minimum of 65 credit hours as given below:

Type of course	Minimum credit hours
A. Course Work	
i) Major course	20
ii) Minor course	08
iii) Supporting course	06
iv) Non–credit compulsory course	--
v) Seminar	01
Sub-Total	35
B. Thesis	30
Grand Total	65

Course Contents
M.Tech. in Renewable Energy Engineering

I. **Course Title : Renewable Energy Technologies**

II. **Course Code : REE 501**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To provide knowledge, understanding and application oriented skills on renewable energy sources and relevant technologies towards their effective utilization for meeting energy demand.

V. **Theory**

Unit I

Solar Energy: Heat transfer, estimation and physical conversion, Instruments for measurement. Energy collection and analysis: FPC, ETC, concentrating collectors. Solar energy application: Direct and indirect. Solar photovoltaic technology: Conversion, Systems components, integrations and applications.

Unit II

Energy from biomass and wastes: Production, distribution, characterization, treatments, recycling. Biomass conversion technologies: Thermo-chemical, bio- chemical and agro-chemical technology. Raw materials, process parameters, end products and utilization.

Unit III

Wind energy: Resource estimation, technologies, performance curves, power and torque characteristics. Airfoils and rotors: Wind mill parameters, wind farms design and considerations.

Unit IV

Alternate Energy Technologies: Ocean Thermal Energy Conversion, Geothermal, Tidal, Hydro. Energy conversion systems: Resources, systems integrations and analysis, applications. Energy storage: Types, materials, characteristics and application.

VI. **Practical**

Analysis of solar collectors. Solar Photovoltaic cell characteristics, analysis of SPV systems. Characterization of biomass. Design and benefit analysis of energy systems. Design and efficiency testing of wind energy conversion devices.

VII. **Learning outcome**

The students is acquainted the skill to understand technical aspects and principles of renewable energy characteristics of the resource base (solar radiation, wind energy, bio energy, etc.) In a further steps an economic analysis of supply technologies.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Solar energy: introduction. Solar radiations measuring Instruments	1
2.	Passive Flat plate solar collectors, types. Passive solar water heaters. Performance of solar water heater. Effect of various parameters on performance	2
3.	Solar passive concentrators: Brief introduction to main types of solar concentrators, solar cookers	1
4.	Solar passive crop dryers: Description of various types of solar crop dryers, Applications of solar crop dryers	2
5.	Solar photovoltaic technology: Conversion, Systems components, integrations and applications	2
6.	Biomass Production, distribution, characterization, treatments, recycling.	1
7.	Review of gasifiers basics; Selection criteria for type and capacity of gasifier; Performance parameters for gasifiers e.g. SGR, turn down ratio etc;	1
8.	Basic design of small scale Imbert type downdraft gasifier (without use of Tables) and Basic features of throatless and inverted downdraft gasifiers (No designing)	1
9.	Baling for densification of biomass and briquetting machines for densification of biomass	1
10.	Bio-chemical and agro-chemical technologies for biomass conversion	2
11.	Raw materials, process parameters, end products and utilization for bio-chemical and agro-chemical technologies	2
12.	Resource estimation of wind energy, technologies and performance curves	2
13.	Power and torque characteristics	2
14.	Wind mill parameters	2
15.	Wind farms design and considerations	2
16.	Ocean Thermal Energy Conversion	2
17.	Geothermal, Tidal and Hydro Energy conversion systems	2
18.	Energy storage: Types, materials, characteristics and application	4
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Analysis of solar collectors	3
2.	Solar Photovoltaic cell characteristics, analysis of SPV systems	3
3.	Characterization of biomass	4
4.	Design and benefit analysis of energy systems	3
5.	Design and efficiency testing of wind energy conversion devices	3
	Total	**16**

X. Suggested Reading

- Culp AW. 1991. *Principles of Energy Conversion.* McGraw-Hill Pub. Co Inc., New York.
- Duffie JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New York.
- Garg HP and Prakash J. 1976. *Solar Energy, Fundamentals and Applications*. Tata McGraw-Hill Pub. Co. Inc., New Delhi.
- Odum HT and Odum EC. 1976. *Energy Basis for Man and Nature*. McGraw-Hill Pub. Co. Inc., New York.
- Rai GD. 2001. *Non Conventional Energy Sources*. Khanna Publishers, Delhi.
- Sukhatme SP. 1997. *Solar Energy, Principles of Thermal Collection and Storage*. Tata McGraw-Hill. Pub. Co. Ltd, New Delhi.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd., London.
- **Ahmed F. Zobaa,Ramesh C. Bansal 2011, HANDBOOK OF RENEWABLE ENERGY TECHNOLOGY, ,** World Scientific Publishing Co. Pte. Ltd., Singapur
- Jean-Claude Sabonnadière , 2009, Renewable Energy Technologies, , Wiley-ISTE, INPG, Grenoble, France.
- KOTHARI, D.P., SINGAL, K. C., RANJAN, RAKESH, 2011, Renewable Energy Sources And Emerging Technologies, , PHI learning Pvt. Ltd, New Delhi
- SOLANKI, CHETAN SINGH, 2009 Renewable Energy Technologies : A Practical Guide For Beginners, PHI learning Pvt. Ltd, New Delhi
- Mehmet Kanoglu , Yunus A. Cengel ,John M. Cimbala, 2020, Fundamentals and Applications of Renewable Energy , McGrawHill

I. Course Title : Solar Thermal Energy Conversion Technologies

II. Course Code : REE 502

III. Credit Hours : 2+1

IV. Aim of the course

To provide in-depth knowledge, understanding and application oriented skills on solar thermal conversion technologies and their effective utilization for meeting energy demand.

V. Theory

Unit I

Characteristics of solar radiation: Attenuation, absorption, scattering and air mass. Solar earth geometry.

Unit II

Solar flux and weather data. Solar radiation data and estimation: Radiation estimation models and applications. Heat and mass transfer in solar energy utilization: Gray surface, sky radiation, radiation heat transfer coefficient, reflectivity, transitivity, transmittance absorption product. Selective surfaces and materials.

Unit III

Solar thermal energy collectors (track and untrack): Heat capacity effect, time constant measurement, design and efficiency calculations, F chart method utility.

Unit IV

Techno-economic feasibility of solar thermal energy applications: Cooking, air heating for drying, steam generation, space heating and cooling, refrigeration, architecture, absorption cooling, thermal power generation.

VI. Practical

Solar radiation measurement, estimation model applications, design of collectors, study of materials used in solar system. Energy balance and efficiency calculationof collectors.

VII. Learning outcome

The student is able to understand the detail knowledge about working and design of various solar thermal devices able to design different solar thermal devices.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Introduction to characteristics of solar radiation and Solar earth geometry	2
2.	Solar fluX and weather data measurement and interpretation	2
3.	Estimation of Solar radiation data using models and estimation	3
4.	Heat and mass transfer in solar energy utilization	2
5.	Gray surface, sky radiation, radiation heat transfer coefficient	2
6.	Reflectivity, Transitivity, Transmittance Absorption	2
7.	Selective surfaces and materials as solar energy collectors	2
8.	Heat capacity effect, time constant measurement of solar energy	2
9.	Design and efficiency calculations of Solar thermal energy	4

Sl. No.	Topic	No. of Lectures
	collectors	
10.	F chart method utility for Designing Solar Thermal Water Heating Systems	2
11.	Techno-economic feasibility of solar thermal energy in cooking, drying of food products, space heating and cooling.	4
12.	Economic feasibility of solar thermal energy in refrigeration, architecture, absorption cooling, thermal power generation.	4
	Total	**30**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Measurement of Solar radiation	1
2.	Estimation of solar energy by model applications	2
3.	Design of solar energy collectors	2
4.	Study of materials used in solar system	1
5.	Energy balance in solar energy collectors	2
6.	Efficiency calculation of collectors	2
	Total	**10**

X. Suggested Reading

- Bansal NK, Kleeman MK and Meliss M. 1990. *Renewable Energy Sources and Conversion Technologies*.Tata McGraw-Hill Pub. Co. Ltd, Delhi.
- Duffie JA and Beckman WA. 2006. *Solar Thermal Engineering Process*. John Wiley & Sons, New Jersey.
- Hsien JS. 2014. *Solar Energy*. Prentice Hall Inc., New Jersey.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company,Dordrecht, Netherland.
- Kalogirou SA. 2013. *Solar Energy Engineering.* Academic Press, Cambridge, Massachusetts.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.
- Pai BR and Ramaprasad MS. 1991. *Power Generation through Renewable Sources of Energy.*
  Tata McGraw-Hill Pub. Co., New Delhi.
- Sukhatme SP and Nayak J. 2008. S*olar Energy: Principles of Thermal Collection and Storage*.Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

I. Course Title : Biomass Energy Conversion Technologies

II. Course Code : REE 503

III. Credit Hours : 2+1

IV. Aim of the course

To understand the bio-conversion technologies and fuels system, types of biomass derived fuels and energy, thermo-chemical conversion of biomass to heat and power, value adding of agro-residues.

V. TheoryUnit I

Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept. Direct use of biomass: Size reduction, baling, pelletization, briquetting technologies.

Unit II

Biochemical conversion of biomass: Feedstock, process design, operation, optimized process parameters and utilization for biogas and bioethanol production.

Unit III

Biomass combustion: Stoichiometric air requirement, chemistry of combustion, design of combustion system, combustion zones, flame structure, stability, emissions. Co-firing of biomass.

Unit IV

Thermo-chemical conversion of biomass: Feedstock, chemistry, reactor design, operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.

Unit V

Cogeneration technologies: Cycles, topping, bottoming, selection, problems, applications. Waste heat recovery: Estimation, systems, design and application.

VI. Practical

Biomass characterization. Design of bioreactors. Study of techno-economical feasibility of bio-chemical conversion process. Performance evaluation of combustion gadgets, gasifiers and pyrolytic converters. Design of waste heat recovery system.

VII. Learning outcome

The students is enable to eXtract the energy from biomass and acquainted the skill to know how to choose the suitable biomass fuels for different industrial applications with design and economics of the system.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept.	3
2.	Direct use of biomass	1
3.	Size reduction, baling, pelletization, briquetting technologies.	2
4.	Biochemical conversion of biomass	1

Sl. No.	Topic	No. of Lectures
5.	Feedstock, process design, operation, optimized process parameters.	2
6.	Utilization for biogas and bioethanol production.	1
7.	Biomass combustion	1
8.	Stoichiometric air requirement, chemistry of combustion.	3
9.	Design of combustion system.	2
10.	Combustion zones, flame structure, stability, emissions.	2
11.	Co-firing of biomass.	1
12.	Thermo-chemical conversion of biomass: Feedstock, chemistry.	2
13.	Reactor design.	1
14.	Operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.	2
15.	Cogeneration technologies: Cycles, topping, bottoming, selection.	2
16.	Cogeneration Problems and applications.	2
17.	Waste heat recovery	2
18.	Estimation, systems, design and application.	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Characterization of biomass	2
2.	Design of bio-reactors	1
3.	Determination of techno-economical feasibility of bio-chemical conversion process.	2
4.	Performance evaluation of combustion gadgets	1
5.	Performance evaluation of gasifiers	1
6.	Performance evaluation of pyrolytic converters	1
7.	Design of waste heat recovery system	2
	Total	**10**

X. Suggested Reading

- Chakravorty A. 1985. *Biogas Technology & other Alternative Technologies*. Oxford & IBH Publication Ltd, Delhi.
- Chaturvedi P. 1995. *Bio-Energy Resources: Planning, Production and Utilization*. Concept Pub. Co., New Delhi.
- Goswami DY. 1986. *Alternative Energy in Agriculture*.Vol. II (Ed), CRC, Press Inc., Florida, USA.
- Stout BA. 1984. *Biomass Energy Profiles*. FAO Agril. Services Bulletin No.54., Elsevier Science Publishers Ltd, England.
- Twidell JW and Weir AD. 2006. *Renewable Energy Sources*. E & F N Spon Ltd, New York.

- Vimal OP. 1984. *Energy from Biomass*.Agrcole Publishing Academy, New Delhi.

I. Course Title : Energy Auditing, Conservation and Management

II. Course Code : REE 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint and equip about the sources of energy, conservation of energy and its management. Study of energy efficiency, energy planning, forecasting and energy economics.

V. TheoryUnit I

Energy conservation: Concepts, energy classification, equivalents, scenario, energy pricing, importance. Energy conservation act.

Unit II

Energy auditing and economics: Energy management, energy audit strategy, types. Energy performance: Bench marking, fuel substitutions, energy audit instruments, material and energy balance. Energy conversion: Energy indeX, cost indeX. Financialmanagement.

Unit III

Thermal energy audit: Performance evaluation, energy conservation opportunities inboilers, steam system and furnaces, insulation, refractory's and other thermal utilities.

Unit IV

Electrical Energy audit: Electrical systems, electricity billing, load management, power factor. Performance evaluation and energy conservation opportunities in motors, compressed air system, HVAC and refrigeration system, fans and blowers, pumps and lighting system.

Unit V

Energy auditing and reporting in industries, Replacement of renewable energy technology option, case study in agro-industries.

VI. Practical

Problems on energy indeX, cost indeX. Problems on material balance and energy balance. Financial management. Energy audit and conservation opportunities in thermal and electrical utilities. Case studies on energy audit and conservation.

VII. Learning outcome

Able to understand the concept of energy auditing, conservation and management. The in-depth knowledge about the quantification, conservation opportunity and retrofitting of energy efficient system integration is eXpected from the course.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Energy conservation: Introduction, Concepts, Scenario	2
2.	Classification of Energy	1
3.	Energy equivalents, energy pricing, importance.	2
4.	Energy conservation act.	2
5.	Introduction to energy management, energy audit strategy and types.	2
6.	Energy performance: Bench marking, fuel substitutions.	1
7.	Energy audit instruments, material and energy balance.	2

Sl. No.	Topic	No. of Lectures
8.	Energy conversion: Energy index, cost index. Financial management.	2
9.	Performance evaluation and energy conservation opportunities in boilers.	1
10.	Insulation, refractory's and other thermal utilities.	2
11.	Performance evaluation and energy conservation opportunities in steam system and furnaces.	2
12.	Electrical Energy audit: Electrical systems, electricity billing, load management, power factor.	2
13.	Performance evaluation and energy conservation opportunities in motors, compressed air system.	2
14.	Performance evaluation and energy conservation opportunities in HVAC and refrigeration system.	2
15.	Performance evaluation and energy conservation opportunities in fans and blowers, pumps and lighting system.	2
16.	Energy auditing and reporting in industries.	1
17.	Replacement of renewable energy technology option.	2
18.	Case study in agro-industries.	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Problems on energy index.	2
2.	Problems on cost index.	2
3.	Problems on material balance.	2
4.	Problems on energy balance.	2
5.	Financial management.	2
6.	Energy audit and conservation opportunities in thermal utilities.	2
7.	Energy audit and conservation opportunities in electrical utilities.	2
8.	Case studies on energy audit and conservation.	2
	Total	**16**

X. Suggested Reading

- *Energy Management*, *Bi-monthly Journal* National Productivity Council, New Delhi.
- Guide Books for *National Certification Examination for Energy Managers and Energy Auditors,* Book 1–4, 2005 Bureau Energy Efficiency, New Delhi.
- Murgai MP and Chandra R. 1990. *Progress in Energy Auditing and Conservation, Boiler Operations.* Wiley Eastern Ltd, New Delhi.
- Murphy WR and McKay G. 1982. *Energy Management*. Butterworth & Co., Publishers Ltd., London.
- Porter R and Roberts T. 1985. *Energy Saving by Waste recycling*. Elsevier applied science publishers, New York, USA.
- Smith CB. 1981. *Energy Management Principles, Applications, Benefits and Savings*. Pergamon Press Inc., Oxford, England.
- Victor B. 1983. *Ottaviano, Energy Management*. An OTIS Publication, Ottaviano

Technical Service Inc., Melville, New York.

I. **Course Title : Wind Energy Conversion and Utilization**

II. **Course Code : REE 505**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To acquire the in-depth knowledge of wind energy conversion systems, wind potential mapping, estimation and analysis of wind data.

V. **Theory**

Unit I

Wind mapping and assessment: Wind energy potential, nature of wind, Weibull and Rayleigh analysis, instruments, history andpower laws.

Unit II

Wind turbine aerodynamics: Momentum theories, basic aerodynamics, airfoils and their characteristics. Horizontal AXis Wind Turbine (HAWT): Blade element theory, wake analysis. Vertical AXis Wind Turbine (VAWT): Aerodynamics, rotor design, power regulation, yaw system.

Unit III

Selection of site. Mechanical and electrical applications. Wind farms: Interfacing, maintenance. Management of power generated by wind mill: Instruments and controls. Stand alone and grid connected systems. Wind energy storage. Wheeling and banking. Cost economics. Testing and certification procedures.

Unit IV

Wind turbine loads: Aerodynamic loads in steady operation, wind turbulence, static. Wind energy control system (WECS). Synchronous and asynchronous generators. Annual Energy Output (AEO). Testing of WECS.

VI. **Practical**

Visit to meteorological observatory. Wind velocity mapping and curve analysis. Wind energy instruments and resource assessment. Design of wind mills, water pumping wind mills. Performance evaluation of wind aero-generator. Wind turbine loads. Economics of wind energy systems.

VII. **Learning outcome**

The students will acquire knowledge regarding mechanism of wind energy and different types of wind machines available to harness wind power and also able to design wind turbine for irrigation as well as for power generation.

VIII. **Lecture Schedule**

Sl. No.	Topic	No. of Lectures
1.	Mapping of Wind energy and its assessment, nature of wind, Wind energy potential	2
2.	Weibull and Rayleigh analysis	2
3.	Instruments, history and taxonomy of wind mills, wind power laws	2
4.	Aerodynamics of Wind turbine, Momentum theories, airfoils and their characteristics	3
5.	Elemental theory of Horizontal and Vertical Axis Wind Turbine (HAWT)	2
6.	Aerodynamics of wind turbines, rotor design, power regulation,	2

Sl. No.	Topic	No. of Lectures
	yaw system	
7.	Selection of site for wind mill installation, Mechanical and electrical applications of wind mills	2
8.	Wind farms: Interfacing and maintenance, Instruments and controls for management of power generated by wind mill	3
9.	Stand alone and grid connected systems, Wind energy storage, Wheeling and banking.	2
10.	Economics of wind mills	2
11.	Testing and certification procedures for wind mills	3
12.	Wind turbine Aerodynamic loads in steady operation, wind turbulence, static.	2
13.	Wind energy control system (WECS), Synchronous and asynchronous generators	2
14.	Annual Energy Output (AEO), Testing of Wind energy control system	3
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Visit to meteorological observatory	1
2.	Wind velocity mapping and curve analysis	2
3.	Wind energy instruments and resource assessment	1
4.	Design of wind mills	1
5.	Water pumping wind mills	1
6.	Performance evaluation of wind aero-generator	2
7.	Study of Wind turbine loads	2
8.	Economics of wind energy systems.	2
	Total	**12**

X. Suggested Reading

- Cheremision NP. 1978. *Fundamental of Wind Energy*: Ann Arbor Science, Pub. Inc., Michigan.
- Eldridge FR. 1980. *Wind Machines*. Van Nostr and Reinhold Co., New York.
- More HG and Maheshwari RC. *Wind Energy Utilization in India,* Technical Bulletin No.CIAE/82/38, CIAE, Bhopal.
- Lipman NH, Muggrove PJ and Pontin GW. 1982. *Wind Energy for the Eighties*. Peter Peregrinus Ltd. Stenvenage, New York.
- Lysen EH. 1983. *Introduction to Wind Energy*. Consultancy Services Wind Energy Developing Countries, Netherlands.
- Manwell JF, McGswan JG and Rogers AL. 2012. *Wind Energy Explained–Theory Design and Application*. John Wiley and Sons, New Jersey.
- Powar AG and Mohod AG. 2010. *Wind Energy Technologies*. Jain Publication, New

Delhi.

I. Course Title : Solar Photovoltaic System Design and Analysis

II. Course Code : REE 506

III. Credit Hours : 1+1

IV. Aim of the course

To provide detail knowledge about working and design of various solar photovoltaic systems for power generation.

V. TheoryUnit I

Physics of solar cells: Crystal structure, band theory, semiconductor, p-n junctions, absorption of radiation, generation, recombination and carrier separation. Standard solar cell structure: I,V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature.

Unit II

Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies, Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion. Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies.

Unit III

Solar PV systems: Balance of System (BoS), SPV system design guideline and methodologies, introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use. Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.

Unit IV

Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.

VI. Practical

Solar cell efficiency testing. SPV fabrication technologies. System integration and BoS matching studies. PV software's operation and utilization. Design and estimation of SPV systems components for agrobased industrial applications. Batteries performance testing.

VII. Learning outcome

Student is able to design different solar photovoltaic system for power generation with system integration and economic analysis.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Physics of solar cells: Crystal structure, band theory, semiconductor, p-n junctions	1
2.	Absorption of radiation, generation, recombination and carrier separation.	2
3.	Standard solar cell structure: I,V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature.	2
4.	Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies.	1
5.	Third generation/emerging PV technologies: Organic PV, Dye	1

Sl. No.	Topic	No. of Lectures
	sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion.	
6.	Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies.	2
7.	Solar PV systems: Balance of System (BoS), SPV system design guideline and methodologies,	1
8.	Introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use.	2
9.	Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.	2
10.	Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), Fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.	2
	Total	**16**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level and efficiency determination.	1
2.	To demonstrate the I-V and P-V characteristics of series combination of PV modules and efficiency determination.	1
3.	To demonstrate the I-V and P-V characteristics of parallel combination of PV modules and efficiency determination.	1
4.	To show the effect of variation in tilt angle on PV module power.	1
5.	To demonstrate the effect of shading on module output power and efficiency determination.	1
6.	Study on SPV fabrication technologies.	1
7.	Study on system integration and BoS matching.	1
8.	PV software's operation and utilization.	1
9.	Design and estimation of SPV systems components for agrobased industrial applications.	1
10.	Battery performance testing.	1
	Total	**10**

X. Suggested Reading

- Garg HP. 1990. *Advances in Solar Energy Technology*. D. Publishing Company, Tokyo.
- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications.* Prentice Hall, Upper Saddle River, New Jersey.
- Kreith F and Kreider JF. 1978. *Principles of Solar Engineering*. McGraw-Hill, New York.
- Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education.* John Wiley & Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Ltd, Delhi.
- Sze SM and Kwok K Ng. 2007. *Physics of Semiconductor Devices*. 3rd Edn. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. Vol.5. McGraw-Hill, New York.
- D. Yogi Goswami, Principles of Solar Engineering. 2022, CRC press,

- Chetan Singh Solanki, "*Solar Photovoltaic: Fundamentals, Technologies and application*", PHI learning Pvt., 2011.

I. Course Title : Renewable Energy Policy, Planning and Economics

II. Course Code : REE 507

III. Credit Hours : 3+0

IV. Aim of the course

To provide the in-depth knowledge about the current energy policy and planning, environmental economics, policy and ecology.

V. Theory

Unit I

Introduction to policy parameters, regulatory bodies. Introduction to overall policy environment on energy sector, policy formulation parameters. Entities: Consumers and their tariffs, generator, DISCOM, Regulators: CERC and SERC, Statutory bodies. Typical issues of Indian power sector.

Unit II

Indian energy Policy: Introduction, Electricity Act, National Policy on Tariff, Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions. Concept of Grid Code, Green Corridor, Solar and Hybrid Parks. Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.

Unit III

Policy and planning: Energy, environment interaction, clean development mechanism, financing of energy systems, software for energy planning, socio- economical approach. Project management in energy: Cost economics-sensitivity and risk analysis.

Unit IV

Energy economics: economic evaluation of renewable energy systems, life cycle costing, components of energy investment and risk and uncertainties in energy investment.

VI. Learning outcome

A student is be able to develop an interdisciplinary knowledge base that will enable them to understand and solve contemporary energy policy, planning and environmental problems.

VII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Introduction to policy parameters and regulatory bodies in Energy	2
2.	Introduction to overall policy environment on energy sector, policy formulation parameters	3
3.	Entities: Consumers and their tariffs	2
4.	Generator, DISCOM, Regulators: CERC and SERC, Statutory bodies.	3
5.	Typical issues of Indian power sector.	2
6.	Introduction to Indian energy Policy and Electricity Act	3
7.	National Policy on Tariff	2
8.	Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions	3

Sl. No.	Topic	No. of Lectures
9.	Concept of Grid Code, Green Corridor, Solar and Hybrid Parks.	3
10.	Clean development mechanism, financing of energy systems	3
11.	Policy and planning in Energy, environment interaction	2
12.	Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.	4
13.	Software for energy planning, socio-economical approach.	3
14.	Project management in energy: Cost economics-sensitivity and risk analysis.	4
15.	Energy economics: economic evaluation of renewable energy systems	3
16.	Life cycle costing, components of energy investment	3
17.	Risk and uncertainties in energy investment	3
	Total	**48**

VIII. Suggested Reading

- BEE Reference book: no.1/2/3/4.
- Bhattacharyya SC. 2011. *Energy Economics*. Springer, New York City, USA.
- Brown CE. 2002. *World Energy Resources.* Springer, New York City, USA.
- Conti J. 2016. *International Energy Outlook.* US Energy Information Administration (*EIA*), Washington.
- Culp AW. 1991. *Principles of Energy Conversion*. McGraw-Hill Int. edition, New York.
- Krithika PR and Mahajan S. 2014. *Governance of Renewable Energy in India: Issues and Challenges*. TERI, New Delhi.
- Parikh JK. 1981. *Modeling Approach to Long Term Demand and Energy Policy Implication for India.* IIASA, Laxenburg, Austria.
- Reddy AKN, Williams RH, Goldenberg J and Johansson TB. 1987. *Energy for a Sustainable World.* Wiley-Eastern Ltd, New Delhi, India.
- TEDDY Year Book Published by Tata Energy Research Institute (TERI).

I. Course Title : Alternate Fuels and Applications

II. Course Code : REE 508

III. Credit Hours : 2+1

IV. Aim of the course

To get acquainted with various alternate fuels, their applications and also to learnsafety factors of alternate fuel, efficiency, economics and commercial considerations.

V. Theory

Unit I

Introduction to alternate fuels: Methanol, ethanol, biogas, producer gas, hydrogen and fuel cell. Production composition and properties, combustion characteristics, comparison with conventional fuels, potential, possibilities and problems.

Unit II

Fuel cell: Principle, classification, system efficiency. Life cycle assessment of fuel cell

systems.

Unit III

Hydrogen fuel: Production, gas cleanup, challenges and opportunities. Hydrogen storage and energy economy.

Unit IV

Utilization: Thermal and mechanical applications. Environmental impact and safety factors of alternate fuel, efficiency, economics and commercial considerations.

VI. Practical

Performance of I.C. engines on alternate fuels, measurement of flue gas parameters, thermal applications of alternate fuels. Hydrogen production. Biomass based fuel cell. Integrated biomass based gasifier for power generation.

VII. Learning outcome

Students will understand various properties of alternate fuels like methanol, ethanol, fuel cells, hydrogen fuel for energy efficient utilization.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Introduction to alternate fuels: methanol, ethanol, biogas, producer gas, and hydrogen fuel cell.	3
2.	Alternate fuels: potential, possibilities and problems.	2
3.	Production, composition and properties of methanol.	2
4.	Production, composition and properties of ethanol.	2
5.	Production, composition and properties of biogas.	2
6.	Production, composition and properties of producer gas.	2
7.	Production and properties of hydrogen fuel cell.	2
8.	Combustion characteristics of alternate fuels, comparison of with conventional fuels.	3
9.	Fuel cell: Principle, classification, system efficiency.	2
10.	Life cycle assessment of fuel cell systems.	2
11.	Hydrogen fuel: gas cleanup.	2
12.	Hydrogen fuel: challenges and opportunities	2
13.	Hydrogen storage and energy economy.	1
14.	Thermal and mechanical applications alternate fuel.	2
15.	Environmental impact and safety factors of alternate fuels, efficiency, economics and commercial considerations.	3
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Performance of I.C. engines on alternate fuels (biogas, producer gas	3

	and bio diesel)	
2.	Measurement of flue gas parameters.	1
3.	Thermal applications of alternate fuels (biogas, producer gas and bio diesel)	3
4.	Hydrogen production.	1
5.	Biomass based fuel cell.	1
6.	Integrated biomass-based gasifier for power generation.	1
	Total	**10**

X. Suggested Reading

- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization inCombustion Engines*. CRC Press, Florida.
- Bungay HR. 1981. *Energy, the Biomass Options.* John Willey & Sons, New York.
- Dahiya A. 2014. *Bioenergy: Biomass to Biofuels*. *Engines*. Springer, New York City, NewYork.
- Demirbas A. 2010. *Biodiesel: A Realistic Fuel Alternative for Diesel Chemicals*. Academic Press, Cambridge, England.
- Klass DL. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals.* Academic Press, Cambridge, England.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India.
- San PA. 1980. *Biochemical and Photosynthetic: Aspects of Energy Production*. Academic Press. London.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press. Florida.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd, New York.

I. Course Title : Biogas Technology and Mechanism

II. Course Code : REE 509

III. Credit Hours : 1+1

IV. Aim of the course

To provide the in-depth knowledge about biogas technology and its mechanism in detail to use the biogas as domestic as well as commercial fuel.

V. Theory

Unit I

Biogas Technology: Potential and status, chemistry, physical conditions and utilization of alternate feedstock materials.

Unit II

Types of reactors: Single phase, two phase processes. High rate biomethanation process, selection of model and size, construction technique, material requirement. Design concept of night soil, kitchen waste, solid state cold condition biogas plants.

Unit III

Biogas distribution and utilization: Properties and uses of biogas, design of gas distribution system. Biogas utilization devices: Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power. Testing of biogas appliances.

Unit IV

Effluent: Handling of effluent biogas plant, effluent treatment and management, BDS applications and enrichment. Cost and financial viability of biogas plants.Repair and maintenance of biogas plants.

VI. Practical

Design of biogas plant for solid and liquid wastes, cost estimation, analysis of biogas, purification of biogas.Performance evaluation of biogas appliances.Testingof biogas burner for heat transfer, thermal and cooking efficiency. Bio digested slurry analysis, use of biogas spent slurry. Carbon credits.

VII. Learning outcome

Students are able to design, select, estimate and analyzed the biogas technology, chemical and physical conditions and get acquainted with various biogas appliances.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Biogas Technology potential and status	1
2.	Chemistry, physical conditions and utilization of alternate feedstock materials	1
3.	Types of reactors: Single phase, two phase processes.	1
4.	High rate bio-methanation process, selection of model and size, construction technique, material requirement	2
5.	Design concept of night soil, kitchen waste, solid state cold condition biogas plants	1
6.	Properties and uses of biogas, design of gas distribution system	1
7.	Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power	2
8.	Testing of biogas appliances	2
9.	Handling of biogas plant effluents, effluent treatment and management	1
10.	Bio digested Slurry applications and enrichment	2
11.	Cost and financial viability of biogas plants	1
12.	Repair and maintenance of biogas plants	1
	Total	**16**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Design of biogas plant for solid and liquid wastes	1
2.	Cost estimation of different biogas plants: KVIC, Janta, Deenbandhu, type	2

3.	Analysis of biogas	1
4.	Experiment on purification of biogas	1
5.	Performance evaluation of biogas appliances	1
6.	Testing of biogas burner for heat transfer, thermal and cooking efficiency	2
7.	Analysis of Bio-digested slurry	2
8.	Study on use of biogas spent slurry	1
9.	Study and analysis of Carbon credits.	1
	Total	**12**

IX. Suggested Reading

- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Pub. House, New Delhi.
- Chawala OP. 1986. *Advances in Biogas Technology.* ICAR, New Delhi.
- Khandelwal KC and Mahdi SS. 1986. *Biogas Technology*. A Practical Hand Book, Vol.I, Tata McGraw-Hill Pub. Co. Ltd, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international (P)
  Ltd, New Delhi.
- Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes.* National Academy of Sciences, Washington.
- Tasneem A, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer Publications, Springer Science and Business Media, New York, USA.
- Van BA. 1981. *Chinese Biogas Manual*. Intermediate Technology Publications, London.

I. Course Title : Energy, Ecology and Environment

II. Course Code : REE 510

III. Credit Hours : 3+0

IV. Aim of the course

To provide detail knowledge of carbon cycle, ecosystem, climate change and global environmental change and inter linkages of renewable energy sources.

V. Theory

Unit I

Global carbon cycle. Carbon reservoirs flow and human interventions. Global warming and climate change. Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.

Unit II

Ecosystem: Kinds, transfection, components of ecosystem, ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.

Unit III

Climate change: Impact and models. Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions. Low carbon technologies: Energy efficiency projects, carbon trading.

Unit IV

Environment, Environmental degradation: Thermal and chemical pollution, primary

and secondary pollutant, air pollution, water pollution, unclear energy hazard, radioactive hazards, mining hazards, land use, oil spills and gas leaks.

Unit V

Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC), Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design andformulation.

VI. Learning outcome

Students will able to understand the relationship between carbon cycle, energy policies, energy use and economic growth and factors affecting environment.

VII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Global carbon cycle.	1
2.	Carbon reservoirs flow and human interventions.	2
3.	Global warming and climate change.	2
4.	Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.	4
5.	Ecosystem: Kinds, transfection, components of ecosystem,	4
6.	Ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.	3
7.	Climate change: Impact and models.	3
8.	Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions	2
9.	Low carbon technologies: Energy efficiency projects, carbon trading.	2
10.	Environment, Environmental degradation	3
11.	Thermal and chemical pollution, primary and secondary pollutant, air pollution,	1
12.	Water pollution	3
13.	unclear energy hazard	1
14.	Radioactive hazards, mining hazards, land use, oil spills and gas leaks.	1
15.	Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC)	4
16.	Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design	4

Sl. No.	Topic	No. of Lectures
	and formulation.	
	Total	**40**

VIII. Suggested Reading

- Canter LC. 1979. *Environmental Impact Assessment.* McGraw Hill Pub. Co., New York.
- Coley D. 2008. *Energy and Climate Change*. John Wiley & Sons, Ltd., New Jersey.
- Dessler A. 2011. *Introduction to Modern Climate Change*. Cambridge University Press, Cambridge, England.
- Essam E and Hinnami EI. 1991. *Environmental Impact of Production and Use of Energy*.
  Tycooly Press Ltd, Dublin.
- Fowler JM. 1984. *Energy and the Environment, Second Edition*. McGraw-Hill, New York.
- Kaushika ND and Kaushik K. 2004. *Energy, Ecology and Environment: A Technological Approach.* Capital Publishing, New Delhi.
- Mathur AN, Rathore NS and Vijay VK. 1995. *Environmental Awareness*, Himanshu Pub.,
  Udaipur.
- Puppy HG. *Energy and Environment, Mankind and Energy Needs*. Elsevier Pub. Co., New York.
- Rathore NS and Kurchania AK. 2001. *Climatic Changes and their Remedial Measures*. Shubhi Publications, Gurgaon.
- Thomdike EH. 1978. *Energy and Environment: A Premier for Scientists and Engineers*. Adson, Wesley Pub. Co., Boston, US.
- Wilson R and Jones WJ. 1974. *Energy, Ecology and the Environment*. Academic Press Inc., Cambridge, Massachusetts, US.

I. Course Title : Design and Analysis of Renewable Energy ConversionSystems

II. Course Code : REE 511

III. Credit Hours : 2+1

IV. Aim of the course

To design and analyze renewable energy conversion systems, thermodynamics involved in it and performance of renewable energy systems.

V. Theory

Unit I

Energy cycle of the earth. Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides, biomass energy, solar energy, wind energy and other renewable energy sources.

Unit II

Thermodynamics of renewable energy conversion: Energy and eXergy analysis of renewable energy power systems. Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.

Unit III

Design of renewable energy systems: Design concept, operational parameters, consideration and rational values for agro industrial applications.

Unit IV

Performance analysis of renewable energy systems: Standards and test codes, optimum performance records, evaluation and maintenance aspects, uses of HOMER (Hybrid Optimization Model for Electric Renewable) software.

VI. Practical

Estimation and assessment of renewable energy sources in India. Thermodynamic principles of energy conversion. Design and operational parameters of renewable energy systems. Study on standards and test codes of renewable energy systems.

VII. Learning outcome

Students will able to design of various energy conversion systems, standards and test codes of renewable energy systems and their performance analysis.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Energy cycle of the earth	1
2.	Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides	2
3.	Estimation and assessment of renewable energy sources: biomass energy, solar energy, wind energy	3
4.	Estimation and assessment of renewable energy sources: other renewable energy sources.	2
5.	Thermodynamics of renewable energy conversion: Energy and energy analysis of renewable energy power systems.	4
6.	Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.	4
7.	Design of renewable energy systems: Design concept, operational parameters,	4
8.	Design of renewable energy systems: Consideration and rational values for agro industrial applications.	4
9.	Performance analysis of renewable energy systems: Standards and test codes, optimum performance records	3
10.	Performance analysis of renewable energy systems: Evaluation and maintenance aspects	3
11.	Uses of HOMER (Hybrid Optimization Model for Electric Renewable) software.	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Estimation and assessment of renewable energy sources in India	1
2.	Thermodynamic principles of energy conversion	2
3.	Design and operational parameters of biogas plant	2
4.	Design of a updraft gasifier using solid biomass	2

5.	Design of solar photovoltaic plant for a hostel/building	2
6.	Life cycle assessment and financial assessment of a photovoltaic plant for a hostel/building	1
7.	Study on standards of renewable energy systems	1
8.	Study on test codes of renewable energy systems	2
	Total	**13**

X. Suggested Reading

- Boyle G. 1996. *Renewable Energy: Power for Sustainable Future*. OXford Univ. Press, England.
- Culp AW. 1991. *Principles of Energy Conservation*. Tata McGraw-Hill, New Delhi.
- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, Hoboken, North America.
- Garg HP and Prakash J. 1997. *Solar Energy: Fundamental and Application*. Tata McGraw-Hill, New Delhi.
- Grewal NS, Ahluwalia S, Singh S and Singh G. 1997. *Hand Book of Biogas Technology*. TMH New Delhi.
- Lambert T and Lilienthal P 2004. *Homer: The Micro-Power Optimization Model.* National Renewable Energy Lab., Philippines.
- Manwell JF, McGowan JG and Rogers AL. 2003. *Wind Energy Explained*. John Wiley, Hoboken, North America.
- Mittal KM. 1985. *Biomass Systems: Principles and Applications*. New Age International, New Delhi.
- Patel MK. 1999. *Wind and Solar Power Systems.* CRC Press, Florida.

I. Course Title : Energy Generation from Agricultural Waste and Byproducts

II. Course Code : REE 512

III. Credit Hours : 2+1

IV. Aim of the course

To focus on agricultural wastes and by products for its utilization for energy generation.

V. Theory

Unit I

By Products: Generation, estimation and utilization. Agricultural and agro industrial by-products/wastes: Properties, characterization, on site handling, storage and processing. Concept, scope and maintenance of waste management and effluent treatment

Unit II

Waste as fuel: Utilization pattern, pretreatments, secondary treatments, mechanism, construction, efficiency and suitability.

Unit III

Utilization of agro based industrial wastes for paper production, production of particle board, fertilizer through vermi-composting and fuel.

Unit IV

Thermo-chemical and biochemical conversion of agricultural waste and byproducts:

Densification, combustion, gasification, eXtraction, pyrolysis, carbonization, torrefaction, liquefaction, anaerobic digestion and fermentation process.

VI. Practical

Estimation and characterization of agricultural waste and byproducts, production of fuel from agricultural wastes and by products, techno-economic feasibility of waste to fuel systems.

VII. Learning outcome

Student will be able to understand the estimation, characterization, storage and handling of agricultural wastes and by products to generate the energy.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Introduction to Agricultural and agro industrial by-products/wastes:.	1
2.	Generation, estimation and utilization of Agricultural and agro-industrial by-products/wastes	2
3.	Properties, characterization, of Agricultural and agro industrial by-products/wastes	1
4.	On site handling, storage and processing Agricultural and agro industrial by-products/wastes	2
5.	Concept, scope and maintenance of waste management and effluent treatment	2
6.	Introduction to Waste as fuel:.	1
7.	Utilization pattern of waste as Fuel in India and world	1
8.	Pretreatments and secondary treatments for waste for conversion to Fuel	2
9.	Mechanism, construction, efficiency and suitability of treatments	2
10.	Utilization of agro based industrial wastes for paper production	2
11.	Production of particle board,	1
12.	Fertilizer through vermi-composting and fuel	1
13.	Introduction to Thermo-chemical of agricultural waste and by-products	1
14.	Introduction to biochemical conversion of agricultural waste and by-products	1
15.	Densification	1
16.	Combustion	1
17.	Gasification	1
18.	Extraction	1
19.	Pyrolysis	1
20.	Carbonization	1
21.	Torrefaction	1
22.	Liquefaction	1
23.	Anaerobic digestion	2
24.	Fermentation process	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Estimation of agricultural waste by remote sensing and field Method	2
2.	Characterization of agricultural waste and by products	1

3.	Determination of moisture content of biomass	1
4.	Determination of Volatile solids	1
5.	Determination of Fixed carbon content of biomass	1
6.	Determination of ash content of biomass	1
7.	Estimation of calorific value of biomass	1
8.	Estimation of calorific value of biogas	1
9.	Estimation of calorific value of producer gas	1
10.	Determination of Lignin Cellulose Hemicellose in Biomass	1
11.	Production of fuel from agricultural wastes and by products,	1
12.	Production of Biogas, Producer gas and Biodiesel from Agricultural waste	2
13.	Techno-economic feasibility of waste to fuel systems	2
	Total	**16**

X. Suggested Reading

- Anonymous. 1984. *Manure Production and Characteristics.* ASAE Standards, America.
- Chahal DS. 1991. *Food, Feed and Fuel from Biomass.* Oxford & IBH, New Delhi.
- David C Wilson. 1981. *Waste Management, Planning, Evaluation, Technologies*. Clarendon Press, Oxford, England, UK.
- Klass DL and George EH. 1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ., New York.
- Luh BS. 1991. *Rice: Production and Utilization*. AVI Publ. Company Inc., Westport,Connecticut.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. *Biomass Briquetting and Utilization.* Jain Bros. Publications, New Delhi.

I. Course Title : Agro Energy Audit and Management

II. Course Code : REE 513

III. Credit Hours : 2+1

IV. Aim of the course

To emphasize the energy audit and its management in agriculture productionsystem and agro based industries.

V. Theory

Unit I

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products.Pattern of energy consumption and their constraints in production of agriculture.

Unit II

Direct and indirect energy, energy audit of production agriculture, rural living andscope of conservation.

Unit III

Energy requirement in different agro-based industries: Energy analysis, energy ratio and specific energy value. Identification of energy efficient machinery systems: energy losses and their management.

Unit IV

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

VI. Practical

Study of energy audit techniques, energy use pattern and management strategiesin various agro-industries, assessment of overall energy consumption, production and its cost in selected agro- industries. Estimation of energy requirement in different agriculture production system, study of energy input/output ratio of different agriculture production system.

VII. Learning outcome

Students will learn detail energy audit, energy balance techniques, energy management strategies, energy conservation planning and practices in agriculture production system.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Energy resources on the farm.	2
2.	Conventional and non-conventional forms of energy and their use.	2
3.	Heat equivalents and energy coefficients for different agricultural inputs and products.	3
4.	Pattern of energy consumption and their constraints in production of agriculture.	3
5.	Direct and indirect energy	2
6.	Energy audit of production agriculture, rural living and scope of conservation.	3
7.	Energy requirement in different agro-based industries.	2
8.	Energy analysis, energy ratio and specific energy value.	2
9.	Identification of energy efficient machinery systems.	2
10.	Energy losses and their management.	2
11.	Energy analysis techniques and methods.	2
12.	Energy conservation planning and practices.	2
13.	Energy balance, output and input ratio, resource utilization.	3
14.	Conservation of energy sources.	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Study of energy audit techniques.	2
2.	Energy use pattern and management strategies in various agro-industries.	2
3.	Assessment of overall energy consumption, production and its cost in	2

	selected agro-industries.	
4.	Estimation of energy requirement in different agriculture production system.	2
5.	Study of energy input/output ratio of different agriculture production system.	2
	Total	**10**

X. Suggested Reading

- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publ. Company, Inc., Westport, Connecticut.
- Kennedy WJ Jr and Turner WC. 1984. *Energy Management.* Prentice Hall, Upper Saddle River, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.
- Rai GD. 1998. *Nonconventional Sources of Energy*. Khanna Publ., New Delhi.
- Singh CP. 1978. *Energy Requirement of Important Farm Operations for Existing Cropping System in Punjab.* PAU, Ludhiana.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F.N. Spon Ltd, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing.* USG Publ. & Distr, Ludhiana.

I. Course Title : Green house Energetic and Passive Architecture

II. Course Code : REE 514

III. Credit Hours : 1+1

IV. Aim of the course

To provide the in-depth knowledge about greenhouse design, energetics, production technique, passive heating concept and evaporative cooling etc.

V. Theory

Unit I

Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector. Instrumentation and control in green house.

Unit II

Passive concepts and components: Passive heating concepts, direct gain, indirect grain, isolated gains and sunspace passive cooling concepts,

Unit III

Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling, use of isolation, shading, paint sand cavity walls for cooling.

Unit IV

Passive heating and cooling: Concepts, roof pond/sky therm, roof radiation trap, vary thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage.

VI. Practical

Design of passive structures for animals, rural housing, study of evaporative cooling,

air and light flows in house, survey of green houses, green house energetic.

VII. Learning outcome

Students get knowledge of thermal energy flows, analysis of green house, instrumentation and control in green house.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector.	3
2.	Instrumentation and control in green house.	2
3.	Passive concepts and components	1
4.	Passive heating concepts	1
5.	Direct gain, indirect grain, isolated gains and sunspace passive cooling concepts	3
6.	Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling	2
7.	Use of isolation, shading, paint sand cavity walls for cooling.	1
8.	Passive heating and cooling	1
9.	Concepts, roof pond/sky theorem, roof radiation trap, vary thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage.	2
	Total	**16**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Design of passive structures for animals.	2
2.	Design of passive structures for rural housing	2
3.	Study of evaporative cooling	1
4.	Study of air and light flows in house	1
5.	Survey of green houses	8
6.	Green house energetic	2
	Total	**16**

X. Suggested Reading

- Parkar BE. 1991. *Solar Energy in Agriculture*. Elsevier, Amsterdam.
- Pattern AR. 1975. *Solar Energy for Heating and Cooling of Building*. Noyal Date Corporation (NDC), Park Ridge, New Jersey, USA.
- Paul JK. 1975. *Passive Solar Energy Design and Materials*. Noyel Data Corporation, ParkRidge, New Jersey, USA.
- Radhamanohar K and Igathinathane C. 2000. *Green House Technology and Management*. B.S. Publication. 4309 Sultan Basar, Hyderabad.
- Sodha MS, Bansal NK, Kumar PKA and Malik MAS. 1986. *Solar Passive: Building Scienceand Design*. Pergamon Press, New York.

I. Course Title : Energy Management in Food Processing Industries

II. Course Code : REE 515

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint and equip the students with different energy management techniques including energy auditing of food industries.

V. Theory

Unit I

Energy forms and units, energy perspective, norms and scenario, energy auditing, data collection and analysis for energy conservation in food processing industries.

Unit II

Sources of energy, its audit and management in various operational units of the agro-processing units, passive heating, passive cooling, sun drying and use of solar energy, biomass energy and other non-conventional energy sources in agro-processing industries.

Unit III

Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources. Energy accounting methods, measurement of energy, design of computer-based energy management systems, economics of energy use.

VI. Practical

Study of energy use pattern in various processing units i.e., rice mills, sugar mills, dal mills, oil mills, cotton-ginning units, milk plants, food industries etc. Energy audit study and management strategies in food processing plants. Identification of energy efficient processing machines. Assessment of overall energy consumption, production and its cost in food processing plants, visit to related food processing industry.

VII. Learning outcome

Student's capability to understand energy sources, analyze energy requirement in food processing operations and to economize it in food industries.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Energy forms and units, energy perspective, norms and scenario	2
2.	Energy auditing: definition, types of energy audit, planning	2
3.	Data collection and analysis for energy conservation in food processing industries.	2
4.	Sources of energy, its audit and management in various operational units of the agro-processing units	2
5.	Passive heating, passive cooling, sun drying and use of solar energy in agro-processing industries.	1
6.	Use of biomass energy and other non-conventional energy sources in	2

Sl. No.	Topic	No. of Lectures
	agro-processing industries.	
7.	Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources.	2
8.	Energy accounting methods, measurement of energy	1
9.	Design of computer-based energy management systems, economics of energy use.	2
	Total	**16**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Study of energy use pattern in rice mill	1
2.	Study of energy use pattern in sugar mill	1
3.	Study of energy use pattern in dal mill	1
4.	Study of energy use pattern in oil mill	1
5.	Study of energy use pattern in cotton-ginning unit	1
6.	Study of energy use pattern in milk plant	1
7.	Energy management strategies in rice mill	1
8.	Energy management strategies in sugar mill	1
9.	Energy management strategies in oil mill	1
10.	Energy management strategies in milk plant	1
11.	Identification of energy efficient processing machines	2
12.	Assessment of overall energy consumption, production and its cost in food processing plants	2
13.	Visit to related food processing industry	1
	Total	**15**

X. Suggested Reading

- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press.
- Rai GD. 1998. *Non-conventional Sources of Energy*. Khanna Publisher.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F. N. Spon Ltd.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publisher and Distributors, Ludhiana.