Program Name : **Diploma in Mechanical Engineering**

Program Code : **ME**

Semester : **Sixth**

Course Title : **Renewable Energy Technologies (Elective-II)**

Course Code : **22661**

1. RATIONALE

Use of renewable sources of energy is the need of the hour. Solar, Wind, micro-hydro and Bio-fuel systems have become reality now and the share of these systems in global energy market is increasing day by day. India has set high targets of employing renewable sources of energy for all possible applications to reduce the dependency on the fossil fuels. This has increased the demand of trained manpower for installation, operation and maintenance of various systems and equipment used in Solar, wind, micro-hydro and bio-fuel systems. This segment has huge potential for innovative solutions and opportunities for self-employment also. This course aims at equipping the technologists in installation, operation and maintenance of various mechanical equipment and systems used in Solar, Wind, Micro-hydro and bio-fuel systems.

2. COMPETENCY

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

- **Maintain the mechanical components of renewable energy systems.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a) Maintain mechanical components of solar thermal systems.
b) Maintain mechanical components of solar PV systems.
c) Maintain mechanical components of wind turbines.
d) Maintain mechanical components micro hydro turbines.
e) Maintain mechanical components of Biomass plants.
f) Maintain mechanical components hybrid renewable energy system.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

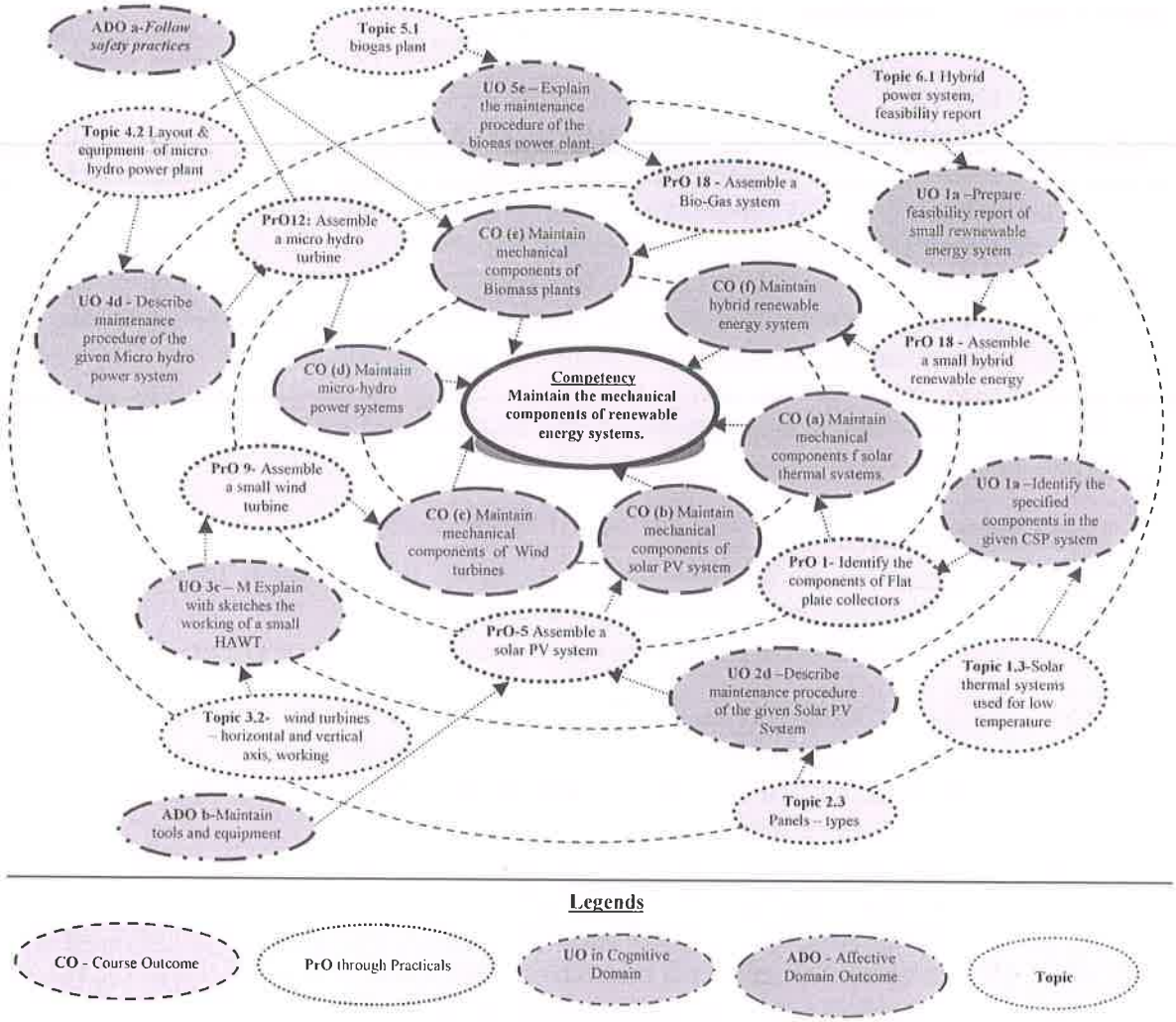

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Identify the components of solar Flat plate collector.	I	02*
2	Identify the components of evacuated tube solar thermal system.	I	02
3	Identify the components of Solar dryer system.	I	02
4	Use pyranometer for measurement of solar radiation flux density.	I	02*
5	Assemble a solar PV system with and without battery connection	II	02*
6	Measure heat output, Maximum power, power output efficiency of solar PV panel.	II	02*
7	Simulation software to calculate PV energy output.	II	02
8	Use vane anemometer for measurement of different locations for	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	site selection for wind mill.		
9	Assemble/dismantle a horizontal axis small wind turbines.	III	02*
10	Assemble/dismantle a vertical axis small wind turbines.	III	02
11	Measure the output power of the turbine, rotation speed of the turbine, wind speed, system voltage and system current.	III	02
12	Assemble/dismantle a micro hydro power system.	IV	02
13	Measure Power output, flow and head for micro hydro power system.	IV	02
14	Assemble/dismantle a biogas power system.	V	02*
15	Assemble/dismantle a biomass gassifier power system.	V	02*
16	Assemble/dismantle a wind-solar hybrid system	VI	02*
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S.No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	20
2	Setting and operation	20
3	Safety measures	10
4	Observations and Recording	10
5	Interpretation of result and Conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a) Follow safety practices.
b) Practice good housekeeping.
c) Practice energy conservation.
d) Work as a leader/a team member.
e) Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organisation Level' in 2nd year

- 'Characterisation Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Poly crystalline/Mono crystalline solar PV panel 20W X	1,2
2	Solar dryer system.	3
3	Solar Cooker	4
4	Solar water heater (flat plate/tube type) -50 Ltrs.	3
5	Pyranometer any make available in the market.	5
6	Vane anemometer any make available in the market	8
7	3-bladed Geared Wind Turbine: 5/10/20/30 kW, Upwind with 20/30 m hydraulically operated tilt-up/tilt-down tubular tower or whichever lowest rating that is available in the market	9,10,11,12,13
8	Wind (1kW) - Solar PV (1kW) Hybrid System	16,17
9	Smokeless Chulhas, Burners, Heaters and Engines.	18
10	Voltmeter, Ammeter	1 to 21
11	Bio gas plant for lab	18

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Solar Thermal Systems	1a. Identify specified components in the given CSP system. 1b. Select CSP for the given application with justification. 1c. Select Solar Dryer system for a given application with justification. 1d. Describe with sketches the maintenance procedure of the given CSP	1.1 Alternative energy sources: primary, secondary and tertiary energy. 1.2 Classification of solar thermal systems 1.3 Concentrated Solar Power (CSP) systems– Flat plate collectors, parabolic collectors, parabolic dish collector, solar tower. 1.4 Domestic-Water heating systems; Commercial-Heating systems used for process heating Installation- standard procedure, precautions, Plumbing – piping, Valves. 1.5 Maintenance: Routine maintenance, procedure for domestic and commercial water heater systems. • Failure maintenance – Major causes, remedies. 1.6 Solar dryers – Classification, construction, working and applications commercial, agro-products, domestic. 1.7 Choice of a system for a given Application-technical and financial criteria used for selection.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit-II Solar Photovoltaic Systems	2a. Identify the specified components in the given rating of the solar PV system. 2b. Explain with sketches the working of the solar PV system 2c. Select Solar Photovoltaic systems for a given situation with justification. 2d. Describe maintenance procedure of the given Solar PV System.	2.1 Classification of Solar Photovoltaic systems – Grid connected, Off-grid, stand-alone systems. 2.2 PV cells – types, merits and demerits 2.3 Panels – types. 2.4 Battery and other accessories – types, rating, methods of selection 2.5 Recent trends and promotional schemes – Net metering. 2.6 Installation, commissioning and maintenance of Solar Roof Top systems, Stand-alone street light.
Unit– III Wind Energy Systems	3a. Explain with sketches of the working of the small HAWT. 3b. Explain with sketches the working of VAWTs 3c. Prepare the specifications of the specified type of small wind turbine 3d. Describe with sketches the functions of the given components of the large wind power plant 3e. Describe the procedure to undertake routine maintenance of small wind turbines. 3f. Describe the procedure to maintain large wind turbines.	3.1 Types of wind energy systems – large and small, commercial and domestic, grid connected and stand-alone. 3.2 Small Horizontal axis wind turbines (HAWTs): construction, working, specifications and maintenance procedure 3.3 Small veritcal axis wind turbines (VAWTs): construction, working, specifications and maintenance procedure 3.4 Large Horizontal axis wind turbines:: construction, working and maintenance procedure
Unit– IV Micro Hydro Power Systems	4a. Explain with sketches the construction and working of specified type of micro-hydro power systems. 4b. Identify various components in the give Micro hydro power systems. 4c. Select micro-hydro systems for a given situation with justification. 4d. Describe maintenance procedure of the given type of Micro power system(s).	4.1 Micro hydro power systems: Classification, Layout, construction and working. 4.2 Installation-procedure, precautions. 4.3 Operating procedures. 4.4 Maintenance of Micro hydro power systems.
Unit –V Bio-energy Systems	5a. Identify various components in the given type of biomass power system. 5b. Describe with sketches the	5.1 Classification of bio-fuels- biogas, biodiesel. 5.2 Biomass power plants – bio-gas plants, gasifiers, digestors, bio-diesel

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	construction of the specified biomass power plant 5c. Explain with sketches the working of the specified biomass power plant 5d. Describe the procedure of installation of the given Bio-Gas plants. 5e. Describe the maintenance procedure of the given biomass power plant	plants: Layout, construction and principle of working and specification for small power plant of all these 5.3 Installation and maintenance procedure of Bio gas plant. 5.4 Applications of various bio-fuels Domestic – heating, cooking, Commercial – process heating, power generation 5.5 Systems used for utilization of bio-fuels – smokeless Chulhas, burners, heaters and engines.
Unit–VI Renewable Energy Hybrid Systems and Feasibility Studies	6a. Prepare layouts of the given hybrid power systems. 6b. Describe the different performance parameters related to the given Wind-Solar PV hybrid system. 6c. Describe the procedure to test the performance of the given Wind-Solar PV hybrid system. 6d. Prepare project feasibility report for installation of renewable energy systems.	6.1 Types of hybrid system: wind- solar, wind-biogas, solar-biogas: Specification, construction and specification of all these 6.2 Power output of hybrid system. 6.3 Installation-procedure, precautions, Operating procedures of Wind-Solar PV hybrid system. 6.4 Choice of systems –technical and commercial feasibility assessment, costing of renewable energy systems.

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Solar Thermal Systems	10	02	04	08	14
II	Solar Photovoltaic Systems	08	02	04	06	12
III	Wind Energy Systems	08	02	04	06	12
IV	Micro Hydro Power Systems	08	00	04	06	10
V	Bio-energy Systems	08	02	04	06	12
VI	Renewable Energy Hybrid systems and feasibility studies	06	02	04	04	10
Total		**48**	**10**	**24**	**36**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews. Participate in field visits to understand actual operation / working of following:

a) Flat plate collector used for domestic water heating application.
b) Flat plate collector used for process heating in commercial / industrial organization.
c) Stand-alone solar photovoltaic lighting Grid connected solar PV power plants
d) Grid connected wind power plants
e) Hybrid plants
f) Bio-gas plants (domestic or commercial)
g) Smokeless Chulhas

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Correlate subtopics with actual renewable energy based appliances and devices.
g) Use proper equivalent analogy to explain different concepts related to these renewable energy conversions.
h) Use Flash/Animations to explain function and construction of Flat plate collector used for domestic water heating application and used for process heating in commercial / industrial organization, Stand-alone solar photovoltaic lighting plant, Grid connected wind mill plant, Hybrid plants.
i) Arrange field or industrial visits to see manufacturing/working of renewable energy systems.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not

be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) Prepare a feasibility report and present it (Group of max 3 students) for employing renewable energy system for any given situation where fossil fuels are used. Following guidelines may be followed.
   i. Various distinctly different industrial or household situations should be visited by the group.
   ii. Annual requirement of total energy for the situation (visited by the respective group) should be estimated using a survey and questionnaire technique.
   iii. Appropriate choice of renewable energy technology should be made based on the availability of local resources.
   iv. The budget required for the installation of the renewable energy system should be estimated by using prevalent market prices of various components and installation costs.

b) The feasibility report should be prepared using various financial parameters such as Return on Investment (ROI) and payback period.

c) Prepare small working models of already existing/improved/new Horizontal/vertical wind turbine, Flat plate collector used for domestic water heating application and used for process heating in commercial / industrial organization, Stand-alone solar photovoltaic lighting plant, Grid connected wind mill plant, Hybrid plants, Wind-Solar PV hybrid system, Smokeless Chulhas, Burners, Heaters and Engines, Biogas plant.

d) Prepare a report for selection of Solar lightning system for a small colony or your institute campus.

e) Prepare a small Solar charger/Solar car/Solar fan/Solar torch/Solar cooler/Solar street light etc.

f) Visit to a commercial or industrial solar water heating installation of at least 500 liters per day capacity and write a report about collector layout, piping and fittings and measurement of performance of the system.

g) Compare constructional details and performance of conventional FPC and evacuated tube FPC.

h) Prepare a layout of solar water heating system for domestic/commercial use. Comprises of plumbing, insulations, control valves and support systems in bad weather conditions.

i) Study various types of solar dryer designs and select best suited dryer for a given application.

j) Study of PV cells : classification - monocrystalline, polycrystalline, thick film, thin film, amorphous, organic.; energy generation mechanism; applications.

k) Study construction and working of horizontal axis wind mill or to visit a nearest wind farm and write a report.

l) Visits to a biogas plant or biomass gasification facility

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Solar Photovoltaic: A Lab Training Module	Solanki, Singh Chetan, Arora, Brij M., Vasi Juzer, Patil, Mahesh B.	Cambridge University Press, New Delhi, (2009), ISBN: 9789382264590
2	Solar Photovoltaic: Fundamentals, Technologies and	Solanki, Singh Chetan	PHI Learning, New Delhi, (2009), ISBN: 9788120351110

S. No.	Title of Book	Author	Publication
	Application		
3	Solar Energy	Sukhatme S.P., Nayak J.K.	Tata McGraw, New Delhi, (2010), ISBN: 9781259081965
4	Introduction to Photovoltaics	Balfour John R., Shaw Michael L., Jarosek Sharlave	Jones and Bartlett Publishers, Burlington, (2011), ISBN: 9781449624736
5	Solar Cells and Their Applications	Fraas Lewis M., Partain Larry D.	Wiley, UK, (2010), ISBN: 9780470446331
6	Concentrating Solar Power Technology	Lovegrove K., Stein W.	Woodhead Publishing, (2012), ISBN:9781845697693
7	Wind Power in Power Systems	Ackermann Thomas	John Wiley and Sons, UK, (2012) ISBN: 9781119942085
8	Renewable Energy Sources and Emerging Technologies	Kothari D.P. Singal K.C.	Prentice Hall India Learning Private Ltd., New Delhi, (2011), ISBN: 9788120344709
9	Solar Energy : Fundamentals and Applications	Garg H. and Prakash J.	McGraw Hill Education, New Delhi, (2017), ISBN: 978-0074636312
10	Introduction to Bioenergy	Nelson Vaughn C., Kenneth L. Starcher	CRC press, UK, (2015) ISBN 9781498716987

14. SOFTWARE/LEARNING WEBSITES

Solar thermal

a. https://mnre.gov.in/file-manager/UserFiles/pdf/Students%20Workbook%20-%20Solar%20Thermal%20System.pdf
b. http://www.climatetechwiki.org/technology/solar-thermal-hot-water
c. http://nptel.ac.in/courses/112105050/m111.pdf
d. http://nptel.ac.in/courses/108105058/15
e. https://www.youtube.com/watch?v=mpHZWYpKDJg

Solar photovoltaic

f. https://www.nrel.gov/workingwithus/re-photovoltaics.html
g. https://mnre.gov.in/solar-photovoltaic-systems
h. https://www.renewableenergyworld.com/solar-energy/tech/solarpv.html
i. https://www.youtube.com/watch?v=jxOvCnQfj_8
j. http://nptel.ac.in/courses/Webcourse-contents/IISc-BANG/notused/Non-Conventional%20Energy%20Systems(28-05-07)/pdfs/chap04.pdf
k. https://www.youtube.com/watch?v=Fuyq6WrM1EA

Wind power

l. https://www.energy.gov/energysaver/buying-and-making-electricity/small-wind-electric-systems
m. http://synergyfiles.com/2015/04/small-scale-vs-large-scale-wind-turbines/
n. https://www.nrel.gov/workingwithus/re-wind.html
o. https://www.youtube.com/watch?v=JJDylOtr5yA
p. https://www.youtube.com/watch?v=NbZepCQUQTg
q. http://nptel.ac.in/courses/108108078/pdf/chap6/teach_slides06.pdf
r. http://nptel.ac.in/courses/108107028/module1/lecture1/lecture1.pdf

Micro, hydro power systems

s. http://www.renewablesfirst.co.uk/hydropower/hydropower-learning-centre/what-is-the-difference-between-micro-mini-and-small-hydro/
t. https://www.youtube.com/watch?v=eXljm_axyu0
u. http://nptel.ac.in/courses/108108078/pdf/chap5/teach_slides05.pdf
v. http://nptel.ac.in/courses/105105110/pdf/m5l01.pdf
w. https://www.youtube.com/watch?v=JBrdUoU2uTE
x. https://www.youtube.com/watch?v=i9yCpuiMze0

Bio energy systems

y. https://www.youtube.com/watch?v=DKvzVlN-sOQ
z. https://www.bioenergyconsult.com/biomass-energy-systems/
aa. https://mnre.gov.in/bio-energy
bb. http://nptel.ac.in/courses/108108078/7
cc. http://nptel.ac.in/courses/102104057/3
dd. http://nptel.ac.in/courses/102104057/
ee. http://nptel.ac.in/courses/102104057/5
ff. http://nptel.ac.in/courses/102104057/4