Draft Report

On

Development of Model Curriculum in Renewable Energy

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Draft Renewable Energy Curriculum

Introduction

In the context of depleting fossil fuel resources and the need to develop sustainable energy systems for the future, it is necessary to incorporate renewable energy in the traditional engineering curricula.

This report proposes two options (Module 1 and Module 2) for the integration of renewable energy into engineering curriculum in India. Before proposing these options, it is necessary to compile data on the existing courses related to renewable energy. A questionnaire was designed for this purpose (Appendix 1) and mailed to engineering colleges in India.

Feedback

The questionnaire was sent to about 200 engineering colleges. 57 completed responses were received. Appendix 2 shows a list of the engineering colleges from which responses were received.

It was found that more than 90% of the respondents had some course on renewable energy in their curriculum. It is likely that the engineering colleges with courses and activity in renewables have been more enthusiastic in responding to the questionnaire. If we assume that the colleges that did not respond do not have a course on renewables then the percentage of colleges with courses on renewables is about 25%(Q4).

Of the 52 colleges that have subjects in renewable energy, 39 offered the course as an elective. This included 26 colleges where renewables accounted for a full elective. This seems to be the preferred route (50% of colleges offering subjects in renewables, opted for a full elective course). In colleges where it was a part subject, it accounted for about 40 % of the subject. In most of the colleges the course on renewables is offered in the 4^{th} year (35 colleges or about 70%), while in 10 engineering colleges it is offered in the 3^{rd} year.

The most common subject title is Non-Conventional Energy Sources (13 or 25% of the subjects). Appendix 3 gives a list of the subject names offered by the engineering colleges.

In some colleges a subject in Renewable Energy was introduced as early as 1976. In most of the colleges this subject has been introduced in the 1990's. Figure 1a shows the distribution of the year of introduction of renewable energy courses and Figure 1b shows the cumulative numbers.

17 respondents (32% of those offering renewable courses) had a laboratory component related to renewable energy.

Almost all respondents (47 out of 49 responding to this question -Q6) felt that there should be a full course in renewables with 31 opting for a compulsory course and 16 preferring an elective.

Respondents were asked to rate the reasons given for renewable energy being included in the under-graduate curriculum on a scale of 1 to 10 (0-not important, 10-critically important).

The reasons with the ratings are given below: (Mean ± standard deviation)

1. Engineers need to have a general awareness of renewable energy (8.64±1.86)
2. Renewable Energy provides design and research challenges (8.26±2.57)
3. Renewable Energy will provide new job opportunities (6.70±2.99)
4. Renewable Energy help in their normal engineering job functions (5.87±2.44)
5. Students are interested in renewable energy (5.06±2.12)

Respondents believe that it is necessary for engineers to have a general awareness of renewable energy and that RE provides design and research challenges.

Respondents were asked to rate the aspects of renewable energy that should be included in the under-graduate curriculum on a scale of 1 to 10 (0-not important, 10-critically important).

The aspects with the ratings are given below:

(Mean ± standard deviation)

Energy crisis and Sustainability.	(8.17±2.50)
Biomass Technologies.	(6.95±2.00)
Solar Thermal Technologies.	(7.82±1.88)

Solar Photovoltaic Technologies.	(7.66±1.93)
Micro – Hydel and Wind.	(6.71±2.00)
Energy Economics.	(7.71±2.10)
Environmental Impacts of Fossil Fuel Use.	(7.70±2.14)
Energy Conservation/ Management	(8.72±1.82)

All components had an inclusion rating greater than 5, indicating that they should be included. Interestingly energy conservation/ management and energy crisis and sustainability had the highest inclusion ratings. This is in tune with the respondents emphasis on engineers needing to have a general awareness of renewable energy.

Almost all respondents (54 out of 56) had faculty who would be interested in teaching a subject on renewable energy. Yet a large proportion of respondents (40 out of 52 or 77%) felt that there was a need to train faculty for this. 14 respondents preferred a 4 week training period, while 13 preferred a 2 week training period (1 week-3, 3 weeks - 4, 8 weeks - 4).

A majority of the engineering colleges had no laboratory facilities for renewable energy. 17 respondents had some experimental facilities related to renewable energy while 37 respondents (69%) did not have any experimental facilities.

A total of about 100 student projects each year were carried out in renewable energy that indicates an average of about 2 projects per engineering college. A similar number of projects are carried out in energy efficiency.

Appendix 1

Renewable Energy Curriculum in Under – Graduate Engineering

1) Name of Institute / College / University:_____

2) Degree ☐ B.Tech ☐ B.E. ☐ Other / specify

Specialisation ☐ Mechanical ☐ Chemical ☐ Electrical

Others ☐ (Please specify)

3) Name of Respondent: _____

Mailing Address: _____

_____

Email id: _____

Phone: _____

Fax: _____

4) Do you have a subject in Renewable Energy ?☐ Yes ☐ No

5**) If yes** please answer the following:,

a) Is it an ☐ Elective ☐ Compulsory Subject

b) Is it a ☐ Full Subject ☐ Part Subject _____%

(Name of subject) _____

c) In which year is it taught? _____ ($1^{st}/2^{nd}/3^{rd}/4^{th}$)

d) Since when has it been introduced ?_____

Please enclose a copy of the syllabus and the text / references.

e) Is it taught by

☐ Regular Faculty

☐ Part Time Faculty

☐ Guest Faculty (only for this subject)

f) Does it have a laboratory component? ☐ Yes (please specify) ☐ No

6) Do you feel renewable energy should be

a) an Elective ☐ Yes ☐ No

b) a compulsory subject ☐ Yes ☐ No

c) Part of a subject ☐ Yes ☐ No

If yes _____%

Name of Subject _____

7) What is the reason you feel that renewable energy (RE) should be included in the undergraduate curriculum? Rate each aspect on a scale of 0 to 10 (0 - not important, 10 – critically important)

☐ Engineers need to have a general awareness of RE issues/technology

☐ Students are interested in RE

☐ RE will help in their normal engineering job functions

☐ RE will provide new job opportunities

☐ RE provides design and research challenges

8) What aspect of renewable energy should be taught to undergraduates? Rate each aspect on a scale of 0 to 10 (0 - not important, 10 – critically important)

☐ Energy crisis and Sustainability.

☐ Biomass Technologies.

☐ Solar Thermal Technologies.

☐ Solar Photovoltaic Technologies.

☐ Micro – Hydel and Wind.

☐ Energy Economics.

☐ Environmental Impacts of Fossil Fuel Use.

☐ Energy Conservation/ Management

9) Do you have faculty who will be interested

a) In teaching this subject ☐ Yes ☐ No

b) Is there a need to train faculty for this? ☐ Yes ☐ No

No. of faculty _____ Preferred duration of Training _____ weeks

10) Do you have existing laboratory facilities for supporting such a course? (specify)

11) What percentage of your B.Tech / B.E. projects are related to

Energy Management _____ % _____ Number

Renewable Energy _____ % _____ Number

12) a) Please provide your suggestions on how renewable energy can be integrated into undergraduate curriculum. Is is possible to re-orient existing subjects to incorporate RE?

12 b) Please provide any comments / suggestions on what a renewable energy subject should include.

c) Any other comments/ Suggestions

Thank you for your time. Please send your response by **January 20, 2003** to:

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Appendix 2

List of Engineering Colleges responded

1. Government Engg. College,Aurangabad (Mechanical)
2. Visvesvaraya National Institute Of Technology, Nagpur
3. Indian Institute Of Science, Banglore
4. Manipal Institute Of Technology,Manipal
5. Siddaganga Institute Of Technology,Tumkur
6. Centre For Energy Studies(JNTU),Hyderabad
7. Malaviya Regional Engg. College, Jaipur
8. Indian Institute Of Technology,Madras
9. Regional Engg. College, Srinagar
10. Birla Institute Of Technology And Science,Pilani
11. Zakir Hussain College Of Engg. And Technology,Aligarh
12. People's Education Society College Of Engg.,Aurangabad
13. Indian Institute Of Technology, Kharagpur
14. Government Engg. College, Jalpaiguri
15. K.K.Wagh College Of Engg., Nashik
16. Indian Institute Of Science, Banglore
17. School Of Energy And Environmental Studies, Indore
18. Erode Segunthar Engineering College, Erode
19. Coimbatore Institute Of Technology, Coimbatore
20. Cochin University Of Science And Technology, Cochin
21. National Institute Of Technology, Kurukshetra
22. Sir M. Visveswaraya Institute Of Technology, Banglore
23. Government Engg. College, Gandhinagar
24. Dr. Babasaheb Ambedkar Technological University,Lonere (Elect.)
25. Sri Ram Engg. College, Tamilnadu
26. Birla Institute Of Technology, Ranchi
27. Engineerig College, Raipur
28. Dr. Babasaheb Ambedkar Technological University,Lonere (Mech.)

29. JNN College Of Engg., Shimoga
30. Pondicherry Engg. College, Pondicherry (Elect.)
31. Pondicherry Engg. College, Pondicherry (Mech.)
32. Department Of Renewable Energy Sources,Udaipur
33. Giani Zail Singh College Of Engg. & Technology,Bhathinda
34. Calicut Regional Engg. College,Calicut (Elect.)
35. College Of Engg. Roorkee, Roorkee
36. Coimbatore Institute Of Technology, Coimbatore
37. Indira Gandhi Institute Of Technology, Dhenkal, Orissa
38. Sardar Vallabhbhai Regional College Of Engg.&Tech., Surat
39. Institute Of Technology, BHU, Varanasi
40. Calicut Regional Engg. College,Calicut (Mech.)
41. Siddaganga Institute Of Technology,Tumkur
42. Aligarh Muslim University, Aligarh
43. Shri G.S. Institute Of Technology & Science, Indore
44. Government College Of Engg., Amravati
45. Government College Of Engg., Aurangabad (Elect.)
46. Government College Of Engg., Kannur
47. Birla Institute Of Technology & Science,Pilani
48. National Institute Of Technology,Warngal(Deemed University)B. Tech
49. NMAM Inst. Of Technology, NITTE, Karkala, Karnataka (Elect.)
50. Pujab Engg. College, Chandigarh
51. Government.Engg. College Salem-636011
52. Bharti VidyapeethDeemed University College Of Engg.
53. NMAM Inst. Of Technology, NITTE, Karkala, Karnataka (Mech.)
54. College Of Agricultural Engg.,TNAU
55. S.P.College of Engg.,Mumbai
56. School Of Energy Studies, Dept.of Physics,Shivaji University,Kolhapur
57. Tribhuvan University, Institute of Engineering

Appendix 3

List of the subject names offered by the engineering colleges

1. Non-Conventional Energy Sources
2. UnConventional Energy Systems
3. Renewable Energy Sources
4. Alternative Sources of Energy
5. Renewable Energy Technologies
6. Renewable Energy
7. Non-Conventional Energy Sources, Elements of mech engg, enrergy audit and conservation and recycling
8. Bio Energy System, Principal of solar thermal Engg., Design of PV system, Water Resources System Auditing
9. Non-Conventional Energy Sources (In Power Plant Engineering)
10. Direct Energy Conversion, Solar Energy Engg.
11. Energy Technology
12. Energy Audit and Conservation
13. Electric Energy Generation and Control (EE4303)
14. Energy Conversion System (Compulsary), Power Station Practice (Elective)
15. Non-Conventional Energy Sources and Power Generation, Power Electronics in Wind and Solar Power Conversions
16. Energy Technologies, Energy Management(UG);Energy Systems Management (PG)
17. Solar Engineering

18. Energy Conversion System and Power Plant Engg.
19. Unconventional Energy Sources
20. Alternate Energy Resources
21. Power systems
22. Energy and Environmental Engg.
23. Energy Systems(Compulsary),Non-Conventional Energy Sources(Elective)
24. Renewable Energy For Food Process Industries Energy Science
25. Solar Cells

Fig. 1a Distribution of year of introduction of Renewable Energy Courses

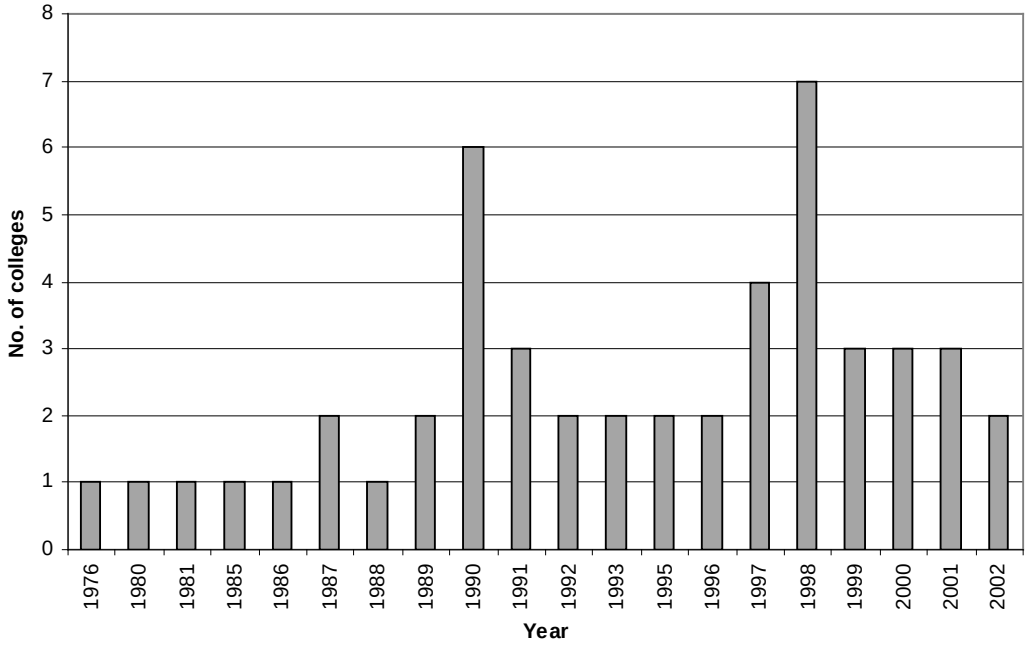
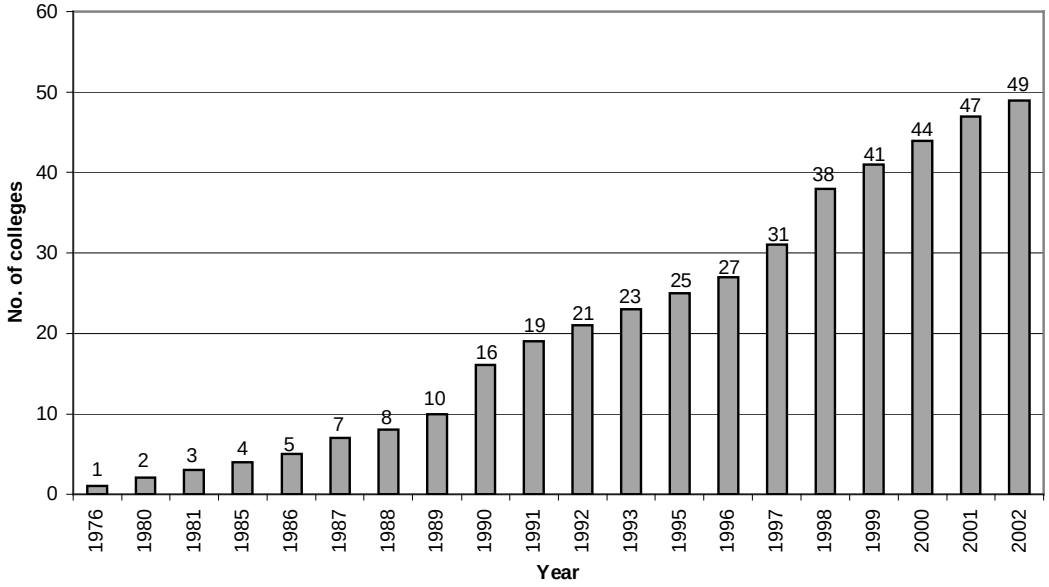


Fig. 1b Number of Renewables Courses operational Vs Year (Cumulative)



Module 1

a) *Compulsory Inputs (Core)* -A core of 20 hours of lectures should be integrated as modules in existing courses. This is recommended for all engineering students, but should be mandatory for mechanical, electrical and chemical engineering. This should be supplemented by a few laboratory experiments.

Suggested Syllabus for Core Inputs

1. Energy Problem, Finite Fossil Reserves, Energy and Environment, Need for Renewables	3 hrs
2. Solar radiation	2 hrs
3. Energy balance for a flat plate solar collector	2 hrs
4. Principles of Wind Energy Conversion Wind m/c and characterization	3 hrs
5. Biomass Gasification	3 hrs
6. Solar PV	2 hrs
7. Renewable Energy Systems Design and Economics	5 hrs
Total	20 hrs

Suggested References (at end of module 2)

The emphasis in the core could differ based on the discipline e.g. the breakup shown above is for Mechanical Engineering. For Electrical Engineering the PV component could be increased and the Biomass Gasification reduced. The component on renewable energy systems would be chosen appropriately by the faculty based on the discipline - e.g an Electrical Engineering curriculum could include the sizing/selection of PV modules, battery, maximum power point tracking, inverter to meet a given power load profile.

Experimental (at least 3) Approx 6 hours

1. Measurement of Solar Radiation
2. Efficiency of a Flat Plate Solar Collector
3. Operation and Efficiency of a Gasifier-Engine
4. I-V Characteristics and Efficiency of a Solar PV cell

In addition to the above, the college could include experiments on wind, micro-hydel, biogas etc.. The objective is to give students a feel of actual systems and experience with some simple measurements.
Since different universities, engineering colleges have different course structures it is difficult to make specific recommendations about how this integration should be achieved. Each Department/ Board of Studies should modify the curriculum appropriately and ensure that the core lectures have been included.

For example, in Mechanical Engineering the inputs could be included in existing courses on Thermodynamics, Energy Conversion, Thermal Engineering, Power Plant Engineering. Internal Combustion Engines, Experimental Engineering.

b) Elective- The engineering student should have the choice of opting for a specialised subject related to renewables in the final year. Some suggested courses are:

1. Wind Energy Systems
2. Solar Thermal Systems
3. Direct Energy Conversion- Solar Photovoltaic, Fuel Cells
4. Waste to Energy
5. Energy Management
6. Solar Passive Architecture
7. Biomass Energy Systems
8. Small Hydro Systems

This list is not intended to be exhaustive. Electives could also couple a series of renewable technologies/ systems and offer it as an elective. These electives should include a greater emphasis on analysis for component and system design and may include appropriate experimental components.

The college should ensure that at least one renewable energy elective is available for students, in case they are interested.

Module 2

A compulsory (core) subject in Renewable Energy is to be offered in the 3rd year or the 4th year.

Suggested Syllabus (Total 40 hours of lectures+ experiments)

1. Energy Problem, Finite Fossil Reserves, Energy and Environment, Need for Renewables and Energy Efficiency **-5 hrs**

2. Renewable Energy Resources – Solar, Wind, Biomass – Solar Radiation Fundamentals -**5 hrs**

3. Renewable Energy Devices and Systems **-25 hrs**

a) **One** of the topics below is to be covered in detail - principle of operation, performance analysis, testing, application case studies **(15 hours)**.

i) *Solar Thermal* - Analysis of Flat Plate Collector, Testing procedures, Solar Pond, Parabolic Collectors, Paraboloid Dish, Central Receiver. Energy Storage systems. Case studies of Solar thermal systems for residential water heating, industrial heating and power generation **-15 hours**

ii) *Biomass Energy Systems* - Biomass Conversion Routes- Combustion, Gasification, Anaerobic Digestion, Pyrolysis, Cogeneration. Performance analysis and testing, Case studies of Biomass systems for thermal applications and Power generation **-15 hours**

iii) *Direct Energy Conversion* - Solar Photovoltaic, I-V characteristics of solar cells, Wafer and Thin Film - manufacturing processes, Tracking - Maximum Power Point Tracking, Battery Characteristics, DC Power Conditioning Converters, AC Power Conditioning -Inverters, Testing of PV systems, Applications of DC power systems and AC power systems, Fuel Cells - principle , types, applications -**15 hours**

iv) *Wind Energy and Small Hydro* - Wind Distribution, Principles of Operation of wind turbines, types of wind turbines and characteristics, Generators for Wind Turbines, Control strategies. Classification of hydro turbines, Performance analysis, Selection and Sizing, Application Case Studies **-15 hours**

b) An *overview of other renewable devices, systems* - This could include devices and systems from the other three sub-categories as well as systems dealing with ocean thermal energy conversion (OTEC), wave, tidal, geothermal etc.. - **10 hours**

4. Economic Viability : Calculation of the cost of energy supply from renewables, Comparison with conventional fossil fuel driven systems in terms of costs and emissions. Calculation of carbon dioxide reduction and incremental costs for renewable options. -**5 hours**

This course should also have experiments that give students a feel of actual systems and experience with some simple measurements in renewable energy

Experimental (at least 4) Approx 8 hours

1. Measurement of Solar Radiation
2. Efficiency of a Flat Plate Solar Collector
3. Operation and Efficiency of a Gasifier-Engine
4. I-V Characteristics and Efficiency of a Solar PV cell
5. Calorific value of Biomass samples

In addition to the above, the college could include experiments on wind, micro-hydel, biogas etc…

Suggested References

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