COURSE SYLLABUS
for
Ph.D (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

Course Title with Credit Load Ph.D. in Renewable Energy Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
*REE 601	Biochemical Conversion of Biomass	2+1
*REE 602	Thermo-Chemical Conversion of Biomass	2+1
*REE 603	Advances in Renewable Energy Systems	2+1
REE 604	New Alternate Energy Systems	2+1
*REE 605	Fuels and Combustion	2+1
REE 606	Advances in Biogas Technology	2+1
REE 607	Solid Waste and Waste Water Management	2+1
REE 608	Advanced Photovoltaic Power Generation	1+1
REE 609	Energy Planning, Management and Economics	3+0
REE 610	Renewable Energy for Industrial Application	2+1
REE 611	Biofuel Technologies and Applications	1+1
REE 612	Energy Modelling and Simulation	1+1
	Total	**22+11**

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
FMPE 612	Farm Machinery Management and System Engineering	2+1
ME 501	Mechatronics and Robotics in Agriculture	2+0
PFE 614	Agri- Project Planning and Management	1+1
	Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.	

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
*CPE-RPE	Research and Publication Ethics Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendationsof the student's advisory committee.	1+1

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

List of other Essential Requirements

Course Code	Course Title	Credit Hours
IDE 691	Doctoral Seminar-I	0+1
IDE 692	Doctoral Seminar-II	0+1
IDE 699	Doctoral Research	0+75

SEMESTER WISE COURSE DISTRIBUTION

Ph.D (Agril. Engg.) Renewable Energy Engineering

Sl. No.	Course Title	Course No.	Major	Minor	Supporting
SEMESTER-I					
1	Biochemical Conversion of Biomass	REE 601	2+1		2+1
2	Thermo-Chemical Conversion of Biomass	REE 602	2+1		
3	Advances in Renewable Energy Systems	REE 603	2+1		
4	Testing and Evaluation of Agriculture Equipment	FMPE 502		2+1	
5	Environmental Engineering for Plants and Animals	ASCE 601		2+1	
11	*Library and Information Service*	*PGS 501*	*1+0 (NC)*		
12	*Basic Concepts in Laboratory Techniques*	*PGS 504*	*0+1 (NC)*		
SEMESTER-II					
1	Research and publication Ethics	CPE-RPE*			1+1
2	Theory of Design and Analysis of Experiment	STAT 601			2+1
3	Fuel and Combustion	REE 605	2+1		
8	Energy Planning Management and Economics	REE 609	3+0		
9	Agril. Waste and By-Product Utilization	PFE 604		2+1	
12	Thesis Research	REE 699	(0+5)		
13	*Technical Writing and Communication Skills*	*PGS 502*	*0+1 (NC)*		
14	*Agricultural Research, Research Ethics and Rural Development Programmes*	*PGS 505*	*1+0 (NC)*		
SEMESTER-III					
1	Thesis Research	REE 699	0+15		
2	*Intellectual Property and its Management in Agriculture*	*PGS 503*	*1+0 (NC)*		
SEMESTER-IV					
1	Thesis Research	REE 699	(0+15)		
SEMESTER-V					
1	Thesis Research	REE 699	(0+20)		
2	Seminar-I	REE 691	(0+1)		
SEMESTER-VI					
1	Thesis Research	REE 699	(0+20)		
2	Seminar-II	REE 692	(0+1)		

NC: Non-credit (*italic*) courses are exempted if undergone during Master's programme.

Type of course	Minimum credit hours
A. Course Work	
i) Major course	12
ii) Minor course	06
iii) Supporting course	05
iv) Non–credit compulsory course	--
v) Seminar	02
Sub-Total	**25**
B. Thesis	75
Grand Total	**100**

Course Contents
Ph.D. in Renewable Energy Engineering

I. Course Title : Biochemical Conversion of Biomass

II. Course Code : REE 601

III. Credit Hours : 2+1

IV. Aim of the course

To impart the advanced knowledge about biochemical conversion technologies of biomass, engineering design and kinetic of bio-energy systems.

V. TheoryUnit I

Biomass formation: Energy recovery and recycling. Biochemical conversion of organic wastes: Methane production, vertical through digesters, high solid digestion, sludge treatment.

Unit II

Lagoons: Composting, contact and filter digestion, reactors, physical and chemical removal of dissolved materials. Activated sludge and other suspended culture process parameters. Waste waters, biological film flow processes, sanitation land fill, pre- digestion of waste.

Unit III

Engineering design of biogas units: Biogas boosters, structural behaviour, alternate construction materials, multi-criteria optimization, immobilization, modular biogas for tropical areas, kinetic models.

Unit IV

Bioconversion of biomass to alcohol: Types and pre-treatment of biomass, production process. Fermenter design and process parameters. Economics of bio-alcohol production, reaction kinetics, gasohol. Bio-hydrogen from algae/biomass.

VI. Practical

Lagoons and compositing. Biogas plant: Analysis of biogas system. Determination of methane production rate and parameters, biogas storage, purification, utilization and kinetic equations. Alcohol production, optimization of process parameters, fermenter designing and evaluation. Economic calculations of biogas and alcohol.

VII. Learning outcome

The student will able to design, analyze and evaluate the various biomass conversion technologies and parameters related to biomass for utilization of it for fuel extraction.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Biomass formation.	1
2.	Energy recovery and recycling.	1
3.	Biochemical conversion of organic wastes.	1
4.	Methane production, vertical through digesters, high solid digestion.	2
5.	Sludge treatment.	1
6.	Lagoons: Composting, contact and filter digestion, reactors.	2
7.	Physical and chemical removal of dissolved materials.	2
8.	Activated sludge and other suspended culture process parameters.	2
9.	Waste waters	1

Sl. No.	Topic	No. of Lectures
10.	Biological film flow processes, sanitation land fill, pre-digestion of waste.	2
11.	Engineering design of biogas units	2
12.	Biogas boosters, structural behaviour.	1
13.	Alternate construction materials.	1
14.	Multi-criteria optimization, immobilization.	2
15.	Modular biogas for tropical areas. Kinetic models	2
16.	Bioconversion of biomass to alcohol	1
17.	Types and pre-treatment of biomass production process.	2
18.	Fermenter design and process parameters.	2
19.	Economics of bio-alcohol production.	1
20.	Reaction kinetics, Gasohol.	1
21.	Bio-hydrogen from algae/biomass.	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Lagoons and compositing.	1
2.	Analysis of biogas systems.	2
3.	Determination of methane production rate and parameters.	1
4.	Biogas storage, purification.	1
5.	Biogas storage utilization and kinetic equations.	1
6.	Alcohol production, optimization of process parameters.	1
7.	Fermenter designing and evaluation.	1
8.	Economic calculations of biogas and alcohol.	2
	Total	**10**

X. Suggested Reading

- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Kiang YH. 1981. *Waste Energy Utilization Technology.* Marcel Dekkar, New York, USA.
- Klan E. 1985. *Energy from Biomass and Wastes.* Institute of Gas Technology, Chicago.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management.* McGraw Hill Book Company, New York, USA.

I. Course Title : Thermo-Chemical Conversion of Biomass

II. Course Code : REE 602

III. Credit Hours : 2+1

IV. Aim of the course

To help students to understand in depth knowledge of thermo-chemical conversion of organic waste, combustion chemistry and different heat based conversion technologies for fuel and power generation.

V. TheoryUnit I

Biomass: Characterization, resources and energy recovery. Thermo-chemical conversion of organic wastes. Chemical thermodynamics, stoichiometry and thermodynamics.

Unit -II

Combustion of fuels: Solid fuels, stoker, types, fluidised bed. Liquid fuels: Atomization, vapour concentration, combustion phenomena. Gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.

Unit III

Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification. Coal gasification technologies. Syngas characteristics. Tar and particulates in gasification. Integrated coal gasification. Gas turbine technologies.

Unit IV

Pyrolysis: Models, regimes, kinetics and effect of process parameters. Radiant heat flux, heterogeneous reactions, wall heat transfer. Fluidised bed reactors: Heat transfer circulating beds, moving bed reactor.

Unit V

Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output, energy density ratios and characterization of finished products.

VI. Practical

Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels. TGA studies. Liquid and gaseous burners, flame studies, flue gas, heat budgeting. Kinetic study on gasifiers. Producer gas based power generation systems. Kinetic and model studies for torrefaction, char coal and bio oil production.

VII. Learning outcome

Students will enable to critical analysis of combustion of fuel and system designfor thermos chemical conversion technologies for domestic and industrial applications.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Biomass: Characterization, resources and energy recovery.	2
2.	Thermo-chemical conversion of organic wastes.	1
3.	Chemical thermodynamics and stoichiometry.	3
4.	Combustion of solid fuels: stoker, types, fluidized bed.	2
5.	Combustion of liquid fuels: Atomization, vapour concentration, combustion phenomena.	2
6.	Combustion of gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.	2

Sl. No.	Topic	No. of Lectures
7.	Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification.	3
8.	Coal gasification technologies, Integrated coal gasification.	2
9.	Syngas characteristics, Tar and particulates in gasification.	2
10.	Gas turbine technologies.	2
11.	Pyrolysis: Models, regimes, kinetics and effect of process parameters.	2
12.	Radiant heat flux, heterogeneous reactions, wall heat transfer.	2
13.	Fluidized bed reactors: Heat transfer circulating beds, moving bed reactor.	2
14.	Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output	2
15.	Energy density ratios and characterization of finished products.	2
	Total	**31**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels	2
2.	Determination of efficiency of improved chulha through water boiling test procedure.	1
3.	Thermo-gravimetric analysis of biomass sample	1
4.	Study of liquid burners	1
5.	Study of gaseous burners	1
6.	Flame studies and flue gases	1
7.	Study on heat budgeting	1
8.	Study on kinetics of fluidized bed gasifier	1
9.	Producer gas based power generation systems	1
10.	Kinetic and model studies for Torrefaction	2
11.	Kinetic and model studies for charcoal production.	2
12.	Kinetic and model studies for bio oil production.	2
	Total	**16**

X. Suggested Reading

- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Klan E. 1985. *Energy from Biomass and Wastes*. Institute of Gas Technology, Chicago.
- Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
- Rezaiyan J and Cheeremisinoff NP. 2005. *Gasification Technologies–A Primer for Engineers and Scientists.* CRC Press, Taylor and Francis group, New York, USA.
- Tchobanoglous G and Elliassen HTR. 1978. *Solid Wastes*. McGraw Hill Book Company,
  New York, USA.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management*. Van Nostrand Reinhold Company, New York.

I. Course Title : Advances in Renewable Energy Systems

II. Course Code : REE 603

III. Credit Hours : 2+1

IV. Aim of the course

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

V. TheoryUnit I

Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies. Design and performance of solar thermal systems, mathematical models, power plants, design and performance.

Unit II

Photovoltaics: Thermodynamic limitations of photocells. Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter. Photo electro chemical cells, photo electrolysis cell.

Unit III

Wind power: Rotor design procedure, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation, performance prediction wind turbine rotor dynamics and dynamic models.

Unit IV

Designing of water pumping wind mills: Electric power, power transformers, electrical machines, ancillary electrical equipment, wind power to consumer/grid. Wind turbine: Sitting, installation and operation issues, offshore wind farms, operation in severe climates.

VI. Practical

Design parameters of air collectors. Thermal analysis and heat loss, regularity models of heliostatic fields, power plant design. Photovoltaic cells characteristic curves. Water pumping. Power control system, grid control devices. Design of wind mills, rotor design procedure, momentum theory and blade element theory. Wind mill installation and operation issues.

VII. Learning outcome

The student is able to design and analyzed the renewable energy systems and relevant technologies critically with economic feasibility.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Solar thermal energy systems.	1
2.	Kinetics and heat transfer analysis, modelling studies.	3
3.	Design and performance of solar thermal systems	2
4.	Mathematical models, power plants, design and performance.	2
5.	Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies.	2
6.	Design and performance of solar thermal systems, mathematical models, power plants, design and performance.	3
7.	Photo-voltaic	1
8.	Thermodynamic limitations of photocells.	2
9.	Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter.	2

Sl. No.	Topic	No. of Lectures
10.	Photo electro chemical cells, photo electrolysis cell	1
11.	Wind power	1
12.	Design procedure of rotor, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation,	3
13.	Performance prediction wind turbine rotor dynamics and dynamic models.	1
14.	Designing of water pumping wind mills.	1
15.	Electric power, power transformers.	1
16.	Electrical machines, ancillary electrical equipment, wind power to consumer/grid.	2
17.	Wind turbine: Sitting, installation and operation issues,	2
18.	Offshore wind farms, operation in severe climates	2
	Total	**32**

IX. Practical

Sl. No.	Topic	No. of Lectures
1.	Design parameters of air collectors.	1
2.	Thermal analysis and heat loss,	1
3.	Regularity models of heliostatic fields	1
4.	Design of power plant.	2
5.	Photovoltaic cells characteristic curves.	1
6.	Analysis of water pumping with photovoltaic cells.	1
7.	Power control systems.	1
8.	Grid control devices.	1
9.	Design of wind mills.	2
10.	Rotor design procedure	1
11.	Momentum theory and blade element theory	2
12.	Installation of wind mill.	1
13.	Wind mill operation issues.	1
	Total	**16**

X. Suggested Reading

- Anderson EE. 1983. *Fundamentals of Solar Energy Conversion*. Addision Wesley publication Company, Boston, United State.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium.* TERI Press, New Delhi, India.
- More HG and Maheshwari RC. *Wind Energy Utilization in India*. Technical Bulletin No.CIAE/82/38,CIAE, Bhopal.
- Powar AG and Mohod AG. 2010. *Wind Energy Technology*. Jain Publication, New Delhi,India.
- Rai GD. 1994. *Nonconventional Sources of Energy*. Khanna Publishers, New Delhi, India.
- Rao S and Parulekar BB. 1994. *Energy Technology Nonconventional, Renewable and Conventional*. Khanna Publishers, New Delhi, India.
- Sitharthan R and Geethanjali M. 2014. *Wind Energy Utilization in India: A Review*. Middle-East Journal of Scientific Research, Pakistan.
- Solanki CS. 2011. *Solar Photovoltaics: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, New Delhi, India.
- Sukhatme SP and Nayak J. 2008. *Solar Energy: Principles of Thermal Collection and Storage.* Tata McGraw Hill Publishing Company Limited, New Delhi, India.

I. Course Title : **New Alternate Energy Systems**

II. Course Code : **REE 604**

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

IV. Aim of the course

To get acquainted with various recent and emerging alternate fuels and their various applications for power generation.

V. Theory

Unit I

Hydrogen production: Water splitting, electrolytic methods, chemical cycle, photo splitting, photo galvanic, photo chemical. Hydrogen storage and utilization. Fuel cells: Reactions, types, design, applications, conversion and problems. Thermoelectric convertor and thermionic convertors. Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types.

Unit II

Tidal energy: Operating mode, energy content. Estimation of wave power, tidal power sites and ocean thermal energy cycle (OTEC): Baseline design, heat design, power cycle design, plant working.

Unit III

Geo-thermal energy system: Classification, binary cycle conversion, water fed heat pumps, electric generation, steam generation, steam field. Heat mining, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks.

Unit IV

Power generation through alternative sources. Environmental pollution: Measurements and control methods, instrumentation, pollution standards, social cost estimates, CO_2 reduction potential, CO_2 sequestration.

VI. Practical

Testing of electrolysis plant, photo electric plant, photo plant, design criteria of fuel cell. Design considerations for alternative energy systems.

VII. Learning outcome

Students are able to understand the various recent and emerging alternate energy sources and their utilization for meeting the increasing energy demand.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Hydrogen production: Water splitting, electrolytic meth-ods, chemical cycle, photo splitting, photo galvanic, photo chemical.	2
2.	Hydrogen storage and utilization.	1
3.	Fuel cells: Reactions, types, design, applications, conversion and problems.	2
4.	Thermoelectric convertor and thermionic convertors.	2
5.	Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types.	2
6.	Tidal energy: Operating mode, energy content.	1
7.	Estimation of wave power, tidal power sites and ocean thermal energy cycle (OTEC)	2

Sl. No.	Topic	No. of Lectures
8.	Baseline design, heat design, power cycle design, plant working.	3
9.	Geo-thermal energy system	1
10.	Classification, binary cycle conversion, water fed heat pumps, electric generation, steam generation, steam field.	4
11.	Heat mining, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks.	3
12.	Power generation through alternative sources.	1
13.	Environmental pollution	1
14.	Measurements and control methods for environmental pollution.	1
15.	Instrumentation, pollution standards,	2
16.	Social cost estimates.	1
17.	CO2 reduction potential, CO2 sequestration.	2
	Total	**31**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Design parameters of air collectors.	1
2.	Thermal analysis and heat loss,	1
3.	Regularity models of heliostatic fields	1
4.	Testing of electrolysis plant	2
5.	Testing of photo electric plant	2
6.	Testing of photo plant.	2
7.	Design criteria of fuel cell	2
8.	Design considerations for alternative energy systems	2
	Total	**13**

X. Suggested Reading

- Culp JA. 1979. *Principles of Energy Conversion*. McGraw-Hill Book Company, London.
- Appleby A C 1987. *Fuel Cells: Trends in Research and Application*. Hemisphere, Washington.
- Blomen LJMJ and Mugerwa MN. 1993. *Fuel Cell System.* Plenum Press, New York, USA.
- Thielhein KD. 1977. *Alternate Energy Sources*. International compendium, Hemi spherepublishing company, London.

I. Course Title : **Fuel and Combustion**
II. Course Code : **REE 605**
III. Credit Hours : **2+1**

IV. Aim of the course

To get acquainted with in depth knowledge about solid, liquid and gaseous fuelsand their combustion kinematics. Understand of different combustion technologies.

V. Theory

Unit I

Solid and liquid fuels: Type and availability, oxidation, hydrogenation of solid fuel and processing of solid fuels. Liquid Fuels: Processing, properties testing of liquid fuels and refining. Liquid fuels from other sources: Preparation and storage. Production technologies for solid and liquid fuel.

U n i t II

Gaseous Fuels: Types, processing and testing of gaseous fuels, gases from biomass refinery gases, LPG, oil gasification, cleaning and purification of gaseous fuels. Gaseous fuel production technologies.

Unit III

Combustion Stoichiometry: Thermodynamics and kinetics, solid, liquid and gaseous fuels. Combustion of solid fuels. Biomass combustion, stages of wood combustion, industrial biomass combustion concepts, types of combustion system.

Unit IV

Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition. Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.

Unit V

Combustion of gaseous fuel: Character, shape and size of the flame. Flame stabilization of bluff bodies. Effect of equivalence on reaction rate and extinction velocity, submerged combustion, combustion with explosion flame, pulsating combustion.

VI. Practical

Determination of fuel properties of solid, liquid and gaseous fuels. Determination of efficiency of combustion system using solid, liquid and gaseous fuel. Standard testing of burners for thermal efficiency for solid, liquid and gaseous fuel.

VII. Learning outcome

Students will able to design, estimate and critical analysis of various combustion techniques for efficient utilization of fuels.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Type and availability of solid and liquid fuels.	1
2.	Oxidation and hydrogenation of solid fuel.	1
3.	Processing of solid fuels.	1
4.	Processing of liquid fuel, properties and testing of liquid fuels.	2
5.	Refining of liquid fuel.	1
6.	Liquid fuels from other sources: Preparation and storage.	1
7.	Production technologies for solid and liquid fuel.	2
8.	Gaseous fuel production technologies.	1

Sl. No.	Topic	No. of Lectures
9.	Gases from biomass, refinery gases and LPG.	2
10.	Oil gasification.	1
11.	Types, processing and testing of gaseous fuels.	2
12.	Cleaning and purification of gaseous fuels.	1
13.	Combustion Stoichiometry: thermodynamics and kinetics.	1
14.	Solid, liquid and gaseous fuels.	2
15.	Combustion of solid fuels, biomass combustion, stages of wood combustion.	2
16.	Industrial biomass combustion concepts.	1
17.	Types of combustion systems.	1
18.	Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition.	2
19.	Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.	2
20.	Combustion of gaseous fuel: Character, shape and size of the flame.	2
21.	Flame stabilization of bluff bodies.	1
22.	Effect of equivalence on reaction rate and extinction velocity.	1
23.	Submerged combustion, Combustion with explosion flame, Pulsating combustion.	1
	Total	**32**

IX. Practical

Sl. No.	Topic	No. of Lectures
1.	Determination of fuel properties of solid fuels.	1
2.	Determination of fuel properties of liquid fuels.	1
3.	Determination of fuel properties of gaseous fuels.	1
4.	Determination of efficiency of combustion system using solid fuels.	1
5.	Determination of efficiency of combustion system using liquid fuels.	1
6.	Determination of efficiency of combustion system using gaseous fuels.	1
7.	Standard testing of burners for thermal efficiency for solid.	1
8.	Standard testing of burners for thermal efficiency for liquid fuel.	1
9.	Standard testing of burners for thermal efficiency for gaseous fuel.	1
	Total	**9**

X. Suggested Reading

- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization inCombustion Engines*. CRC Press, Boca Raton, Florida.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India Publication, New Delhi, India.
- Sarkar S. 1990. *Fuels and Combustion*. Orient Longmans, Bombay.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press, Boca Raton, Florida.

I. Course Title : Advances in Biogas Technology

II. Course Code : REE 606

III. Credit Hours : 2+1

IV. Aim of the course

The students will understand advances in biogas technology and its mechanism in detail. To analyze the case studies for understanding success and failures. To facilitate the students in developing skills in the decision making process.

V. TheoryUnit I

Worldwide review of anaerobic digesters, realistic potential- of biogas, analysis of biogas system and proposed means for their prospects. Engineering design of biogas units for biogas production from solid and liquid wastes.

Unit II

Design parameters: Affecting and failure of biogas systems, structural behavior and conditions of fixed dome digesters, alternate construction- materials, gas holders for gas production in colder regions, heating, stirring etc.

Unit III

Multi-criteria optimization design of fermentation systems, immobilization, modular biogas for tropical rural areas. Toxicity effect of pesticides herbicides on the anaerobic digestion process. Kinetic models, design equations, contact and anaerobic filter digesters, high rate digesters.

Unit IV

Scrubbing, purification and compression of biogas. Scaling-up and standardization of biogas plant for power generation and heating. Advanced biofuels: Bio-CNG/ renewable natural gas (RNG) as vehicle fuel. Liquefaction of biogas.

VI. Practical

Engineering design and analysis of biogas system. Development of kinetic equations. Biogas purification, compression and liquefaction. Industrial applications of biogas.

VII. Learning outcome

The student is able to analyse the various aspects of biogas energy management systems, Carry out techno-economic feasibility for biogas plant, to apply the knowledge in planning and operations of biogas energy system.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Review of anaerobic digesters	1
2.	Realistic potential- of biogas	1
3.	Analysis of biogas system	2
4.	Proposed means for prospects of biogas systems	1
5.	Engineering design of biogas units for biogas production from solid and liquid wastes	3
6.	Design parameters: Affecting and failure of biogas systems	2
7.	Structural behavior and conditions of fixed dome digesters	2
8.	Alternate construction- materials for biogas plants	1
9.	Design of biogas plants for colder regions	1
10.	Heating and stirring systems for biogas plants	2

Sl. No.	Topic	No. of Lectures
11.	Multi-criteria optimization design of fermentation systems contact and anaerobic filter digesters, high rate digesters	2
12.	Immobilization, modular biogas for tropical rural areas	2
13.	Toxicity effect of pesticides herbicides on the anaerobic digestion process	1
14.	Chemical kinetics and mathematical modeling of bio-methanation process	2
15.	Contact and anaerobic filter digesters, high rate digesters	1
16.	Scrubbing, purification and compression of biogas.	2
17.	Scaling-up and standardization of biogas plant for power generation and heating	2
18.	Bio-CNG/renewable natural gas (RNG) as vehicle fuel	2
19.	Liquefaction of biogas	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Engineering design and analysis of biogas system	3
2.	Development of kinetic equations	3
3.	Biogas purification, compression and liquefaction	3
4.	Industrial applications of biogas	3
5.	Preparation of Detailed Project Reports for commercial biogas projects	4
	Total	**16**

X. Suggested Reading

- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Publication House, New Delhi.
- Abbasi T, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer publications, New York, USA.
- Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international Publication Limited, 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.

I. **Course Title : Solid Waste and Waste Water Management**

II. **Course Code : REE 607**

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

IV. **Aim of the course**

To provide in depth knowledge, understanding and application oriented skills on sources, quality, classification and characteristics of solid waste along with municipal and compost treatment and remote sensing technologies for waste management.

V. **TheoryUnit I**

Solid waste: Sources, quality, classification and characteristics, collection and reduction at source, handling, storage, transportation and disposal methods.

Unit II

Reactor for anaerobic digestion: Contact and filter digestion, homogenous and non-homogeneous reactors. Energetic and kinetics of anaerobic treatment.

Unit III

Gas transfer, mass models, bubble aeration, film flow oxygen transfer, stripping, solids removal. Activated sludge and other suspended culture processes parameters. Biosorption of contact stabilization.

Unit IV

Sanitation land fill, municipal and compost treatment. Pre-digestion of waste. Sensors, ICT and remote sensing technologies for waste management.

VI. **Practical**

Design principles in waste treatment, equipment specification and instrumentation. Mathematical modelling of BOD and COD reduction rate, recovery by batch distillation.

VII. **Learning outcome**

The student is able to estimate, characterize and design of solid waste conversion system and also able to understand the energetic and kinetics of anaerobic treatment, sanitation land fill, pre-digestion of waste etc.

VIII. **Lecture Schedule**

Sl. No.	Topic	No. of Lectures
1.	Introduction to Solid waste	1
2.	Sources, classification and characteristic and quality	2
3.	Collection and handling and Transportation	2
4.	Disposal methods, reduction at source	3
5.	Reactor for anaerobic digestion	2
6.	Contact and filter digestion	2
7.	Homogenous and non-homogeneous reactors	2
8.	Energetic and kinetics of anaerobic treatment.	2
9.	Gas transfer, mass models,	3
10.	Bubble aeration, film flow oxygen transfer, stripping, solids removal.	2
11.	Activated sludge and other suspended culture processes parameters.	2
12.	Biosorption of contact stabilization	1

Sl. No.	Topic	No. of Lectures
13.	Sanitation land fill,	2
14.	Municipal and compost treatment	2
15.	Predigestion of waste.	1
16.	Sensors, ICT and remote sensing technologies for waste management	3
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Design principles in waste treatment	3
2.	Specification of equipment for waste treatment	2
3.	Instrumentation for waste treatment	2
4.	Mathematical modelling of BOD and COD reduction rate	3
5.	Development of computer code for Mathematical modelling of BOD and COD reduction rate	3
6.	Recovery by batch distillation.	3
	Total	**16**

X. Suggested Reading

- Bridgwater AV and Mum-ford CJ. 1979. *Waste Recycling and Pollution Control Handbook.* Van Nostrand Reinhold Company, New York.
- Kreith F and Tchobanoglous G. 2002. *Handbook of Solid Waste Management.* McGraw Hill Book Company, New York.
- Ramachandra TV. 2006. *Management of Municipal Solid Waste.* Capital Publication Company, New Delhi.
- Tchobanoglous G, Theisenand H and Elliassen R. 1978. *Solid Wastes*. McGraw Hill Book Company, New York.

I. Course Title : Advanced Photovoltaic Power Generation

II. Course Code : REE 608

III. Credit Hours : 1+1

IV. Aim of the course

To develop a comprehensive technological understanding in solar PV system components. To provide in depth understanding of design parameters to help design and simulate the performance of a solar PV power plant. To pertain knowledge about planning, project implementation and operation of solar PV power generation.

V. Theory

Unit I

Semiconductors: Transport properties, junctions, dark and illumination characteristics. Single junction and multi junction films. Solar PV concentrator cells and systems. Thin film solar cells: Nano, micro, and polycrystalline solar cells.

Unit II

Systems for remote applications and large solar PV power plants: System integrations, roof top system, sizing methodology, power control, storage, tracking and control. PCID simulation of industrial solar cell structure, software's in solarcell simulation.

Unit III

Space charge control, low pressure diode, MMPT, cesium converter, system considerations. Photo electro chemical cells and materials. Photogalvanic cells: Recent development.

Unit IV

Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics. Software's for PV system integration and designing. PV system for ground mounted and rooftop plants with shadow analysis.

VI. Practical

PV systems for typical applications, water pumping, solar PV tracking and mechanical clock tracking. Testing of power control system for output regulation, charging and discharging characteristics of storage by PV panels.

VII. Learning outcome

Student will able to design different solar photovoltaic system for power generation. Design and simulate a PV power plant using software tool, Plan, project implementation, operation and maintenance. Carry out techno-economic- environmental performance evaluation of a solar PV power plant.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Semiconductors: Transport properties, junctions, dark and illumination characteristics.	1
2.	Single junction and multi junction films, Solar PV concentrator cells and systems.	1
3.	Thin film solar cells: Nano, micro, and polycrystalline solar cells.	1
4.	Systems for remote applications, Large solar Photovoltaic power plants: System integrations, roof top system and sizing methodology	2
5.	Power control, storage, tracking and control in Photovoltaic power plants.	1
6.	PCID simulation of industrial solar cell structure, software's in solar cell simulation	2

Sl. No.	Topic	No. of Lectures
7.	System considerations for Space charge control, low pressure diode, MMPT and cesium converter	2
8.	Photo electro chemical cells and materials	1
9.	Recent development in Photogalvanic cells	1
10.	Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics	1
11.	Softwares for PV system integration and designing.	2
12.	PV system for ground mounted and rooftop plants with shadow analysis	1
	Total	**16**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Typical applications of Photovoltaic (PV) systems	1
2.	Applications of Photovoltaic systems in water pumping	2
3.	Study of Solar PV tracking and mechanical clock tracking	2
4.	Testing of power control system for output regulation	3
5.	Charging and discharging characteristics of storage by PV panels.	2
	Total	**10**

X. Suggested Reading

- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Fonash SJ. 1982. *Solar Cell Device Physics*. Academic Press, Cambridge, England.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company,Dordrecht, Netherland.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications*. Prentice Hall, 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 and Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, Delhi.
- Sze SM and Kwok KN. 2007. *Physics of Semiconductor Devices*. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. McGraw Hill, New York.

I. Course Title : **Energy Planning, Management and Economics**

II. Course Code : **REE 609**

III. Credit Hours : **3+0**

IV. Aim of the course

To acquaint and equip with energy planning, management and economical evaluation for agricultural production system.

V. TheoryUnit 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. Direct and indirect energy.

Unit II

Energy audit of production agriculture and rural living and scope of conservation. Identification of energy efficient machinery systems, energy losses and their management.

Unit III

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

Unit IV

Energy forecasting, energy economics, energy pricing and incentives for energy conservation, factors effecting energy economics. Techno-economic evaluation of RET's, computation of programme for efficient energy management.

VI. Learning outcome

The student will be able to quantify, analyze and forecast the demand and supply of different energy for agriculture production system.

VII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Energy resources on the farm: Conventional and non-conventional forms of energy and their use.	3
2.	Heat equivalents and energy coefficients for different agricultural inputs and products.	3
3.	Pattern of energy consumption and their constraints in production agriculture. Direct and indirect energy.	3
4.	Energy audit of production agriculture and rural living and scope of conservation.	4
5.	Identification of energy efficient machinery systems	3
6.	Energy losses and their management.	4
7.	Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources.	4
8.	Energy conservation planning and practices.	4
9.	Energy forecasting	3
10.	Energy pricing and incentives for energy conservation,	3

Sl. No.	Topic	No. of Lectures
11.	Energy economics and factors affecting energy economics	4
12.	Techno-economic evaluation of RET's	4
13.	Computation of programme for efficient energy management.	3
	Total	**45**

VIII. Suggested Reading

- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publication, United State.
- Kennedy WJ and Turner WC. 1984. *Energy Management.* Prentice Hall, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.
- Rai GD. 1998. *Nonconventional Sources of Energy.* Khanna Publication, New Delhi.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F N Spon, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publication, Chicago.

I. Course Title : Renewable Energy for Industrial Application

II. Course Code : REE 610

III. Credit Hours : 2+1

IV. Aim of the course

To provide the knowledge regarding the energy consumption pattern in agro based industries, quantification techniques and identification of opportunities for renewable energy sources.

V. Theory

Unit I

Elucidation of unit operations in industry. Energy quantification techniques, system boundary, estimation of productivity, plant capacity utilization, energy density ratio and energy consumption pattern. Energy flow diagram conservation opportunities identification.

Unit II

Solar energy for industrial application: Solar water heating, steam solar cooking system, industrial solar dryer and solar process heat, solar cooling system (refrigeration, air conditioning and solar architecture technology), solar furnace and solar greenhouse technology for high-tech cultivation. Solar photovoltaic technology for industrial power.

Unit III

Bio energy for industrial application: Quantification of industrial bio-waste, characterization, power generation through bio-methanation, gasification and dendro thermal power plant.

Unit IV

Wind energy: Aero generator of new era and national and international state of art in wind power generation. Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.

VI. Practical

Elucidation and energy consumption for unit operations in industry. Study of energy quantification and identification of opportunities for RET's. Design of solar dryers.

Design of solar photovoltaic system. Design of gasifiers for thermal energy and power generation. Design of combuster (gasifier stove). Study of solar greenhouse. Study of biogas engine generator set. Case study of agro-industrial energy estimation and visit to RSE power generation site.

VII. Learning outcome

Students will be acquainted with energy quantification techniques, design of system, economic evaluation and utilization of renewable energy sources for agro-industrial applications.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Elucidation of unit operations in industry.	1
2.	Energy quantification techniques, system boundary,	2
3.	Estimation of productivity, plant capacity utilization,	2
4.	Energy density ratio and energy consumption pattern.	2
5.	Energy flow diagram conservation opportunities identification.	1
6.	Solar energy for industrial application.	1
7.	Solar water heating.	1
8.	Steam solar cooking system.	1
9.	Industrial solar dryer and solar process heat.	2
10.	Solar cooling system (refrigeration, air conditioning and solar architecture technology).	2
11.	Solar furnace.	1
12.	Solar greenhouse technology for high-tech cultivation.	2
13.	Solar photovoltaic technology for industrial power.	1
14.	Bio energy for industrial application	1
15.	Quantification of industrial bio-waste, its characterization	2
16.	Power generation through bio-methanation,	2
17.	Gasification and dendro thermal power plant.	2
18.	Wind energy: Aero generator of new era.	1
19.	National and international state of art in wind power generation.	2
20.	Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.	3
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Elucidation and energy consumption for unit operations in industry.	1
2.	Study of energy quantification and identification of opportunities for RET's	1
3.	Design of solar dryers.	2
4.	Design of solar photovoltaic system.	2
5.	Design of gasifiers for thermal energy and power generation.	2
6.	Design of combuster (gasifier stove).	2

7.	Study of solar greenhouse.	1
8.	Study of biogas engine generator set.	1
9.	Case study of agro-industrial energy estimation	2
10.	Visit to RSE power generation site.	1
	Total	**15**

X. Suggested Reading

- Duffie JA and Beakman WA. 2006. *Solar Energy Thermal Process*. John Wiley and Sons, New York.
- Kumar S. 2011. *Energy Conservation Building User Code Guide.* Bureau of Energy Efficiency, New Delhi.
- Rathore NS, Kurchania AK and Panwar NL. 2007. *Non- Conventional Energy Sources*. Himanshu Publications, Udaipur, Rajasthan.
- Sayigh AAM. 2012. *Solar Energy Engineering*. Academic Press, New York.
- Singh P, Kurchania AK, Rathore NS and Mathur AN. 2005. *Sustainable Development through Renewable Energy Sources*. Yash Publications, Bikaner, Rajasthan.

I. Course Title : Biofuel Technologies and Applications

II. Course Code : REE 611

III. Credit Hours : 1+1

IV. Aim of the course

To get acquainted with recent biofuel production technologies and their applications. To perform financial estimations of the biofuel projects. To get insight of the various biofuel technologies.

V. TheoryUnit I

Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization. World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.

Unit II

Bioethanol: First and second generation ethanol production technologies. Production of syngas from biomass, production of methanol from syngas, production of ethanol from lingo-cellulosic biomass. Syngas and poly-generation, chemical conversion of syngas to methanol and ethanol and some advanced fuels like bio butanol, bio- propanol.

Unit III

BioCNG: Biogas to green vehicle fuel, anaerobic digestion. Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.

Unit IV

Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel, biodiesel from algae, biodiesel engines.

Unit V

Pyrolysis oil: Fast pyrolysis technologies, composition and issues of bio oil. Bio oil upgradation technologies.

VI. Practical

Evaluation of liquid fuel system for heat and power generation and characterization of liquid fuel, transesterification process. Engine performance on biodiesel. Biogas- engine system for transport vehicle. Bio oil production by pyrolysis.

VII. Learning outcome

Student will able to understand the bio-fuel production technologies with financial viability and applications of bio-fuel in different sector of development.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization.	1
2.	World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.	1
3.	Bioethanol: First- and second-generation ethanol production technologies.	1
4.	Production of syngas from biomass.	1
5.	Production of methanol from syngas.	1
6.	Production of ethanol from lingo-cellulosic biomass.	1
7.	Syngas and poly-generation.	1
8.	Chemical conversion of syngas to methanol and ethanol, some advanced fuels like bio butanol, bio-propanol.	1
9.	Bio CNG: Biogas to green vehicle fuel, anaerobic digestion.	1
10.	Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.	1
11.	Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel.	2
12.	Biodiesel from algae, biodiesel engines.	1
13.	Pyrolysis oil: Fast pyrolysis technologies.	1
14.	Composition and issues of bio oil	1
15.	Bio oil up-gradation technologies.	1
	Total	**16**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Evaluation of liquid fuel system for heat and power generation.	2
2.	Characterization of liquid fuel.	1
3.	Transesterification process.	2
4.	Engine performance on biodiesel.	1
5.	Biogas-engine system for transport vehicle.	1
6.	Bio oil production by pyrolysis.	1
	Total	**08**

X. Suggested Reading

- Boyle G. 2008. *Renewable Energy.* Atlantic Publishing Company, New Delhi.

- Gonsalves JB. 2006. *An Assessment of the Biofuels Industry in* John *India.* Wiley & Sons, New Delhi.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium. Education.* TERI Press, Delhi.
- Klass D. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals.* Entech International, Barrington, Illinois, USA.
- Mitzlaff KV. 1988. *Engines for Biogas–Theory, Modification, Economic Operation*. Deutsches Zentrum für Entwicklungstechnologien–GATE, Germany.

I. Course Title : Energy Modelling and Simulation

II. Course Code : REE 612

III. Credit Hours : 1+1

IV. Aim of the course

The objective of this course is to provide in depth knowledge about various mathematical models, interdependence of energy, ecology and environment, energy modelling in the context of climate change.

V. TheoryUnit I

Model: Basics, system, boundary, interaction, types of models, physical, analogy models and applications. Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment, modelling concept and application.

Unit II

Energy Modelling: Review of various energy sector models, energy demand analysis and forecasting, energy supply assessment and evaluation, energy demand, supply balancing, energy modelling in the context of climate change.

Unit III

Model studies in gasification, pyrolysis, biogas, fermentation, biodiesel, solar, wind technologies and heat transfer applications. Moving boundary models.

Unit -IV

Energy economics of energy sources: Investment and cost management in various energy technologies. Economics of energy generation, energy conservation economics, financial analysis, sensitivity and risk analysis.

VI. Practical

Formulating dimensionless numbers, applications, types of models, mathematical model formulation and types, Software's and model evaluation. Development of models in thermo-chemical and biochemical conversion processes. Studies on model development in solar and wind technologies, economics of energy generation and conservation, financial analysis.

VII. Learning outcome

Students will get thorough knowledge about energy modelling of gasification, pyrolysis, biogas system, fermentation, biodiesel production system, solar and wind technologies etc.

VIII. Lecture Schedule

Sl. No.	Topic	No. of Lectures
1.	Introduction to Model	1

Sl. No.	Topic	No. of Lectures
2.	Basics, system, boundary, interaction, types of models, physical, analogy models.	2
3.	Model applications.	1
4.	Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment.	3
5.	Modelling concept and application.	1
6.	Energy Modelling	1
7.	Review of various energy sector models.	1
8.	Energy demand analysis and forecasting.	1
9.	Energy supply assessment and evaluation	1
10.	Energy demand, supply balancing.	2
11.	Energy modelling in the context of climate change.	2
12.	Model studies in gasification, pyrolysis.	2
13.	Model studies in biogas, fermentation.	1
14.	Model studies in biodiesel.	1
15.	Model studies in solar.	1
16.	Model studies in wind technologies.	1
17.	Heat transfer applications.	1
18.	Moving boundary models.	1
19.	Energy economics of energy sources	1
20.	Investment and cost management in various energy technologies.	2
21.	Economics of energy generation.	1
22.	Energy conservation economics, financial analysis.	2
23.	Energy conservation sensitivity and risk analysis	2
	Total	**32**

IX. List of Practicals

Sl. No.	Topic	No. of Lectures
1.	Formulating dimensionless numbers.	1
2.	Applications of dimensionless numbers.	1
3.	Types of models for dimensionless numbers.	1
4.	Mathematical model formulation and types.	2
5.	Software's and model evaluation.	2
6.	Development of models in thermo-chemical	1
7.	Development of models in biochemical conversion processes.	1
8.	Studies on model development in solar technologies.	1
9.	Studies on model development in wind technologies	1
10.	Economics of energy generation and conservation	2
11.	Financial analysis.	1

	Total	14

X. **Suggested Reading**

- Desai A V 1990. *Energy Planning and Economics.* New Age International Publication Limited, New Delhi.
- Munasinghe M and Meier P 1993. *Energy Policy Analysis and Modelling* (*Cambridge Energyand Environment Series*). Cambridge University Press, England.