M. Tech.

in

Renewable Energy Technologies and Management



Centre for Energy Studies
Indian Institute of Technology Delhi
Hauz Khas
New Delhi-110016

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Preamble

This is an M. Tech. Programme on Renewable Energy Technologies and Management for Sponsored Candidates from Abroad and India (on both Full Time and Part Time Basis). In future, if appropriate, the programme may also be offered to regular students admitted through GATE. A brief outline of the concept behind floating this programme is presented in the following paragraphs.

1. Introduction

Design, development and dissemination of appropriate energy technologies is important for meeting the growing energy requirement for economic growth as well as for improvement in the quality of human life. Harnessing of renewable energy sources with the help of appropriate technologies is expected to address a variety of global challenges including those of fossil fuel scarcity and their potential depletion, energy security, energy access, inter- and intra-generational equity in usage of fossil fuels, environmental sustainability as well as increasing cost of fossil fuel based energy delivery. Development and large scale dissemination of renewable energy technologies has been prioritized by a large number of countries across the globe with some countries having ambitious plans to deploy environmentally sustainable energy supply options to meet their energy demand. Most of the other countries across the globe have also initiated activities to harness renewable energy sources. A variety of promotional and support measures have been taken by a large number of countries of the world for this purpose. From a modest beginning in mid-nineteen seventies, considerable progress has been made in several technologies that include wind power, solar photovoltaic and thermal applications, as well as production of biogas, bio-ethanol and bio-diesel from biomass feed stocks. For the past two calendar years, at global level, incremental electricity generation capacity based on renewable energy has been more than that based on fossil fuels. Moreover, the commitments made by a large number of countries as per their respective Intended Nationally Determined Contributions (INDC's) under the Paris Climate Agreement of December 2015 also necessitate large scale harnessing of renewable sources of energy. As a consequence, majority of these countries have decided to prioritize development and deployment of renewable energy technologies. For example, the International Solar Alliance (ISA) with its headquarters in India is mandated to promote renewable energy utilization in member countries and India is expected to play a pivotal role in this initiative. India has highly ambitious plans towards large scale utilization of renewable sources of energy with deployment of solar, wind, hydro and biomass energy technologies. The country could also aims at a leadership role in terms of development of renewable energy technologies and their transfer to a large number of developing countries in Asia, Africa and Latin America. Moreover, the country can also contribute towards capacity building in the field of renewable energy for manpower in a large number of other countries of the world.

Development, deployment, operation and maintenance of renewable energy technologies require knowledgeable and skilled manpower at all levels. Potential manpower requirement is expected to be with renewable energy project developers, EPC contractors, O&M contractors, Sales and Marketing entities, Financing institutions, organizations engaged in Lender's and Owner's engineering, Consulting organizations, government institutions and academic organizations. As per the estimates reported in the literature renewable energy sector has a huge potential to create employment avenues in most of the countries including India. Moreover, with many of its academic institutions having globally acclaimed credentials in imparting quality education and training at relatively lower cost of tuition and living expenses, India can contribute effectively towards human resource development in most of the developing countries in the field of renewable energy. It is with this background that the Centre for Energy Studies (CES) of the Indian Institute of Technology Delhi proposes to offer a Master of Technology (M. Tech.) programme on "Renewable Energy Technologies and Management" for candidates sponsored by stakeholder organizations in India and

other countries of the world. Once established the programme may also be offered to regular M. Tech. students admitted through GATE.

In India the renewable energy based electricity generation capacity had reached 73GW in October 2018 and the country envisages achieving an installed capacity of 175 GW by the year 2022. However, the overall contribution of non-hydro renewable energy technologies is still very limited as compared to their potential and there is an urgent need to design, develop and disseminate these technologies with minimum dependence on external sources. This is also applicable to a large number of other countries of the world.

In order to ensure that share of renewable sources of energy in the global energy supply mix is substantially increased, large scale dissemination of renewable energy technologies is necessary. This will require a large number of knowledgeable and skilled manpower to design, develop, install, operate, repair, and maintain renewable energy systems. An important characteristic of renewable energy technology development and dissemination is its effect at two distinct levels. While the centralized large scale harnessing of renewable energy sources (such as electric power generation using solar, wind, geothermal, waves, tides, ocean thermal gradients, mini hydro, etc.) and large-scale industrial process heating application would, in general, provide employment opportunities in the organized sector, the decentralized (invariably household-level) applications of these sources (improved cook-stoves, solar cookers, biogas plants, solar photovoltaic lanterns, solar domestic hot water systems, etc.) have immense potential for creating skilled manpower requirements usually centered around private/individual entrepreneurs. To meet the manpower requirement of both the above types of potential renewable energy applications, it is important that educational efforts in this area take into account the job requirement of both types of applications. Renewable energy education must, therefore, ensure that trained manpower for large-scale systems is available along with skilled entrepreneurs for design, development, trouble-shooting, and maintenance of renewable energy based decentralized systems. For a balanced and accelerated diffusion of various renewable energy technologies adequate number of competent and well trained professional are needed (for resource assessment, technology development, system design, installation, operation, repair and maintenance, performance monitoring, information processing, planning, financing etc.). Workforce development is one of the critical factors to success in implementing any strategy towards renewable energy technology development and dissemination. It is necessary to periodically seek inputs from the industry about

a) any gap(s) between existing and desired levels of renewable energy education and training,

b) important programmes/ courses for professional already employed in the field of renewable energy and

c) required skills and knowledge with the new entrants to renewable energy industry.

This necessitates that sincere efforts be made in the area of renewable energy education and training to provide the required technical manpower at all levels. The desirable features of a university level renewable energy education programme may include:

a) It should cover all renewable energy resources with particular emphasis (if needed) on some specific ones depending upon the local needs and resource availability characteristics.
b) It should cover all aspects relevant to the development and deployment of renewable energy technologies such as

    i. resource assessment,

ii. design, manufacture, installation, performance monitoring, trouble shooting and maintenance of technologies,
iii. financial, economic and energetic aspects of renewable energy technology utilization,
iv. socio-cultural acceptability,
v. assessment of associated environmental impacts, and
vi. project development and management aspects.

c) It should provide a balance between theory and practical aspects. Therefore, its curricula should include inputs on laboratory and demonstration experiments, hands-on-skills training, trouble- shooting, design and manufacture related inputs besides lectures, tutorials, assignment and seminar etc.

d) The renewable energy sector is witnessing rapid changes in terms of technology options, costs, policy measures etc. Therefore, the programme should be flexible and dynamic thus allowing for future improvements in the content and structure of teaching/training programme.

e) It should be compatible with global efforts to facilitate effective and mutually beneficial experience sharing and interaction with other institutions in the world.

The Centre for Energy Studies (CES), Indian Institute of Technology Delhi is the first academic unit established in the country for imparting education and training in the field of energy. Presently it offers two M. Tech. programmes, a doctoral programme and several UG level courses that include components of renewable energy technologies. However, with huge envisaged targets for renewable energy deployment and rapid increase in the capacities installed, the need for professionals specially prepared for the field of renewable energy is being strongly felt by the industry as well as other stakeholder organizations. The M. Tech. programme on Renewable Energy Technologies and Management aims at providing the requisite manpower for contributing to all aspects of the targeted development and deployment of renewable energy technologies on a global scale. The programme aims to provide the students with a solid foundation (in terms of knowledge and skills) to meet the growing challenge of achieving energy and environmental sustainability by harnessing renewable sources of energy. The programme is designed to prepare students for the current and future challenges faced by industry, existing and potential consumers, investors as well as policy makers. The programme addresses all the key aspects of renewable energy utilization – from state of the art renewable energy technologies to economic and financing considerations.

On successful completion the M. Tech. programme the students would have

a) understanding of different renewable sources of energy and technologies to harness them, storage technologies, regulation and control, distribution options etc.

b) knowledge and understanding of national and international regulations pertaining to renewable energy technologies as well as relevant policy initiatives,

c) the ability to develop initial design of renewable energy systems and their subsystems,

d) the ability to analyze the role of different components in affecting the overall functioning of the system as well that of other components, and

e) the ability to identify the topic for and carry out independent research and also to present the findings of the same along with the approach used for the study.

2. Important Details of the M. Tech. Programme:

The M. Tech. programme is designed for students with engineering (chemical, civil, electrical, energy, engineering physics, mechanical) and science (physics) backgrounds. In case of candidates with adequate professional experience in the field of renewable energy, other academic backgrounds (management, civil engineering, chemistry, and mathematics) may also be considered for admission in the programme.

To begin with, the programme is to be offered to sponsored candidates only (both on full time and part time basis, with the latter for professionals working within 50 km of IIT Delhi). The candidates would preferably be drawn from organizations currently engaged in renewable energy related activities or likely to initiate activities in the field. Attempt would be made to attract foreign students in the course.

Each batch of the M. Tech. programme can have a maximum strength of 35 students. For full time sponsored candidates, bachelor accommodation may be arranged outside the Institute on payment basis.

The students on successful completion of the M. Tech. programme would acquire requisite knowledge in the specific domain(s) and also have necessary skills to respond to the needs of the renewable energy sector. The curriculum and pedagogies of the M. Tech. programme have been accordingly developed with its important characteristics including the following:

Core Courses: These cover basics of solar, wind, biomass and hydro energy resources and technologies, a laboratory component offering experiments on various relevant aspects of renewable energy technologies, and a course on economics and financing of renewable energy technologies. While Major Project Part-I is also included under the core component of the programme, Part-II is elective.

Elective Courses: A wide variety of elective courses would be offered under the programme with the possibility of selecting electives to acquire knowledge and skills in one of the several broad aspects that may include:

a) Solar Energy Technologies,

b) Grid Integration of Renewables,

c) Alternative Fuels and Vehicles for Transportation,

d) Renewable Energy and Environment,

e) Renewable Energy Management.

Bridge Courses: In view of potentially heterogeneous academic backgrounds of the students likely to be admitted to the programme it is necessary to have provision for Bridge courses that could be offered during first and second semester of the programme. Depending on the academic and professional background as well as the level of preparedness (to be assessed through a test upon joining the programme), each student may be asked to study one or more of the following five bridge courses on Audit basis

a) Basic Electrical Engineering,

b) Basic Thermal Engineering,

c) Applied Mathematical and Computational Methods

d) Introduction to Project Management

e) Technical Writing.

Major Project (Part-I and Part-II): The Major Project undertaken by a student would have direct relevance to his/her current job responsibilities or proposed future professional interests. The students would be encouraged and facilitated to undertake their Major Project in collaboration with industry and/or other stakeholder organizations. Foreign students would be allowed to carry out Part-II component of the Major Project in their country (if desired) with provision for arranging final viva-voce through video-conferencing. Further, the flexibility of sponsored candidates with appropriate field experience doing course work in place of Major Project Part – II may also be allowed.

Internship and Field Visits: In order to provide field exposure and experience of working on field level issues, the programme has a provision of internship during the summer break and the same can be continued in the third semester (without affecting other scheduled course work) to the students.

Special Courses: The programme would have provision for offering short duration courses (V – category) on special topics by experts visiting the Institute. Also in view of the fact that the programme is an emerging area with rapid technological, commercial and policy/regulatory developments, there would be a provision for providing details of latest developments under a course entitled "Advanced Energy Systems".

Additional Activities in Future: Depending on the response to the two year M. Tech. programme and with a careful assessment of requirements at the field level, it is envisaged to assess the suitability of offering one-year postgraduate diploma programmes on (i) renewable energy technologies and (ii) renewable energy management primarily to attract working professionals unable to get two year leave for the M. Tech. programme. In fact, the need and possibility of offering one-semester certificate level courses on specific aspects of renewable energy utilization is also envisaged to be assessed in due course. After gaining some experience, it is also envisaged to explore possibilities of offering such programme(s) on modular basis and also in distance mode. This programme is also expected to be the M. Tech. component of a Dual Degree Programme (B. Tech. in Energy Engineering and M. Tech. in Renewable Energy Technologies) presently being developed by the faculty of the Centre.

Programme Structure of the M. Tech. Programme on
Renewable Energy Technologies and Management for Sponsored Candidates

Overall Credit Structure (PC: Programme Core; PC: Programme Elective; OE: Open Elective)	PC	PE	OE	Total
Credits	27	24	-	51
Bridge (Audit) Courses	0 - 4	0	0	0 - 4

In addition, each student will have to undertake one or more bridge course(s) depending on the preparedness and background of the student as compulsory audit course(s). Semester-wise course distributions for full time and part time programmes are presented in the Programme Structure

along with a list of courses that can be offered under different categories of the programme. As mentioned earlier, it is envisaged to provide a large basket of programme elective courses so that depending on the professional background, current job responsibilities, preference and future plans of the student he/she can select appropriate set of four elective courses during the M. Tech. programme. Of course, a student would have the option of studying more number of elective courses (as audit courses) to acquire additional knowledge and skills in other areas as well.

The M. Tech. programme is expected to attract working professionals from foreign countries as students and consequently offer enhanced opportunities for mutual collaboration. Such a programme would also be useful and attractive for executives working in Indian industry and other stakeholder organizations (both on sponsored Full-Time and Part-Time basis). Moreover, such an M. Tech. programme could also be designed with an exit option after one year (with a PG Diploma) and attract working foreign nationals with feasibility of devoting just one year for acquisition of knowledge and skills in specific areas of their requirement and/or interest (and even one semester Certificate programme on a specific topic).

Master of Technology in *Renewable Energy Technologies and Management*

PROGRAMME STRUCTURE

Programme Code**: ESR**

The overall credits structure

Category	PC	PE	OE	Total
Credits	27	24	0	51
Bridge (Audit) Courses	0 – 4	0	0	0 - 4

Programme Core (PC): ESR

ESL 739	Bioenergy: Resources, Technologies and Applications	3-0-0	3
ESL 742	Economics and Financing of Renewable Energy Systems	3-0-0	3
ESL 753	Solar Thermal Technologies and Applications	3-0-0	3
ESL 755	Solar Photovoltaic Devices and Systems	3-0-0	3
ESL 768	Wind and Small Hydro Energy Systems	3-0-0	3
ESP 705	Renewable Energy Laboratory	0-0-6	3
JRD 799	Minor Project (ESR)	0-0-6	3
JRD 801	Major Project Part -1(ESR)	0-0-12	6

Bridge (Audit) Courses (BA): ESR

(Based on Student's background and preparedness)

ESN 702	Introduction to Project Management	1-0-0	0
ESN 703	Technical Writing	1-0-0	0
ESN 704	Basic Thermal Engineering (***for non-Mechanical students***)	1-0-0	0
ESN 712	Basic Electrical Engineering (***for non-Electrical students***)	1-0-0	0
ESN 791	Applied Mathematics and Computational Methods	1-0-0	0
	Total PC	**(15-19)-0-24**	**27**

Programme Electives (PE): ESR

ESL 718	Power Generation, Transmission and Distribution	3-0-0	3
ESL 729	Renewable Energy and Environment	3-0-0	3
ESL 730	Direct Energy Conversion	3-0-0	3
ESL 732	Bioconversion and Processing of Waste	3-0-0	3
ESL737	Plasma Based Materials Processing	3-0-0	3
ESL 744	Plasmas for Energy and Environment	3-0-0	3
ESL 746	Hydrogen Energy	3-0-0	3
ESL 749	Developing Energy Efficiency and Renewable Energy Projects	3-0-0	3
ESL 751	Renewable Energy Resource Assessment and Forecasting	3-0-0	3
ESL 752	Carbon Audit and Management	3-0-0	3
ESL 756	Energy Policy and Planning	3-0-0	3
ESL 757	Renewable Energy Regulations and Law	3-0-0	3
ESL 771	Instrumentation and Control in Energy Systems	3-0-0	3
ESL 772	Energy Storage	3-0-0	3
ESL 773	Battery Storage	3-0-0	3
ESL 774	Quantitative Methods for Energy Management and Planning	3-0-0	3
ESL 780	Zero Emission Vehicles	3-0-0	3
ESL 790	Policy and Regulatory Aspects of Power System Operation with Increasing Renewable Energy Share	3-0-0	3
ESL 791	Renewable Energy Integration and Power Systems	3-0-0	3
ESL 792	Advanced Energy Systems	3-0-0	3
ESL 796	Operation and Control of Electrical Energy Systems	3-0-0	3
ESL 797	Operation of Electrical Energy Systems with Large Scale Integration of Renewable Energy Sources	3-0-2	4
ESL 798	Distributed and Decentralized Energy Systems	3-0-0	3
ESL 799	Essentials of Electrical Power Generation by Renewable Energy Sources	2-0-2	3
ESL 840	Solar Architecture	3-0-0	3
ESL 842	Negative CO_2 Emission Technologies	3-0-0	3
ESL 845	Net Zero Energy Buildings	3-0-0	3
ESL850	Solar Refrigeration and Air-Conditioning	3-0-0	3
ESL 852	Emerging Materials for Next Generation Photovoltaic Applications	3-0-0	3
ESL 855	Solar Photovoltaic Power Generation	3-0-0	3
ESL 875	Alternative Fuels for Transportation	3-0-0	3
ESL 880	Solar Thermal Power Generation	3-0-0	3
ESL 885	Solar Industrial Process Heating	3-0-0	3
ESP 706	Renewable Energy Simulation Laboratory	0-0-6	3
ESV 891	Special Topics on Emerging Trends in Energy and Environmental Technologies	1-0-0	1
JRD 802	Major Project Part-2 (ESR)	0-0-24	12
JRS 801	Independent Study (ESR)	0--0	3

Programme Electives (PE): From outside Centre

ASL760	Renewable Energy Meteorology	3-0-0	3
CLL 723	Hydrogen Energy and Fuel Cell Technology	3-0-0	3
ELL 758	Power Quality	3-0-0	3
ELL 764	Electric Vehicles	3-0-0	3
ELL 765	Smart Grid Technology	3-0-0	3
MCL 825	Design of Wind Power Farms	3-0-2	4
PYL 727	Energy Materials and Devices	3-0-0	3

SEMESTER WISE COURSE DISTRIBUTION

FULL TIME (4-Semester Schedule) *ESR*

SEMESTER	Courses							Lecture Courses	Contact hrs/week				Credits
									L	T	P	Total	
I	ESL 739 (3-0-0) 3	ESL 768 (3-0-0) 3	ESL 755 (3-0-0) 3	ESL 753 (3-0-0) 3	PE-1 (3-0-0) 3	BA-1 (1-0-0) 0 [If required]	BA-2 (1-0-0) 0 [If required]	5 - 7	15 - 17	0	0	15 - 17	**15**
II	ESP 705 (0-0-6) 3	ESL 742 (3-0-0) 3	PE-2 (3-0-0) 3	PE-3 (3-0-0) 3	PE-4 (3-0-0) 3	BA-3 (1-0-0) 0 [If required]	BA-4 (1-0-0) 0 [If required]	4 - 6	12 - 14	0	6	18 - 20	**15**
SUMMER	Internship and JRD 801 [Major Project Part-1 (ESR) (0-0-12) 6]												
III	JRD 801 Major Project Part-1 (ESR) (0-0-12) 6 [and Internship]					JRD 799 Minor Project (ESR) (0-0-6) 3		0	0	0	18	18	**09**
IV	JRD 802 Major Project-2 (ESR) (0-0-24) 12 [with option to carry out in the home country for a foreign national student with provision for presentations through video conference]							0 or 4	0 or 12	0	0 or 24	12 or 24	**12**
	PE-5 (3-0-0) 3	PE-6 (3-0-0) 3	PE-7 (3-0-0) 3	PE-8 (3-0-0) 3									
													Total 51

PART TIME (6-Semester Schedule) *ESR*

SEMESTER	Courses (Number, abbreviated title, L-T-P, Credits)						Lecture Courses	Contact h/week				Credits
								L	T	P	Total	
I	ESL 739 (3-0-0) 3	ESL 768 (3-0-0) 3	ESL 753 (3-0-0) 3	BA-1 (1-0-0) 0 [If required]			3 - 4	9 - 10	0	0	9 - 10	**9**
II	ESL 742 (3-0-0) 3	ESP 705 (0-0-6) 3	ESL 755 (3-0-0) 3	BA-2 (1-0-0) 0 [If required]			2 - 3	6 - 7	0	6	9 - 10	**9**
SUMMER												
III	PE-1 (3-0-0) 3	PE-2 (3-0-0) 3	BA-3 (1-0-0) 0 [If required]				2 - 3	6 – 7	0	0	6 - 7	**6**
IV	PE-3 (3-0-0) 3	PE-4 (3-0-0) 3	BA-4 (1-0-0) 0 [If required]				2 - 3	6 - 7	0	0	6 - 7	**6**
SUMMER	Internship and JRD 801 [Major Project Part-1 (ESR) (0-0-12) 6]											
V	JRD 801 Major Project Part-1 (ESR) (0-0-12) 6 (and Internship)					JRD 799 Minor Project (ESR) (0-0-6) 3	0	0	0	18	18	**9**
VI	JRD 802 Major Project Part-2 (ESR) (0-0-24) 12						0 or 4	0 or 12	0	0 or 24	12 or 24	**12**
	PE-5 (3-0-0) 3	PE-6 (3-0-0) 3	PE-7 (3-0-0) 3	PE-8 (3-0-0) 3								
											Total	**51**

Note:
PC: Programme Core
PE: Programme Elective
BA: Bridge (Audit) Courses

COURSE TEMPLATES

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PROGRAMME CORE COURSES

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COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Bioenergy: Resources, Technologies and Applications		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL739		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESR
Programme Elective for:	---
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	Nil

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant overlap with any UG/PG course of the Dept./Centre/ School	ESL 714 (5%) ESL 731 (15%) ESL 732 (20%) ESL 875 (10%)
	(b)	Significant overlap with any UG/PG course of other Dept./Centre/ School	CLL 728 (10%) RDL 700 (5%) RDL 722 (15%)
8.2	Supersedes any existing course		Nil

9.	**Not allowed for**	Nil

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester
11.	**Faculty who will teach the course** Profs. K. A. Subramanian, S. K. Tyagi, Kaushik Saha	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course is aimed at dissemination of important information of bioenergy to enable students to acquire knowledge on cutting-edge technologies for conversion of various biomass feedstock to bioenergy / biofuel production and their utilization in combustion engines / devices and fuel cells. On successful completion of the course, the students would be able to contribute towards providing biomass based sustainable energy solutions.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to bioenergy; biomass harvesting; availability and assessment of biomass for bioenergy applications; characterization of biomass feedstock (physico-chemical properties, ultimate, proximate, compositional, calorific value, thermogravimetric, differential thermal and ash fusion temperature analyses); classification of biomass feedstock: first, second and third generation biofuels; hybrid biofuels, basic principles of chemical thermodynamics; carbon neutral fuels. Different pre-treatment processes of biomass; different production routes for biomass conversion to biofuels: biochemical methods (anaerobic, enzymatic- saccharification and fermentation process, and dark fermentation, ABE fermentation); chemical processes (trans-esterification, hydro-processing, micro-emulsification); thermochemical methods (combustion, gasification, pyrolysis, partial oxidation, auto-thermal reforming) for biofuels production including synthesis gas, bio-hydrogen, ethanol, butanol, biogas, methanol, dimethyl ether and paraffinic fuels; Biomass compaction (briquetting and palletisation); biofuel quality upgradation; and biomass and biofuel fuel quality norms. Biomass based incineration plant for heat generation; co-firing of biomass for heat generation for industrial processes; Biomass fuelled combustion devices for cooking and heating applications; Utilization of biomass in external combustion engines including steam turbine power plant and Stirling engines; Case studies for setting up biomass based small power plant (~ 1MW) capacity for rural electrification; utilization of biofuels in gas turbine, internal combustion engines and fuel cells; analysis of carbon neutral and carbon credit.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to bioenergy, harvesting and availability assessment of biomass	3
2	Characterization of biomass feedstock	3
3	Classification of biomass feedstock	2
4	Basic principles of chemical thermodynamics, and carbon neutral fuels	3
5	Different pre-treatment processes of biomass	2
6	Biochemical methods (anaerobic, enzymatic-saccharification and fermentation process, and dark fermentation, ABE fermentation) for biofuel production	4

7	Chemical processes (trans-esterification, hydro-processing, micro-emulsification) for biofuel production	2
8	Thermochemical methods (combustion, gasification, pyrolysis, partial oxidation, auto-thermal reforming) for biofuels production including synthesis gas, bio-hydrogen, ethanol, butanol, biogas, methanol, dimethyl ether and paraffinic fuels for biofuel production	4
9	Biomass compaction (briquetting and palletisation)	1
10	Biofuel quality upgradation, and biomass and biofuel fuel quality norms	2
11	Biomass based incineration plant for heat generation; co-firing of biomass for heat generation for industrial processes	2
12	Industrial Biomass cookstove for cooking and heating	2
13	Utilization of biomass in external combustion engines (steam turbine power plant and Stirling engines); Case studies	4
14	Case studies for setting up biomass based small power plant	2
15	Utilization of biofuels in gas turbine, internal combustion engines and fuel cells	4
16	Analysis of carbon neutral and carbon credit	2
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1-3	Availability assessment of biomass feedstocks
1-3	Potential of food – feed – fertilizer – fuel – fibre conflict in biomass utilization
2	Basic biomass characterization : Ultimate and Proximate Analysis
10	Physico-chemical properties of Biofuel and fuel quality test methods and norms
13	Thermodynamic cycles of Rankine, Brayton, Otto and dual cycles
16	Calculation of CO_2 emission from the power plants using the exhaust gas compositions

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

1. Jay J. C., Biomass to Renewable Energy Processes, Taylor and Francis, CRC Press, 2018
2. Konur O., Bioenergy and Biofuels, Taylor and Francis, CRC Press, 2018
3. Love J. and Bryant J. A., Biofuels and Bioenergy, John Wiley & Sons, 2017
4. Henderson O. P., Biomass for Energy, Nova Science Publishers, 2011
5. Mukunda, H. S., Understanding Clean Energy and Fuels from Biomass, Wiley India, 2011

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	----
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**		**Centre for Energy Studies**	
2.	**Course Title**	Economics and Financing of Renewable Energy Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL742		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESR
Programme Elective for:	JEN
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. T. C. Kandpal, K. Ravi Kumar, S. Karak, S. Kar, D. Sahu

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** Upon completing the course, the student will be able to: • Undertake detailed techno - economic evaluation of various renewable energy technologies and systems. • Identify various feasible mechanisms and strategies of financing renewable energy projects.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Overview of renewable energy technologies. Relevance of economic and financial viability evaluation of renewable energy technologies, Basics of engineering economics, Financial feasibility evaluation of renewable energy technologies, Social cost – benefit analysis of renewable energy technologies. Technology dissemination models, Volume and learning effects on costs of renewable energy systems, Dynamics of fuel substitution by renewable energy systems and quantification of benefits. Fiscal, financial and other incentives for promotion of renewable energy systems and their effect on financial and economic viability. Financing of renewable energy systems, Carbon finance potential of renewable energy technologies and impact of other incentives. Software for financial evaluation of renewable energy systems. Case studies on financial and economic feasibility evaluation of renewable energy projects.

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Overview of renewable energy technologies	2
2	Relevance of economic and financial viability evaluation of renewable energy technologies	1
3	Basics of engineering economics	4
4	Financial feasibility evaluation of renewable energy projects,	6
5	Social cost -Benefit analysis of renewable energy projects	3
6	Technology dissemination models	2
7	Volume and learning effects on costs of renewable energy systems	2
8	Dynamics of fuel substitution by renewable energy systems and quantification of benefits	2
9	Fiscal, financial and other incentives for promotion of renewable energy systems and their effect on financial and economic viability	3
10	Financing of renewable energy systems	5

11	Carbon finance potential of renewable energy technologies and impact of other incentives	4
12	Software for financial evaluation of renewable energy systems	3
13	Case studies on financial and economic feasibility evaluation of renewable energy projects	5
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	------	------
Total Tutorial hours (14 times 'T')		------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	------
Total Practical / Practice hours (14 times 'P')		------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1-2	Introduction to various renewable energy technologies
3-5	Cost of renewable energy technologies (Web based search for costs of projects in the field)
6-7	S-curve and its characteristics
9-13	Policies and support measures announced by Govt. of India and state governments in the country
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Campbell H., Broron R., Benefit- Cost Analysis, Cambridge University Press, 2003.
2. Kandpal T. C., Garg H. P., Financial Evaluation of Renewable Energy Technologies, Macmillan India Ltd., 2003.
3. Park C. S., Contemporary Engineering Economics, Prentice Hall Inc., 2002.
4. Thuesen G. J., Fabrycky W. J., Engineering Economy, Prentice Hall Inc., 2001.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	RET Screen, HOMER, SAM, PV Systems
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	-----
20.5	Equipment	----
20.6	Classroom infrastructure	---
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	-----
21.2	Open-ended problems	-----
21.3	Project-type activity	-----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Solar Thermal Technologies and Applications		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL753		
6.	**Course Status** (Course Category for Program) (list program codes: eg., EE1, CS5, *etc*.)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESR
Programme Elective for:	---
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	Nil

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		(course number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL 770 (~15%) ESL 880 (~15%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering** (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Profs. K. Ravi Kumar, Dibakar Rakshit, T. C. Kandpal

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** The course will provide the knowledge to the students on fundamentals of solar thermal energy systems, concentrating versus non-concentrating systems, various components of solar thermal energy systems, applications in the relevant fields such as power generation, industrial process heating, water distillation, building heating and cooling, cooking and materials processing etc.

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14.	**Course contents:** Solar radiation, Solar angles, classifications of Solar thermal collectors, Non-concentrating and concentrating collectors, Heat transfer fluids, Tracking mechanisms, Emerging solar thermal technologies, Application of solar thermal technologies: Power generation, Industrial process heating, Water distillation, Refrigeration, Building heating and cooling, Cooking, Drying, Thermal energy storage systems: Sensible, Latent and Thermochemical energy storage, Integration of thermal energy systems with various end use applications, Economic analyses of solar thermal energy systems, Life cycle assessment of solar thermal energy systems.

15. Lecture Outline(with topics and number of lectures)

Module no.	**Topic**	**No. of hours** (not exceeding 5h per topic)
1	Basics of solar radiation, solar angles, measurements and estimation of solar radiation	5
2	Classifications of solar collectors, flat plate and evacuated tube solar collector	3
3	Concentrating solar collectors, design considerations, design of receivers for heat collection	4
4	Tracking systems for solar concentrators	2
5	Heat transfer fluids for solar collectors	2
6	Emerging technologies in solar concentrators	2
7	Stand-alone and solar aided power generation	3
8	Solar thermal energy systems for various industrial process heating	4
9	Water Heating, Water distillation, drying	3
10	Solar cooker, solar building heating and cooling, and solar refrigeration	3
11	Application of solar energy in building heating and ventilation (Trombe wall, Phase change material etc.)	3

12	Thermal energy storage systems: Sensible, Latent and Thermochemical energy storage system, materials for energy storage, design consideration.	3
13	Challenges involved in integration of solar thermal energy systems with various applications and possible solutions	3
14.	Life cycle assessment of solar thermal energy systems.	2
Total Lecture hours (14 times 'L')		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours

Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
2-3	Basic optics of solar collection-reflection from, refraction and absorption in a glass
5, 7-12	Basics of heat transfer
10-11	Basics of Refrigeration and air conditioning
7-8	Thermal power generation- Carnot, Rankine, Brayton and Stirling cycle.
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Peter P., The Performance of Concentrated Solar Power (CSP) Systems: Analysis, Measurement and Assessment, Woodhead Publishing, 2017.
2. Garg H.P., Prakash J., Solar Energy: Fundamentals and Applications, Tata McGraw-Hill, 1st Revised Edition, 2016.
3. Goswami D. Y., Principles of Solar Engineering, CRC Press, 3rd Edition, 2015.
4. Duffie J. A., Beckman W.A., Solar Engineering of Thermal Processes, John Wiley and Sons, 4th edition, 2013.

5. Kalogirou S. A., Solar Energy Engineering: Processes and Systems, Academic Press, 2nd Edition, 2013.
6. Lovegrove K., Stein, W., Concentrating Solar Power Technology: Principles, Developments and Applications, Woodhead Publishing, 2012.
7. Sukhatme S., Nayak J: Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 3rd edition, 2008.

20. Resources required for the course (itemized student access requirements, if any)

1	Software	---
2	Hardware	----
3	Teaching aids (videos, etc.)	---
4	Laboratory	---
5	Equipment	---
6	Classroom infrastructure	---
7	Site visits	---
8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	---
2	Open-ended problems	
3	Project-type activity	
4	Open-ended laboratory work	
5	Others (please specify)	

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Solar Photovoltaic Devices and Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL755		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESR
Programme Elective for:	JES
Open category Elective for all other programs (No if Institute Core)	YES

7.	**Pre-requisite(s)**	ESL730/ESL770 so that the basics of PV Device physics are known to the students. Electronics: The students should know semiconductor device physics

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☒Every semester ☐I sem ☐II sem ☐Either semester

11.	**Faculty who will teach the course** Profs. V. Dutta, Vamsi Krishna, Sandeep Pathak, Supravat Karak

12.	**Will the course require any visiting faculty?**	Yes

13.	**Course objectives** The Coursewill be introducing the students to all the aspects of PV technology. This will enable them to understand the requirements for PV materials and PV systems for different applications. The role of PV in autonomous, hybrid and distributed generation will be emphasized.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Photovoltaic materials will be discussed in details. This will include materials in bulk and thin film forms. The role of microstructure (single crystal, multicrystalline, polycrystalline, amorphous and nano-crystalline) in electrical and optical properties of the materials will be emphasized. The need for different cell design will be identified and the technology route for making solar cells will be discussed. Different methods of characterization of materials and devices will be discussed. Applications of Photovoltaic for power generation from few watts to Megawatts will be introduced.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Review of Photovoltaic Conversion	02
2	Thermodynamics of Photovoltaic Conversion	03
3	First, Second and Third Generation PV Devices: Design and Fabrication	12
4	PV device characterization	03
5	PV system for standalone applications (Lighting, Water Pumping etc.)	06
6	PV system for grid interactive applications	06
7	PV based hybridsystem	02
8	Very Large Scale Photovoltaic (VLSPV)	02
9	PV Instrumentation	04
10	Environmental effects of Photovoltaic	02

	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Energy Bands and energy Gap, Carrier concentration at Thermal Equilibrium, Carrier-Transport Phenomena.
1	Junction depletion region, Current-Voltage Characteristics of junctions in reverse and forward directions
2,3	Silicon manufacturing and properties, low cost industrial technologies
4,5	Module design- series and parallel considerations of solar cell, Hot spot generation
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Brendel R. and Goetzberger A., Thin Film Crystalline Si Solar cells, Wiley VCH, 2003.
2. Roger A.M.and VentreJ., Photovoltaic Systems Engineering, CRC Press, 2000.
3. Bhattacharya T., Terrestrial solar photovoltaic, Narosa Publishing House, 1998.
4. France L. and Ang T.G., Photovoltaic Engineering Handbook, Adam Hilger, 1990.
5. Fahrenbuch A.L. and Bube R. H., Fundamentals of solar cells, Academic Press, 1983.
6. Martin G. A., High Efficiency Silicon Solar Cells, Trans Tech. Publications, 1987.
7. Chopra K. L. and Das S.R., Thin Film Solar Cells, Plenum Press, 1981.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Photovoltaic System Design Software (TRANSYS)
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	LCD Projector, OHP and Black Board Facilities
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Wind and Small Hydro Energy Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL768		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESR
Programme Elective for:	JES
Open category Elective for all other programs (No if Institute Core)	YES

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☒I sem ☐II sem ☐Either semester

11.	**Faculty who will teach the course** Profs. T S Bhatti, Ashu Verma, Sumit Chattopadhyay

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** The subject will enhance the understanding of the students on basic concepts of aerodynamics, horizontal and vertical axis wind turbines, small hydro system components and design, hybrid systems and controls

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction, General theories of wind machines, Basic laws and concepts of aerodynamics, Micro-siting, Description and performance of the horizontal–axis wind machines, Blade design, Description and performance of the vertical–axis wind machines, The generation of electricity by wind machines, case studies, Overview of micro mini and small hydro, Site selection and civil works, Penstocks and turbines, Speed and voltage regulation, Investment issues, load management and tariff collection, Distribution and marketing issues, case studies, Wind and hydro based stand-alone / hybrid power systems, Control of hybrid power systems, Wind diesel hybrid systems

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	General theories of wind machines, Basic laws and concepts of aerodynamics	6
2	Description and performance of the horizontal–axis wind machines, Blade design	6
3	Description and performance of the vertical–axis wind machines,	5
4	Micro-siting, The generation of electricity by wind machines, case study	5
5	Overview of micro mini and small hydro, Siteselection and civil works	6
6	Penstocks and turbines	6
7	Speed and voltage regulation, Investment issues, load management and tariff collection, Distribution and marketing issues, case studies,	4
8	Wind and hydro based stand-alone / hybrid power systems, Control of hybrid power systems, Wind diesel hybrid systems	4

	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Manwell J. F., McGowan J. G. and Rogers A. L., Wind Energy Explained – Theory, Design and Application John Wiley & Sons, Ltd., 2002.
2. Hansen M. O. L., Aerodynamics of Wind turbines, Earthscan, 2008.
3. Bianchi F.D., Battista H. D. and Mantz R. J., Wind Turbine Control Systems-Principles, Modelling and Gain Scheduling Design, Springer, 2007.

4. Harvey A., Brown A. and Hettiarachi P., Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes, ITDG, 1993.
5. Laguna M., Guide on How to Develop a Small Hydropower Plant, ESHA,2004.
6. Ritter R., Good & Bad of Mini Hydro Power, GTZ, 2009.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	Power point presentation, OHP and black board Facilities
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	15 %
21.2	Open-ended problems	05 %
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	Some typical examples

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Renewable Energy Laboratory		
3.	**L-T-P structure**	0-0-6		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESP705		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESR
Programme Elective for:	---
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	----
8.2	Supersedes any existing course		---

9.	**Not allowed for**	Any student other than from CES PG programmes

10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester
11.	**Faculty who will teach the course** Almost all faculty of the Centre will be involved	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** The main focus of this laboratory is to provide exposure and hands-on-skills practice to the students on various aspects of renewable energy sources and technology. The students would be able to get detailed insights into the design and operational aspects of renewable energy devices and systems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): -------

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
Course Total		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	------	------
Total Tutorial hours (14 times 'T')		------

17. Lecture Outline (with Description and number of hours)

Module no.	Description	No. of hours
1	General Introduction	3
2	Introduction of first cycle experiments by the faculty members	3
3	Introduction of second cycle experiments by the faculty members	3
4	Elemental characterization of a fuel using CHNS(O) analyser	3
5	Testing of biomass cook stoves with biomass pellets: a) emission characteristics b) thermal performance	3
6	Numerical simulation training for modelling of fuel spray using alternative fuel.	3
7	Numerical simulation training for modelling internal combustion engine using alternative fuel.	3
8	Performance and emission characteristics of a dual bio-diesel fueled	3

	engine	
10	Performance and emission characteristics of a spark ignition engine for methanol-gasoline blend	3
11	Wavelength dependent energy conversions efficiency from solar cell	3
12	Synthesis of MAPbX3 perovskite nano-crystals	3
13	Fabrication of perovskite (ABX3) solar cell	3
14	Performance analysis of the solar flat plate collector	3
15	Determination of light pipe efficiency under sunny sky conditions & Study of internal illumination distribution with a light-pipe in a test room	3
16	Determination of specific heat, latent heat and melting-solidification characteristic of a Phase Change Material	3
17	Solar radiation measurement	3
18	Heat transfer analysis of an absorber tube of parabolic trough collector	3
19	Experimental investigation of thermal energy storage system for solar cooking applications	3
22	Characteristics of induction generation based wind energy conversion system	3
23	Determination of first and second figures of merit (F1 and F2) of a box type solar cooker	3
24	Study of characteristics of different hydro turbines	3
25	Measurement of photoluminescence (PL) of a solar cell	3
26	Analysis of impact of PV and wind integration on transmission and distribution system operation using ETAP/MATLAB	3
27	Study of transients of power system consisting Modular Multilevel Converter based HVDC grid	3
28	Study of various faults and protection mechanism in Power System having Modular Multilevel Converter based HVDC grid	3
Total Practical / Practice hours (14 times 'P')		**84**

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	**Description**
1-14	Basic principles of operation of the analysers, instruments
1-14	Concepts of accuracy, repeatability, precession, least count etc.
1-14	Uncertainty analysis of the measured results
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Subramanian K. A., Biofueled Reciprocating Internal Combustion Engines, CRC Press (2018)
2. Konur O., Bioenergy and Biofuels, Taylor and Francis, CRC Press (2018)

3. Dincer I., Zamfirescu C., Sustainable Energy Systems and Applications, Springer (2011)
4. Kothari D. P., Sharma D. K., Energy Engineering: Theory and Practice, S. Chand Publisher, (2000).
5. Garg H. P., Kandpal T. C., Laboratory Manual on Solar Thermal Experiments, Narosa Publishing (1999).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	TRNSYS, MATLAB, DDA, CONVERGE, ANSYS
2	Hardware	Required as appropriate in experiments
3	Teaching aids (videos, etc.)	----
4	Laboratory	All CES Laboratories
5	Equipment	Required as appropriate in experiments
6	Classroom infrastructure	----
7	Site visits	PV Substation
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

BRIDGE (AUDIT) COURSES

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COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Introduction to Project Management		
3.	**L-T-P structure**	1-0-0 **(a course offered under the basket of Bridge Courses on Audit basis)**		
4.	**Credits**	0	**Non-graded Units**	Not Applicable
5.	**Course number**	ESN702		
6.	**Course Status** (Course Category for Program): Bridge Course on Audit Basis			

Institute Core for all UG programs	NO
Programme Linked Core for:	ESR
Departmental Core for:	
Departmental Elective for:	
Minor Area / Interdisciplinary Specialization Core for:	
Minor Area / Interdisciplinary Specialization Elective for:	
Programme Core for:	
Programme Elective for:	
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		-
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	-
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	-
8.2	Supersedes any existing course		-

9.	**Not allowed for**	Not allowed for UG/PG students outside department.

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒ Either semester

	(check one box)	

11.	**Faculty who will teach the course:** Profs. T. C. Kandpal, Ashu Verma, K Ravi Kumar

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** On successful completion of this bridge course the students will be able to understand and discuss basic concepts of project management that are useful for developing renewable energy projects.

14.	**Course contents:** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Project initiation and planning, Site and technology selection, Regulatory, permitting and environmental compliance, Project feasibility assessment, Identification and mitigation of risks, Planning execution as well as monitoring of projects , Operation and maintenance of projects.

15. Lecture

Module no.	Outline Topic	No. of hours
1.	Project initiation and planning	1
2.	Site and technology selection	2
3.	Regulatory, permitting and environmental compliance	1
4.	Project feasibility assessment	2
5.	Identification and mitigation of risks	2
6.	Planning execution as well as monitoring of projects	3
7.	Operation and maintenance of projects.	1
8.	Case studies	2
Total Lecture hours (14 times 'L')		**14**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component

Module no.	Description
1-7	Case studies available in the literature on development, establishment and operation of photovoltaic and wind power plants

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) Prasanna C., Projects: Planning, analysis, Selection, Financing, Implementation and Review, Tata McGraw Hill (2008)
2) Fong A. and Tippett J. (editors), Project development in the Solar Industry, CRC Press (2013)
3) Neill S., Stapleton G. and Martell C., Solar Farms: The Earthscan Expert Guide to Design and Construction of Utility Scale PV Systems, Earthscan (2017)

20. Resources required for the course (itemized student access requirements, if any)

1	Software	
2	Hardware	
3	Teaching aids (videos, etc.)	
4	Laboratory	
5	Equipment	
6	Classroom infrastructure	
7	Site visits	
8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	
2	Open-ended problems	
3	Project-type activity	
4	Open-ended laboratory work	
5	Others (please specify)	

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

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COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Technical Writing		
3.	**L-T-P structure**	1-0-0 **(a course offered under the basket of Bridge Courses on Audit basis)**		
4.	**Credits**	0	**Non-graded Units**	Not Applicable
5.	**Course number**	ESN703		
6.	**Course Status** (Course Category for Program) Bridge Course on Audit Basis			

Institute Core for all UG programs	NO
Programme Linked Core for:	ESR
Departmental Core for:	
Departmental Elective for:	
Minor Area / Interdisciplinary Specialization Core for:	
Minor Area / Interdisciplinary Specialization Elective for:	
Programme Core for:	
Programme Elective for:	
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		-
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	-
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	CLP 704 (~ 20%)
8.2	Supersedes any existing course		-

9.	**Not allowed for**	- Not allowed for UG/PG students outside department.

10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒ Either semester

11.	**Faculty who will teach the course:** Profs. Sandeep Pathak, Sumit Chattopadhyay, R. Narayanan

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** On successful completion of this bridge course the students will be able to improve their presentation and communication skills as well as become adept in scientific and technical report writing.

14.	**Course contents:** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Language and Communication skills, Basic ethics and styles of Scientific/Technical document writing, Referencing in proper format, Planning Design and Layout of presentation, Important technical jargon for Energy Engineers.

15. Lecture

Module no.	Outline Topic	No. of hours (< 5 hours)
1.	Language:	
	a) Grammar	2
	b) Vocabulary development	2
	c) sentence syntax	2
2.	Communication skills: Etiquetes, coherence and clarity in speech	2
3.	Basic ethics and styles of Scientific/Technical document writing:	
	a) Plagiarism	1
	b) Guidelines for paper/patent and other technical documents as per template provided	1
	c) Analysis, synthesis and evaluation of scientific information	2
4.	Planning Design and Layout of presentation	1
5.	Important technical jargon for Energy Engineers	1
Total Lecture hours (14 times 'L')		**14**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component

Module no.	Description
1	Basic English Language grammar
2, 4	Reading of leading Energy related journals

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) Wren P. C., Martin H. and Rao N. D. V. P., High School English Grammar and Composition, Blackie ELT Books (S. Chand Publishing) (2018).
2) Carnegie D., The Quick and Easy Way to Effective Speaking, Rupa (2016).
3) Quirk R., Greenbaum S., Leech G. and Svartik J., A comprehensive grammar of the English language, Pearson Education India (2010).
4) Jones L., Working in English, 1st ed. Cambridge Univ. Press (2001).
5) Frank M., Writing as thinking: A guided process approach, Phoenix ELT (1989).
6) Hamp-Lyons L. and Heasely B., Study Writing: A course in written English for academic and professional purposes, Cambridge Univ. Press. (1987).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	
2	Hardware	
3	Teaching aids (videos, etc.)	
4	Laboratory	
5	Equipment	
6	Classroom infrastructure	
7	Site visits	

8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	
2	Open-ended problems	
3	Project-type activity	
4	Open-ended laboratory work	
5	Others (please specify)	

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

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COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**			Centre for Energy Studies	
2.	**Course Title**	Basic Thermal Engineering			
3.	**L-T-P structure**	1-0-0 **(a course offered under the basket of Bridge Courses on Audit basis for non-Mechanical Engineers)**			
4.	**Credits**	0	**Non-graded Units**	---	
5.	**Course number**	ESN704			
6.	**Course Status** (Course Category for Program)				
Institute Core for all UG programs				---	
Programme Linked Core for:				ESN, JEN, ESR	
Departmental Core for:				---	
Departmental Elective for:				---	
Minor Area / Interdisciplinary Specialization Core for:				---	
Minor Area / Interdisciplinary Specialization Elective for:				---	
Programme Core for:				---	
Programme Elective for:				---	
Open category Elective for all other programs (No if Institute Core)				Yes	
7.	**Pre-requisite(s)**	Nil			

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant overlap with any UG/PG course of the Dept./Centre/ School	No
	(b)	Significant overlap with any UG/PG course of other Dept./Centre/ School	(≤10%)
8.2	Supersedes any existing course		Nil

9.	**Not allowed for**	Not allowed for UG/PG students outside department.

10.	**Frequency of offering**	☒ Every semester ☐ I sem ☐ II sem ☐ Either semester
11.	**Faculty who will teach the course**	Profs. Dibakar Rakshit, Ravi Kumar, S. K. Tyagi, K. A. Subramanian

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This is a bridge course which is aimed to teach basic of thermal engineering to students who are not having sufficient exposure to the thermal related subject. This course will bridge this gap and at end of this course, the students could well understand the thermal related subjects.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): First and second law of thermodynamics, Thermal fluid systems, Standard cycles, Mixtures of gases, Heat transfer, Fluid mechanics, Practical examples, Use of steam tables.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	First and second law of thermodynamics, heat and work transfer and vice versa, Type of systems (open, closed, isolated)	2
2	Application of steady flow energy equation in compressor, Turbine, Condenser etc.,	2
3	Standard thermodynamic cycles(Carnot, Brayton, Rankine, Otto, Diesel, Dual), relationship between pressure-volume and temperature-entropy	2
4	Mixture of Gases, Characteristics equation, Boyles law, Charles law, Dalton law	1
5	Basics of heat transfer: conduction, convection and radiation, Thermal fluid systems	2
6	Basic of fluid mechanics: Continuity equation, Bernoulli's equation, Navier-stoke equation	2
7	Simple numerical problems related to thermal systems	2
8	Use of Steam Table: Specific volume, specific entropy, specific enthalpy, dryness fraction	1
	Course Total	**14**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
		-------

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description

19. Suggested texts and reference materials

1. Boles M. A. and Cengel Y. A., Thermodynamics: An Engineering Approach, McGraw-Hill Education, 2014.
2. White F. M., Fluid mechanics, McGraw-Hill Education, 2011.
3. Incropera F. P., Dewitt D. P., Bergman T. I. and Lavine A. S., Fundamentals of heat and mass transfer, John Wiley & Sons, 2005.

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----

4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	----
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

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COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**			Centre for Energy Studies	
2.	**Course Title**	Basic Electrical Engineering			
3.	**L-T-P structure**	1-0-0 **(a course offered under the basket of Bridge Courses on Audit basis for non-Electrical Engineers)**			
4.	**Credits**	0	**Non-graded Units**	---	
5.	**Course number**	ESN712			
6.	**Course Status** (Course Category for Program)				
Institute Core for all UG programs				---	
Programme Linked Core for:				ESN, JEN, ESR	
Departmental Core for:				---	
Departmental Elective for:				---	
Minor Area / Interdisciplinary Specialization Core for:				---	
Minor Area / Interdisciplinary Specialization Elective for:				---	
Programme Core for:				---	
Programme Elective for:				---	
Open category Elective for all other programs (No if Institute Core)				Yes	
7.	**Pre-requisite(s)**	Nil			

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant overlap with any UG/PG course of the Dept./Centre/ School	No
	(b)	Significant overlap with any UG/PG course of other Dept./Centre/ School	(≤10%)
8.2	Supersedes any existing course		Nil

9.	**Not allowed for**	Not allowed for UG/PG students outside department.

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course** Profs. Ashu Verma, T.S Bhatti, Sumit Chattopadhyay	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** To familiarize students of CES from streams other than electrical about basics of electrical engineering required for interdisciplinary subjects.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Electrical energy, Single phase and Three phase circuits, Electrical machines, Electrical energy conservation, Power electronics and Power quality, Controls.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Electrical energy	1
2	Single phase and Three phase circuits	4
3	Electrical machines	4
4	Electrical energy conservation	2
5	Power electronics and Power quality	2
6	Controls	1
	Course Total	**14**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1-3	AC/DC circuit analysis
4-6	Basic electrical devices

19. Suggested texts and reference materials

1. Vincent D. T., Principles of Electrical Engineering, Prentice Hall of India (1989)

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	Yes
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----

21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

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COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**			Centre for Energy Studies	
2.	**Course Title**	Applied Mathematics and Computational Methods			
3.	**L-T-P structure**	1-0-0 **(a course offered under the basket of Bridge Courses on Audit basis)**			
4.	**Credits**	0	**Non-graded Units**	---	
5.	**Course number**	ESN791			
6.	**Course Status** (Course Category for Program)				
Institute Core for all UG programs				---	
Programme Linked Core for:				JEN, ESR	
Departmental Core for:				---	
Departmental Elective for:				---	
Minor Area / Interdisciplinary Specialization Core for:				---	
Minor Area / Interdisciplinary Specialization Elective for:				---	
Programme Core for:				---	
Programme Elective for:				---	
Open category Elective for all other programs (No if Institute Core)				Yes	
7.	**Pre-requisite(s)**	Nil			

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant overlap with any UG/PG course of the Dept./Centre/ School	No
	(b)	Significant overlap with any UG/PG course of other Dept./Centre/ School	(≤10%)
8.2	Supersedes any existing course		Nil

9.	**Not allowed for**	Not allowed for UG/PG students outside department.

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course** Profs. R. Narayanan, R. Uma, D. Sahu and S. Kar	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This 1-credit course is designed with the objective of giving some basic mathematical background to those students who did not have it at their graduation level. In these days of computers, numerical methods have become indispensable. Basics of Fourier series / transform and Laplace transform are also included here, MATLAB is being used very much for research purpose.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Fourier and Laplace transform, Complex and vector analysis, Matrices, Numerical and computational methods, Finite difference, Numerical methods of integration, Least square curve fitting, Introduction to C++ and MATLAB

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Fourier and Laplace transform	2
2	Complex and vector analysis	2
3	Matrices	2
4	Numerical and computational methods	2
5	Finite difference	1
6	Numerical methods of integration	2
7	Least square curve fitting	1
8	Introduction to C++ and MATLAB	2
	Course Total	**14**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	---	---
Course Total		---

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
	Course Total	

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description

19. Suggested texts and reference materials

1. Kreysig E., Advanced Engineering Mathematics, Tenth Edition, John Wiley & Sons Inc. (2015)
2. Gerald C. F. and Wheatley P. O., Applied Numerical Analysis, Seventh Edition, Pearson. (2003)

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	C++ and MATLAB
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	Blackboard, LCD Projector, OHP
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----

21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

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PROGRAMME ELECTIVE COURSES

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COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**		Centre for Energy Studies	
2.	**Course Title**	Power Generation, Transmission and Distribution		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL718		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JES, ESR
Open category Elective for all other programs (No if Institute Core)	---

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	EEL796 (<10%) EEL794 (<10%)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☒II sem ☐Either semester

11.	**Faculty who will teach the course** Profs. T S Bhatti, Ashu Verma, Sumit Chattopadhyay

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** The subject will enhance the understanding of the students on power system dynamic stability, generation control, AC and DC transmission, and reactive power control, distribution systems along with conventional and intelligent controls.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Generation: Synchronous generator operation, Power angle characteristics and the infinite bus concept, dynamic analysis and modeling of synchronous machines, Excitations systems, Prime-mover governing systems, Automatic generation control; Auxiliaries: Power system stabilizer, Artificial intelligent controls, Power quality; AC Transmission: Overhead and cables, Transmission line equations, Regulation and transmission line losses, Reactive power compensation, Flexible AC transmission; HVDC transmission: HVDC converters, advantages and economic considerations, converter control characteristics, analysis of HVDC link performance, Multi-terminal DC system, HVDC and FACTS; Distribution: Distribution systems, conductor size, Kelvin's law, performance calculations and analysis, Distribution inside and commercial buildings entrance terminology, Substation and feeder circuit design considerations, distribution automation, Futuristic power generation.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Synchronous generator operation, Power angle characteristics and the infinite bus concept, dynamic analysis	4
2	modeling of synchronous machines, Excitations systems, Prime-mover governing systems, Automatic generation control	9
3	Power system stabilizer, Artificial intelligent controls, Power quality;	6
4	Overhead and cables, Transmission line equations, Regulation and transmission line losses, Reactive power compensation, Flexible AC transmission	4
5	HVDC converters, advantages and economic considerations, converter control characteristics, analysis of HVDC link performance, Multi-terminal DC system, HVDC and FACTS	9
6	Distribution systems, conductor size, Kelvin's law, performance calculations and analysis, Distribution inside and commercial buildings entrance terminology	4

7	Substation and feeder circuit design considerations, distribution automation, Futuristic power generation	6
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Kim C.K., Sood V.K., Jang G.S., Lim J., Lee J., HVDC Transmission: Power Conversions Applications in Power Systems, Wiley – IEEE Press, 2009.
2. Gonen T., Electric Power Transmission System Engineering Analysis and Design, CRC Press, 2009.
3. Wood A. J. and Wollenberg B.F., Power Generation, Operation, and Control. John Wiley & Sons, 2003.
4. Anderson P.M. and Fouad A. A., Power System Control and Stability, Wiley-IEEE Press, 2002.
5. Kundur P., Power system stability and control, McGraw-Hill, 1994.
6. Elgerad O. I., Electric Energy Systems Theory: An Introduction, T M H Edition, 1982.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	Power Point Presentation and OHP, Black Board Facilities
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	Some typical examples

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Renewable Energy and Environment		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL729		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL710 (< 30 %), ESL330 (< 30 %)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	
8.2	Supersedes any existing course		---
9.	**Not allowed for**		

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. K. A. Subramanian, V. K. Komarala, S. Pathak, S. Karak, D. Rakshit, K. Ravi Kumar, S. Chattopadhyay, A. Verma, S K Tyagi, S Kar, D Sahu, K. Saha

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** On successful completion of the course the students will be able to compare the Renewable Energy based energy delivery systems with the conventional ones in terms of emissions and pollutants affecting the environment. The course will provide the students an understanding of various sources of environmental pollution, global warming, role of and effect of harnessing renewable energy sources on environment, the preventive measures and protocols that need to be adopted to negate the adverse effects of climate change, environmental pollution and global warming. The students would be able to evaluate both conventional and renewable energy systems in terms of life cycle analysis and also to assess the effect of large scale harvesting of renewable energy sources on the environment.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Current challenges in terms of environmental pollutions, Sources of pollution and global warming, harmful effects of environmental pollution, preventive measures and protocols to minimize environmental damage, availability and economic aspects of renewable energy sources, effects of renewable energy sources on the environment

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction: Concepts of pollution and climate change, sources of environmental pollution	4
2	Power Generation sector:	2
	a) conventional energy sources	
	b) life cycle analysis of conventional sources	2
	c) renewable energy sources (solar)	2
	d) life cycle analysis of renewable energy sources (solar)	2
	e) renewable energy sources (wind)	2
	f) life cycle analysis of renewable energy sources (wind)	2
3	Transport sector:	
	a) conventional and renewable fuel based systems	4
	b) life cycle analysis of conventional and renewable fuel-based systems	4
4	Process heating:	
	a) conventional and renewable energy based systems	2
	b) life cycle analysis of conventional and renewable energy based systems	4

5	Pollutant emission reduction measures for conventional and renewable energy sources	4
6	Prospects of renewable energy based systems in rural and urban areas	2
7	Environmental impact of pollution on human health and living beings	2
8	Environmental Ethics	4
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1, 5, 6	Basics of Renewable Energy
1, 5, 6	Basics of air, water and land pollution
1, 5, 6	Global energy consumptions: current trends and future projections
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Twidell J. and Weir T., Renewable Energy Resources, Routledge, Taylor & Francis (2015).
2. Gerber L., Designing Renewable Energy Systems: A Life Cycle Assessment Approach, CRC Press (2014).
3. Singh A., Pant D., Olsen S. I. (Editors), Life Cycle Assessment of Renewable Energy Sources, Springer, (2013).
4. Kaltschmitt M., Streicher W., Wiese A., Renewable Energy: Technology, Economics and Environments, Springer (2007).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	----
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Direct Energy Conversion		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL730		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	JES
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	YES

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL360 (12%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. A. Ganguli, V. Dutta, Vamsi Krishna, R. Narayanan, R. Uma

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** To Provide adequate inputs on a variety of issues relating to Direct Energy conversion Systems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Basic science of energy conversion, Indirect verses direct conversion, Physics of semiconductor junctions for photovoltaic and photo-electrochemical conversion of solar energy, Fabrication and evaluation of various solar cells in photovoltaic power generation systems, Technology and physics of thermo-electric generations, Thermal-electric materials and optimization studies, Basic concepts and design considerations of MHD generators, Cycle analysis of MHD systems, Thermonic power conversion and plasma diodes, Thermo dynamics and performance of fuel cells and their applications.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction	2
2	Physics of semiconductors junctions for P.V.& Photo-electrochemical conversion	4
3	Solar cells	
	a) Fabrication and evaluation of various solar cells	4
	b) applications	2
4	Technology and Physics of Thermoelectric generations, Multi stage generators	5
5	Thermoelectric materials and optimization studies	3
6	Thermionic power conversion and plasma diodes	4
7	MHD generators	
	a) Basic concepts and design considerations	5
	b) Thermodynamical Aspects	4
	c) Cycle analysis of MHD systems	2
8	Fuel Cells	
	a) Thermodynamical aspects	4
	b) Performance	4
	c) Applications	2
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Semiconductors: types, fermi level-n junction, metal semiconductor junction, Energy forms and units, Thermodynamics: reversible and irreversible processes, enthalpy, laws of thermodynamics, thermodynamic power cycles, Vectors and vector operations
4	Underlying principle of thermoelectricity
6	Derivation of Richardson-Dushman equation & space-charge limited current, Plasma Definition
7a	Lorentz force, local form of ohm's law in j, e and σ form, concept of source impedance in generators, maximum power transfer theorem
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Bagotsky V. S., Fuel Cell Problems and Solutions, John Wiley & Sons, 2009.
2. Rosa R. J., Magneto hydrodynamic Energy Conversion, Springer, 1987.
3. Angrist S. W., Direct Energy Conversion, Pearson, 1982.
4. Chang S. S. L., Energy Conversion, Prentice Hall, 1963.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	Power point projector and OHP, Black Board Facilities
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

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COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**		Centre for Energy Studies	
2.	**Course Title**	Bioconversion and Processing of Waste		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL732		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JES, ESR
Open category Elective for all other programs (No if Institute Core)	YES

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☒I sem ☐II sem ☐Either semester

11.	**Faculty who will teach the course** Profs. K. A. Subramanian

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** To give an idea about different biomass and other solid waste materials as energy source and their processing and utilization for recovery of energy and other valuable products. A comprehensive knowledge of how wastes are utilized for recovery of value would be immensely useful for the students from all fields.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Biomass and solid wastes, Broad classification, Production of biomass, photosynthesis, Separation of components of solid wastes and processing techniques, Agro and forestry residues utilisation through conversion routes: biological, chemical and thermo chemical, Bioconversion into biogas, mechanism, Composting technique, Bioconversion of substrates into alcohols, Bioconversion into hydrogen, Thermo chemical conversion of biomass, conversion to solid, liquid and gaseous fuels, pyrolysis, gasification, combustion, Chemical conversion processes, hydrolysis and hydrogenation, Solvent extraction of hydrocarbons, Fuel combustion into electricity, case studies.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to biomass and other solid wastes	1
2	Classification of solid wastes	2
3	Biomass wastes, Compositions, Characteristics, Properties, Structural Components	4
4	Production of Biomass and Biomass wastes, Photosynthesis	2
5	Utilization of wastes as feed stocks for chemicals	4
6	Preprocessing techniques and separation of components for feed stocks preparation	3
7	Thermo chemical conversion of wastes into solid, liquid gases through pyrolysis and gasification	6
8	Combustion principles and appliances for utilization of solid wastes	6
9	Bioconversion of wastes into biogas, alcohols and other products	9

10	Chemical conversion processes, hydrolysis and hydrogenation, Solvent extraction of hydrocarbons	3
11	Fuel combustion into electricity, case studies	2
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

1. Tchobanoglous G., Theisen H., Tchobanoglous S. V., Theisen G., Samuel H.V., Integrated Solid Waste management: Engineering Principles and Management issues, New York, McGraw Hill (1993).

2. Samir S., Zaborsky R., Biomass Conversion Processes for Energy and Fuels, New York, Plenum Press (1981).
3. Joseph H. D., Joseph P., John H., Solid Waste Management, New York, Van Nostrand, (1973).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	Power point projector and OHP, Black Board Facilities
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	Theory

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

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COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**		Centre for Energy Studies	
2.	**Course Title**	Plasma Based Materials Processing		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL737		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JES, ESR
Open category Elective for all other programs (No if Institute Core)	YES

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL870 (< 5%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	PHL680 (<5 %)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. A. Ganguli, R. Narayanan, D. Sahu, S. Kar

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** In the last few decades, plasma based materials processing has pervaded almost all areas, from semiconductors and plasma based coatings to plasma nitriding and plasma immersed ion implantation to plasma pyrolysis. Thus a comprehensive knowledge of how plasmas are utilized for different types of materials processing would be immensely useful for the future engineers from all fields.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction: Plasma based processing of materials. Plasma Concepts: Plasma fluid equations, single particle motions, unmagnetized plasma dynamics, diffusion and resistivity, the DC sheath and probe diagnostics. Basics of Plasma Chemistry: Chemical reactions and equilibrium, chemical kinetics, particle and energy balance in discharges. Low Pressure Plasma Discharges: DC discharges, RF discharges - Capacitively and inductively coupled, microwave, ECR and helicon discharges. Low Pressure Materials Processing Applications: Etching for VLSI, film deposition, surface modification and other applications (plasma nitriding, plasma ion implantation, biomedical and tribological applications). High Pressure Plasmas: High pressure non-equilibrium plasmas, thermal plasmas – the plasma arc, the plasma as a heat source, the plasma as chemical catalyst. Applications of High Pressure Plasmas: Air pollution control, plasma pyrolysis and waste removal, plasma based metallurgy – ore enrichment, applications in ceramics, plasma assisted recycling.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction	2
2	Fluid equations for plasma	3
3	Single particle motions, unmagnetized plasma dynamics	2
4	Diffusion & transport	3
5	DC sheaths – basic equations, Bohm sheath criterion, Child-Langmuir law, Matrix sheath, collisional sheath, Langmuir probe diagnostics	5
6	Energy and enthalpy, entropy and Gibbs free energy, chemical Equilibrium	3
7	Elementary reactions, gas phase kinetics, surface processes and kinetics	5
8	Plasma equilibrium – electropositive and electronegative	2

9	DC discharges	2
10	RF Discharges – capacitively and inductively coupled	4
11	ECR and helicon discharges	2
12	Plasma etching, nitriding deposition and implantation	2
13	High pressure non-equilibrium plasmas, thermal plasmas – the plasma arc	2
14	The plasma as a heat source – plasma torch, the plasma as chemical catalyst	2
15	Air pollution control, plasma pyrolysis and waste removal, plasma based metallurgy – ore enrichment, applications in ceramics, plasma assisted recycling	3
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Overview of Plasma Applications and Plasma as the Fourth State of Matter, Plasma & Sheath Formation; Practical Plasma Sources.
2	Thermal Equilibrium.
3	Diffusion Across a Magnetic Field.

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

Lieberman M. A. and Lichtenberg A. J., Principles of Plasma Discharges and Materials Processing, John-Wiley (2005). John P. I., Plasma Sciences and the Creation of Wealth, Tata McGraw-Hill Book Co. Ltd. (2005). Rossnagel S. M., Cuomo J. J., and Westwood W. D., Handbook of Plasma Processing Technology, Noyes Publications (1990).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	Power point projector and OHP, Black Board Facilities
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

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COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Plasmas for Energy and Environment		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL744		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Profs. A Ganguli, R. Narayanan, D. Sahu, S. Kar

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course will provide students a broad knowledge base about • Industrial plasma technology applications from the energy perspective. • Solutions offered by plasma-based technologies for environmental protection.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to plasmas; thermal and non-thermal plasmas; Laboratory plasma sources, Plasma in the Industry from the energy perspective (Fusion: the green technology; Plasma-surface modifications, Polymers, Nano-powders, Textile, lasers, Lamps and Displays, Power demand, Aerospace and Plasma thrusters, Micro-satellite application, Supercomputers) Environment perspective (Environmental control of exhaust gas treatment, Plasma treatment of Volatile Organic Compounds and some other plasma ecological technologies, Collection and removal of fine particles in plasma chambers; Hazardous waste problem and Plasma-assisted recycling; Biomedical and health)

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to plasmas	2
2	Thermal and non-thermal plasmas	1
3	Laboratory plasma sources	3
4	Energy perspective of plasma applications:	
	a) Fusion (The Green Technology)	5
	a) Space applications	5
	b) Energy Efficient Industrial applications	5
5	Environment perspective of plasma applications:	
	a) Wastes using plasma techniques	
	i. Handling	3
	ii. Recycling	3
	b)	
	i. Plasma treatment of VOC's	3
	ii. Other plasma ecological techniques	3
	c) Green plasma technology for the	
	i. Commercial Industry	3
	ii. Health Industry	3
6	Collection and removal of fine particles in plasma chambers	3
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	------	------
Total Tutorial hours (14 times 'T')		------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	------
Total Practical / Practice hours (14 times 'P')		------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Different States of Matter, electromagnetic Equations, conservation equations in differential form
2-3	Ionization and Excitation Potentials, Types of atomic and molecular collisional processes
4	Basic idea of the Fission and Fusion concepts
5	Idea of Criteria Pollutants, Air Quality Index (AQI), Bio-chemical Oxygen Demand (BOD), photochemical smog, Energy transfer in an ecosystem
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Meichsner J., Schmidt M., Schneider R., Wagner H., Non-thermal Plasma Chemistry and Physics, CRC Press, 2013.
2. Kawai Y., Ikegami H., Sato N., Matsuda A., Uchino K., Industrial Plasma Technology: Application from Environment to Energy Technologies, Wiley-VCH Publications, 2010.
3. Fridman A., Plasma Chemistry, Cambridge University Press, 2008. Lieberman M. A., Lichtenberg A. J., Principles of Plasma Processes and Material Processing, John Wiley and Sons Inc., 2005.
4. John P. I., Plasma Sciences and the Creation of Wealth, Tata McGraw-Hill Publishing Company

Limited, 2005.
5. Roth J. R., Industrial Plasma Engineering Volume 1: Principles and Volume 2: Applications, IOP Publishing, 1995 (Reprint 2000).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	-----
20.5	Equipment	----
20.6	Classroom infrastructure	----
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	-----
21.2	Open-ended problems	-----
21.3	Project-type activity	-----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Hydrogen Energy		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	Not Applicable
5.	**Course number**	ESL 746		
6.	**Course Status** (Course Category for Program) (list program codes: e.g., EE1, CS5, *etc*.)			

Institute Core for all UG programs	No
Programme Linked Core for:	----
Departmental Core for:	-----
Departmental Elective for:	-----
Minor Area / Interdisciplinary Specialization Core for:	-----
Minor Area / Interdisciplinary Specialization Elective for:	-----
Programme Core for:	-----
Programme Elective for:	JES, JEN, ESR
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	None

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---
10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. K. A. Subramanian, Kaushik Saha

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** (about 50 words. "On successful completion of this course, a student should be able to…"): To teach fundamentals of hydrogen energy as energy systems, production processes, storage, utilization, and safety that is necessary for taking some important elective subjects as well as to increase the potential for job opportunities in automotive industries and hydrogen

	production & its infrastructure development related sectors as about 40% energy is being consumed by automotive sectors.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction of Hydrogen Energy Systems: Hydrogen pathways introduction – current uses, General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and Hydrogen production power plants. Hydrogen Production Processes: Thermal-Steam Reformation – Thermo chemical Water Splitting – Gasification – Pyrolysis, Nuclear thermo catalytic and partial oxidation methods. Electrochemical – Electrolysis – Photo electro chemical. Biological – Photo Biological – Anaerobic Digestion – Fermentative Micro-organisms. Hydrogen Storage: Physical and chemical properties – General storage methods, compressed storage – Composite cylinders – Glass micro sphere storage - Zeolites, Metal hydride storage, chemical hydride storage and cryogenic storage. Hydrogen Utilization: Overview of Hydrogen utilization: I.C. Engines, gas turbines, hydrogen burners, power plant, refineries, domestic and marine applications. Hydrogen fuel quality, performance, COV, emission and combustion characteristics of Spark Ignition engines for hydrogen, back firing, knocking, volumetric efficiency, hydrogen manifold and direct injection, fumigation, NOx controlling techniques, dual fuel engine, durability studies, field trials, emissions and climate change. Hydrogen Safety: Safety barrier diagram, risk analysis, safety in handling and refueling station, safety in vehicular and stationary applications, fire detecting system, safety management, and simulation of crash tests.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours (< 5h per topic)
1	Introduction to Hydrogen Energy Systems	4
2	Hydrogen Production Processes	10
3	Hydrogen Storage	7
4	Hydrogen Utilization	14
5	Hydrogen Safety	7
Total Lecture hours (14 times 'L')		**42**

16. Brief description of tutorial activities: Not Applicable

Module no .	Description	No. of hours
Total Tutorial hours (14 times 'T')		----

17. Brief description of Practical / Practice activities: Not applicable

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		---

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Atomic structure of hydrogen, Resources for hydrogen, Hydrogen cycle, physio-chemical properties of hydrogen
2-3	Suitable materials for hydrogen energy system, hydrogen energy storage technologies
4-5	Modification of necessary infrastructure change for hydrogen energy implementation from conventional system, National and international policy on hydrogen, Hydrogen safety codes
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Ball M. and Wietschel M., The Hydrogen Economy Opportunities and Challenges, Cambridge University Press (2009).
2. Bockris J.O. M., Energy options: Real Economics and the Solar Hydrogen System, Halsted Press and London publisher (1980).
3. Babu M.K.G., Subramanian K.A., Alternative Transportation Fuels: Utilization in Combustion Engines, CRC Press (2013).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	Power point projector, OHP and Black Board Facilities
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	40%
2	Open-ended problems	30%
3	Project-type activity	30%
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Developing Energy Efficiency and Renewable Energy Projects		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	Not Applicable
5.	**Course number**	ESL749		
6.	**Course Status** (Course Category for Program) (list program codes: e.g., EE1, CS5, *etc*.)			

Institute Core for all UG programs	No
Programme Linked Core for:	----
Departmental Core for:	-----
Departmental Elective for:	-----
Minor Area / Interdisciplinary Specialization Core for:	-----
Minor Area / Interdisciplinary Specialization Elective for:	-----
Programme Core for:	-----
Programme Elective for:	JEN, ESN, ESR
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	None

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---
10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. T. C. Kandpal, K. Ravi Kumar

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** (about 50 words. "On successful completion of this course, a student should be able to…"): To introduce all relevant steps as well as the issues and challenges involved in developing projects on energy efficiency and renewable energy utilization. The course also aims at discussion on policy, regulatory and other support measures that can promote such projects.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Relevance of developing energy efficiency and renewable energy projects, Key project development concepts, Project motivation- key drivers-pre development- gauging market characteristics that provide motivation for the project and assessment of market readiness, Project development framework-essential elements, project development environment including existing policy environment- relevant codes (such as ECBC), Pre-investment phase – assessing potential sites, identifying partners, Assessment of commercially available energy technologies for improving energy efficiency and harnessing renewable energy, preparation of business plan (that includes feasibility study, engineering design, Financial closure, permitting activities and related documentation and agreements), consensus with project stakeholders, Implementation phase – Procurement, land acquisition, site preparation, construction, installation, commissioning of the project, operation of the facility, Actual implementation of the business plan, Monitoring and evaluation of the business and the project performance, Issues in implementation of energy efficiency and renewable energy projects, Essential areas for strong project development in renewable energy - site, resource, permits, technology, team and capital, Size and diversity of potential project sponsors and also of projects in the field of renewable energy and energy efficiency, Risks with energy efficiency and renewable energy projects and appropriate de-risking/ mitigation measures and approaches, dispute resolution, Role of policies and support measures in promoting energy efficiency and renewable energy, Developing community driven projects, Developing projects for improving energy access, socially inclusive projects, Issues in using public lands for developing renewable energy projects, Various considerations in selecting local versus imported technologies, Challenges in implementing energy efficiency in public sector within government financial and other regulations, Environmental impact and sustainability assessment of energy efficiency and renewable energy projects and projects while addressing environmental issues, Utility scale versus local projects, Examples and Case Studies – developing PV/wind power projects, projects for enhanced LED use in domestic, commercial, institutional and industrial sectors, environmental management projects.

15. Lecture Outline (with topics and number of lectures)

Module no.	**Topic**	**No. of hours** (< 5h per topic)
1	Relevance of developing energy efficiency and renewable energy projects	1
2	Key project development concepts, Project motivation- key drivers-pre development- gauging market characteristics that provide motivation for the project and assessment of market readiness	3
3	Project development framework-essential elements, project development environment including existing policy environment- relevant codes (such as ECBC)	3
4	Pre-investment phase – assessing potential sites, identifying partners, Assessment of commercially available energy technologies for improving energy efficiency and harnessing renewable energy, preparation of business plan (that includes feasibility study, engineering design, financial closure, permitting activities and related documentation and agreements), consensus with project stakeholders	5
5	Implementation phase – Procurement, land acquisition, site preparation,	5

	construction, installation, commissioning of the project, operation of the facility, Actual implementation of the business plan, Monitoring and evaluation of the business and the project performance, Issues in implementation of energy efficiency and renewable energy projects	
6	Essential areas for strong project development in renewable energy - site, resource, permits, technology, team and capital, Size and diversity of potential project sponsors and also of projects in the field of renewable energy and energy efficiency	4
7	Risks with energy efficiency and renewable energy projects and appropriate de-risking/ mitigation measures and approaches, dispute resolution	4
8	Role of policies and support measures in promoting energy efficiency and renewable energy, Developing community driven projects	4
9	Developing projects for improving energy access, socially inclusive projects	3
10	Issues in using public lands for developing renewable energy projects Various considerations in selecting local versus imported technologies	2
11	Challenges in implementing energy efficiency in public sector within government financial and other regulations, Environmental impact and sustainability assessment of energy efficiency and renewable energy projects and projects while addressing environmental issues	4
12	Utility scale versus local projects	1
13	Examples and Case Studies – developing PV/wind power projects, projects for enhanced LED use in domestic, commercial, institutional and industrial sectors, environmental management projects	3
Total Lecture hours (14 times 'L')		**42**

16. Brief description of tutorial activities: Not Applicable

Module no .	Description	No. of hours
Total Tutorial hours (14 times 'T')		----

17. Brief description of Practical / Practice activities: Not applicable

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		---

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
4	Basics of engineering economics- measures of financial/economic performance.
4, 6, 7, 10	Introduction to solar, wind and biomass technologies.
8, 11	Energy efficiency measures in domestic, agricultural and industrial sectors.
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Carbon Trust, A Guide to Implementing Energy saving Opportunities, Department of Energy and Climate Change, United Kingdom (2015).
2. IEA, How2 Guide for Wind Energy Roadmap Development and Implementation, International Energy Agency (IEA), Vienna (2014).
3. Federal Energy Management Program, US Department of Energy, Developing Renewable Energy Projects Larger than10MWe at Federal Facilities, Report DOE/GO-102013-3915 (2013).
4. Springer R., A Framework for Project development in the Renewable Energy Sector, National Renewable Energy Laboratory, USA, Technical Report, NREL/TP-7A40-57963 (2013).
5. CEC, Guide to Developing a Community Renewable Energy Project in North America, Commission for Environmental Cooperation (CEC), Montreal, Canada (2010).
6. IEA, 16 Case Studies on the Deployment of Photovoltaic technologies in Developing Countries, International Atomic Energy Agency (IEA), IEA-PVPS.T9-07 (2003).
7. Wade H. A., Solar Photovoltaic Project Development, UNESCO Publishing (2003).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	----
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**			Centre for Energy Studies	
2.	**Course Title**	Renewable Energy Resource Assessment and Forecasting			
3.	**L-T-P structure**	3-0-0			
4.	**Credits**	3	**Non-graded Units**	---	
5.	**Course number**	ESL751			
6.	**Course Status** (Course Category for Program) (list program codes: eg., EE1, CS5, *etc*.)				

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	Nil

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	ASL760 (~25%) RDL700 (~10%)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering** (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** (Minimum 2 names for core courses / 1 name for electives) Profs. K. Ravi Kumar, Dibakar Rakshit, T. C. Kandpal

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** The course will provide the students an understanding of assessment of various non-conventional energy resources such as solar energy, wind energy, biomass, geothermal, waves, tides and ocean thermal energy and its forecasting.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Types of non-conventional sources, Solar energy: principles and applications, meteorological considerations for solar power: solar resource assessment, solar forecasting for different timescales, uncertainty estimation evaluation of solar forecasting skill, Wind energy: wind resource assessment, measurement and distribution, Assessment techniques, Site selection for wind monitoring stations, wind forecasting for different timescales using statistical and numerical methods. Biomass: Sources of biomass, measurement of productivity and statistical analysis of data, Forecasting based on statistical analysis. Geothermal energy: Geological survey for geothermal regions, Types of geothermal resources, Thermal gradient measurements, Monitoring micro seismic activity, Reflection seismic, Deep exploration drilling and testing with estimation. Ocean thermal, waves and tidal energy: Measurement and statistical analysis for assessment and forecasting Ocean thermal, waves and tidal energy.

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (< 5h per topic)
1	Introduction to renewable sources of energy: Solar energy, Wind energy, Biomass energy, Geothermal energy, Ocean thermal energy, wave and tidal energy.	4
2	Principal of meteorology and numerical weather prediction: Introduction to meteorology for renewable energy forecasting, Observational data and assimilation into numerical weather prediction model, Probabilistic of forecasting.	4
3	Solar Energy Assessment: uncertainty in the assessment, means of resource assessment: satellite based, land station based, software based (Meteonorm, SolarGIS)	4
4	Solar Energy Forecasting: Meteorological consideration Solar forecasting for different timescales Forecasting and uncertainty in the forecasting, Clear sky models, Persistence forecast, Evaluation of solar forecasting skills.	4
5	Wind Energy Assessment: Wind resource and origins, Measurement and distribution, Site selection for wind monitoring station, Assessment techniques.	3

6	Wind Energy Forecasting: Wind forecasting using statistical and numerical methods, short term prediction models, upscaling models, spatio-temporal forecasting, ramp forecasting variability forecasting and uncertainity of wind power predictions .	4
7	Biomass Energy Assessment: Statistical analysis of data, Forecasting based on statistical data.	3
8	Biomass Energy Forecasting: Sources and generation of biomass, Measurement of productivity.	3
9	Geothermal Energy Assessment and Forecasting: Geological survey for geothermal regions, Distribution of geothermal energy, Types of geothermal resources, Thermal gradient measurements and monitoring micro seismic activity, Reflection seismic, deep exploration drilling and testing with estimation.	4
10	Ocean thermal energy Assessment and Forecasting: Measurement and statistical analysis for assessment and forecasting of Ocean thermal.	3
11	Forecasting and Assessment of waves and tidal energy: Measurement and statistical analysis for assessment and forecasting of Waves and Tidal energy, statistical and time series model, wave energy converters.	4
12	Characterization of forcast errors and benchmarking of renewable energy forecasting: ANEMOS benchmark, WIRE benchmark.	2
Total Lecture hours (14 times 'L')		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
1-7	Basic knowledge of Solar energy, Wind Energy, Biomass Energy, Geothermal energy and Ocean Thermal Energy.
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Kariniotakis G. (Ed.), Renewable Energy Forecasting: From Models to Applications. Woodhead Publishing (2017).
2. Jan K., Solar Energy Forecasting and Resource Assessment, Academic Press, (2013).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	---
2	Hardware	---
3	Teaching aids (videos, etc.)	---
4	Laboratory	---
5	Equipment	---
6	Classroom infrastructure	---
7	Site visits	---
8	Others (please specify)	---

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	---
2	Open-ended problems	---
3	Project-type activity	---
4	Open-ended laboratory work	---
5	Others (please specify)	---

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Carbon Audit and Management		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	Not Applicable
5.	**Course number**	ESL752		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	----
Programme Linked Core for:	----
Departmental Core for:	----
Departmental Elective for:	----
Minor Area / Interdisciplinary Specialization Core for:	----
Minor Area / Interdisciplinary Specialization Elective for:	----
Programme Core for:	----
Programme Elective for:	ESN, ESR
Open category Elective for all other programs (No if Institute	----

7.	**Pre-requisite(s)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		----
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	----
8.2	Supersedes any existing course		----

9.	**Not allowed for**	----

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Profs. T. C. Kandpal, K. Ravi Kumar, K. A. Subramanian, Kaushik Saha

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** On successful completion this course a student will be able to(i) identify the effects of carbon emissions on the environment and consequent challenges, (ii) acquire necessary knowledge and skills to conduct carbon audits and life cycle analysis to identify carbon management opportunities, (iii) implement efficient and effective carbon management strategies in the energy sector and energy intensive industries and document the same.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Greenhouse gas emissions from the energy sector and their time trend; Climate change and other potential impacts of enhanced greenhouse effect caused by anthropogenic emissions primarily from extraction, conversion, transport, storage and utilization of energy carriers; Carbon foot print; Carbon audit; Carbon management- tools and accounting techniques; Life cycle assessment; Policies, regulations, protocols and standards; Carbon credits and carbon economics

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (< 5hr per topic)
1	Energy and society, Climate change and the greenhouse gases, Relative contribution of various sectors to global anthropogenic greenhouse gas emissions, mitigation, adaptation and other potential strategies	4
2	(a) Energy as a measure source of carbon emissions	2
	(b) Estimation of carbon emissions from extraction, conversion, storage, transport and utilization of various energy carriers	4
3	Carbon footprints, Carbon audit, estimation of direct and supply chain carbon footprints, Need for reducing carbon footprints, Identification of niche areas for carbon management, Sustainable development and carbon management	5
4	Policies, regulations and protocols for carbon management	4
5	(a) Tools and accounting techniques for carbon audit and management	2
	(b) Sustainability accounting, Life cycle assessment approach, Integrated supply chain analysis with respect to carbon	4
	(c) Standards (ISO 14044 and PAS 2050 etc.)	1
6	(a) Approaches to carbon management in energy generation,	3

	transport, water and wastewater, manufacturing, information and communication technology etc.	
	(b) Carbon management in new buildings and cities, Carbon implications of waste reduction and recycling, Strategies for carbon storage in soil and in oceans	3
7	(a) Energy generation for a low carbon society	1
	(b) Carbon credits, Trading schemes, Carbon economics, Low carbon investments, Carbon labeling	5
8	Challenges and opportunities in carbon management in energy sector and energy intensive industries and applications	4
Course Total		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	----	----
Total Tutorial hours(14 times 'T')		-----

17. Brief description of Practical / Practice activities:

Module no.	Description	No. of hours
	----	----
Total Practical / Practice hours(14 times 'P')		----

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Subramanian S. M., The Carbon Footprint Handbook, CRC Press (2015).
2. UNDP, Carbon Handbook, United Nations Development Programme (2014).
3. Emmanuel R., Keith B., Carbon Management in the Built Environment, Routledge (2012).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	----
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**		**Centre for Energy Studies**	
2.	**Course Title**	Energy Policy and Planning		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL756		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JEN, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL 750 (≤ 30%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	Students who have passed ESL 750

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Profs. T. C. Kandpal, K. Ravi Kumar, S. Karak, S. Kar, D. Sahu

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** Upon successful completion of this course the student will have an overview of issues involved with energy source, economy environmental considerations to chalk out the planning and policy.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Energy (and power) policies in the country, Tariffs and subsidies, Energy utility interface, Private sector participation in power generation, State role and fiscal policy, Energy and development, National energy plan, Role of modeling in energy policy analysis, Energy data base, Energy balances, Flow diagrams, Reference energy system, Energy demand analysis, Trend analysis, Econometric models, Elasticity approach, Input-output models, Simulation/process models, Energy supply analysis, Costs of exploration and economics of utilization of depletable and renewable resources, Scarcity rent, International energy supply, Energy demand supply balancing, Energy -economy interaction, Energy investment planning, Energy environment interaction, Energy Pricing. Can we add energy policy in India?

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Energy and development	2
2	Relevance of energy policy planning and issues involved	3
3	Tariffs and subsidies	2
4	Tax structure	2
5	National energy plan	2
6	Energy Models	5
7	Trend analysis of energy demand	2
8	Econometric models	2
9	Elasticity approach of energy demand estimation	2
10	Input-output model based energy demand forecasting	2
11	Energy supply analysis	3
12	Costs of exploration and alternate energy options	4
13	International energy supply	2
14	Demand supply balance and energy investment planning	5
15	Energy Pricing	2
16	Energy environment interaction	2
Course Total		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	------	-----
Total Tutorial hours (14 times 'T')		-----

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	-----	-----
Total Practical / Practice hours (14 times 'P')		-----

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
6-8	Basic statistics-Measures of statistical dispersion, Central limit theorem, Standard error of the mean, Interval estimates, Hypothesis testing
12-14	Alternative energy options for electricity generation, Transport and space heating/cooling
16	Clean Development Mechanism
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Mangone G. J., Energy Policies of the world, Elsevier, 2003.
2. Munasinghe M., Meier P., Energy Policy analysis and Modelling, Cambridge University Press, 1993.
3. Stephen W., Armstrang J. R., State Energy Policy: Westview Press, 1993.
4. Codoni R., Park H., Ramni K. V., Integrated Energy Planning Volumes I, II and III, Asian and Development Centre, Kuala Lumpur, 1985.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	-----
20.5	Equipment	----
20.6	Classroom infrastructure	---
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	-----
21.2	Open-ended problems	-----
21.3	Project-type activity	-----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Renewable Energy Regulations and Law		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	Not Applicable
5.	**Course number**	ESL757		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	----
Programme Linked Core for:	----
Departmental Core for:	----
Departmental Elective for:	----
Minor Area / Interdisciplinary Specialization Core for:	----
Minor Area / Interdisciplinary Specialization Elective for:	----
Programme Core for:	----
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		----
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	----
8.2	Supersedes any existing course		----

9.	**Not allowed for**	-

10.	**Frequency of offering** (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Prof. T. C. Kandpal, Ashu Verma

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** On successful completion of the course the students will be able to understand and analyze various regulatory and legal issues pertaining to large scale development and dissemination of renewable energy technologies. The course would provide the students with comprehensive knowledge and understanding of rules and regulations governing harnessing of renewable sources of energy with international and comparative perspective. Also it would examine the emerging legal regime in several countries of the world who have made considerable progress in theis regard. The students should be able to explain and evaluate the regulatory frameworks for different renewable energy technologies.

14.	**Course contents :** Introduction, Energy acts and regulations, building energy codes and environmental emissions related norms, institutional structure for and incentives and other support measures for promoting renewable energy technologies, complimentary policies on energy conservation and environmental emissions mitigation, Regulations pertaining to renewable energy project establishment as well as integration with the existing supply structure, Regulations for energy pricing and its trading

15. Lecture

Module no.	Outline Topic	No. of hours
1.	Challenges in large scale harnessing of renewable sources of energy and relevance of policies, regulations and legal provisions	3
2.	Acts pertaining to Electricity, Energy Conservation, Renewable Energy	5
3.	Building Energy Codes, Standards and Ratings for energy end use equipments and promotion of renewable energy technologies	4
4.	Institutional structure for promoting renewable energy development and deployment, functions and roles of different institutions, examples of some countries	4
5.	Jurisdiction and responsibilities of central (federal), state level, and local bodies in promoting renewable energy technologies.	2
6.	Examples (case studies) of renewable energy development structures in some countries	2
7.	Incentives for promoting renewable energy technologies – renewable purchase obligation, renewable fuel standards, feed-in tariffs, net metering etc.	4
8.	Complimentary policies – energy conservation, demand side management,	4

	demand response, emission standards	
9.	Regulations and policies pertaining to establishment of renewable energy projects, grid integration of renewables, distributed generation, micro-grids and rural electricfication with case studies	4
10.	Resource specific licensing of solar, wind, biomass and hydro energy , Technology specific legislation	3
11.	Electricity tariff, Implications of increased penetration of renewable energy share, Pricing of electricity and fuels	4
12.	Electricity trading and renewable energy based electricity generation	3
Total Lecture hours (14 times 'L')		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
2	Study of relevant acts related to energy in general and renewable energy in particular for the home country/state of the student
7	Study and analysis of various incentives offered by the government for promoting renewable energy technologies
9-12	Understanding electricity market(s) in the home country/state
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) Mayor L-I. V., Clean Energy Law and Regulation, Widdy, Simmonds & Hill Publishing (2017)
2) Perez- Arriaga I. (Ed.), Regulations of the Power Sector, Springer (2013)
3) Massai L., European Climate and Clean Energy Law and Policy, Earthscan (2012)
4) Gerrard M. B., The Law of Clean Energy: Efficiency and Renewables, American Bar Association (2011)
5) Country specific policy and regulatory documents to be provided during course delivery

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	OHP, Blackboard, Powerpoint
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Instrumentation & Control in Energy Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL771		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR, JEN
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		----
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	EEL 758 (≤ 5 %) EEL 774 (≤ 10 %)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Prof. V. Dutta, Prof. T. S. Bhatti, Prof. A. Verma, Prof. R. Uma, Prof. D. Rakshit, Prof. K. Ravi Kumar, Prof. S. Kar, Prof. D. Sahu, Prof. Sumit Chattopadhyay

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** After completing this course, the students will gain knowledge about the operating principles of 1. Various electrical, thermal and environmental measurement devices. 2. Operation of various controllers used in generation, transmission and distribution sector. 3. Control of thermal and electrical systems using various techniques, communications systems, controllers.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Basic measurement concepts, Measurement errors, Thermo-flow measurement – Pressure, Velocity, Force, Temperature, Thermal radiation, Heat flux, Humidity, Uncertainty analysis, Measurement of wind speed, Wind direction, Solar irradiance, Head and discharge for hydro systems;Controls of solar and wind energy systems.Measurement sensors for electrical systems: Voltage, Current, Frequency, Temperature, Phase sequence measurement, Current transformers, Potential transformers, Phase difference measurements other measuring devices. Analog signal conditioning, A/D, D/A converters, Digital data processing, Sample and hold circuits, Clipping circuits, Opto-couplers, PMU, PMDC. General purpose control devices, feedback/open control loop, SISO, MIMO systems, State space representation of system equations, Stability analysis of control systems: Eigen values, Eigen vectors, S-domain analysis. Measurement and control of harmonics in electrical systems. Air pollution sampling and measurement of particulates, SO_x, NO_x, CO, O_3, Hydrocarbons.

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Basic measurement concepts, error, measurement sampling	2
2	Measurement of temperature using various techniques, instruments for temperature measurement	2
3	Measurement of thermal radiation and heat flux	3
4	Various measurement techniques and instruments for measurement of pressure, force, humidity, H & Q measurements for hydro sites	3
5	Measurement & Control of solar and wind energy systems	5
6	Measurement sensors for electrical systems: voltage, current,	5

	frequency, temperature, phase sequence measurement, current transformers, potential transformers, phase difference measurements other measuring devices	
7	Analog signal conditioning, A/D, D/A converters, digital data processing, sample and hold circuits, clipping circuits, opto-couplers, PMU, PMDC.	4
8	General purpose control devices, feedback/open control loop: SISO, MIMO systems, state space representation of system equations, stability analysis of control systems: eigen-values, eigen-vectors, S-domain analysis.	4
9	Measurement and control of particulate matter, smoke, SO_x, NO_x, CO, O_3, hydrocarbons.	5
10	Design and performance estimation of gravity settlers, cyclones, bag filter, ESP etc.	5
11	Pollution measurement & control	2
12	Uncertainty handling in measurements	2
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours

Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1-4	Basics of measurement systems
5	Basic understanding of solar and wind energy systems
6	Basics of generation, transmission and distribution system
8	Characteristics and operation of various electronic components like diode, transistors thyristors, IGBTs, MOSFET etc.
9	Basic controllers, PI, PID, Transfer function, S-Domain representation of system (S-Transform).
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Venkatesan, S. P., Mechanical Measurement, 2nd edition, Ane Books Pvt. Ltd. (2016).
2. Schnelle Jr. K. B., Brown C. A., Air Pollution Control Technology Handbook, CRC Press, 2002 (*Indian Reprint*: 2014).
3. Holman J. P., Experimental Methods for Engineers, 8th Edition, The McGraw Hill Companies (2012).
4. Roman M., Instrumentation and measurement in electrical engineering, Brown Walker Press (2011).
5. Billingsley J., Essentials of Control Techniques and Theory, CRC Press (2010).
6. Beckwith T. G., Buck L. N., Marangoni R. D., Mechanical Measurements, Addison-Wesley (2006).
7. Pal B., Chaudhury B., Robust Control in power systems, Springer(2005).
8. Khazan A. D., Transducers and their Elements, Prentice Hall(1994).
9. Murty D. V. S., Transducers and Instrumentation, Prentice-Hall of India Pvt. Ltd. (1995).
10. Nakra B. C., Chaudhry K. K., Instrumentation Measurement and Analysis, TMH Ltd.(1985).
11. Afgan N. H., Measurement Techniques in Power Engineering, Hemisphere Publishing Corporation(1985).
12. Rangan C. S., Sarma G. R., Mani V. S. V., Instrumentation Devices and Systems, TMH Ltd.(1983).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	-----
5	Equipment	----
6	Classroom infrastructure	----
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	-----
2	Open-ended problems	-----
3	Project-type activity	-----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Energy Storage		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	----
5.	**Course number**	ESL772		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisites (course no./title)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course**	Profs. D. Rakshit, S. C. Kaushik, A. Verma, T. S. Bhatti, K. A. Subramanian, K. Ravi Kumar, Sumit Chattopadhyay, Kaushik Saha
12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** After successful completion of this course the students will have knowledge of • Various thermal and electrical energy storage devices. • Optimization of energy storage for optimal use.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Sensible Thermal Energy Storage, Latent Energy Storage, Thermal Management System design using Latent Thermal Energy Storage, Optimization of Thermal Energy Systems, Thermochemical heat storage system, Battery Electrical Energy Storage Systems, Pumped storage systems, Other electrical energy storage systems, Integration of energy storage systems, energy storage system optimization.

15. Lecture Outline (with topics and number of lectures)

Module No.	Topic	No. of hours
1	Significance and types of Energy Storage	3
2	Sensible Thermal Energy Storage	3
3	Latent Energy Storage	3
4	Thermal Management System design using Latent Thermal Energy Storage	3
5	Assessment of Thermal Energy System a) Evaluation of thermo-physical properties of storage materials	1
	b) Distinction between energy and exergy	1
	c) Energy and exergy in performance assessment of systems	3
	d) Exergy and environment assessment	1
6	Optimization of Thermal Energy Systems	3
7	Thermochemical heat storage system , thermal energy storage system for heating and hot water in residential buildings	3
8	a) Hydrogen energy storage	1
	b) Hydrogen based fuel cell	2
	c) Solar hydrogen production	3
9	Battery Electrical Energy Storage Systems:	
	a) Types of batteries & electrical behavior	2
	b) Influence in interconnected systems	2
10	Pumped storage systems: configuration, operation	2
11	Other electrical energy storage system e.g. Flywheel, super-capacitors etc.	2
12	Integration of energy storage systems with distributed generation systems and electric grid	4
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
--	--	------
Total Tutorial hours (14 times 'T')		------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	------
Total Practical / Practice hours (14 times 'P')		------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
All	Students will be given a large number of numerical problems for practice.
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Khalilpour, K.R., Anthony V. A., Community Energy Networks with Storage-Modeling Frameworks for Distributed Generation, Springer (2016).
2. Cabeza, L.F., Advances in Thermal Energy Storage Systems: Methods and Applications, Woodhead Publishing, UK (2015).
3. Kalaiselvam, S., Parameshwaram R., Thermal Energy Storage for Sustainability-Systems Design, Assessment and Applications, Academic Press Inc. (2014).

20. Resources required for the course(itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	-----
5	Equipment	----
6	Classroom infrastructure	---
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	-----
2	Open-ended problems	-----
3	Project-type activity	-----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Battery Storage		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	----
5.	**Course number**	ESL773		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisites (course no./title)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	CLL722 (≤ 10 %)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course**	Profs. K. Ravi Kumar, Sandeep Pathak, Sumit Chattopadhyay, Kaushik Saha

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** The objective of this course is to provide an advanced level understanding on batteries that are used in energy storage devices in a wide variety of engineering devices. The course will impart knowledge on the fundamental electrochemistry of battery systems, different types of batteries including Li-ion and beyond. The course will also dwell upon sustainable design, recycling and management of batteries.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to energy storage systems and devices, Rechargeable batteries and their Fundamental electrochemistry, Lithium batteries, Nickel metal hydride battery, Lead-acid battery, High temperature batteries for back-up applications, Flow batteries for load leveling and large scale grid application, Ni-Hydrogen batteries for space and marine applications, Manufacturing technologies of batteries, Sustainable design of batteries, Hybridization of battery, Battery recycling technologies, Battery applications for stationary and secondary use, Battery chargers and battery testing procedures, Battery management, Regulations and safety aspects of high voltage batteries, Super capacitors.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1.	Introduction to energy storage systems and devices	4
2.	Rechargeable batteries and their fundamental electrochemistry	4
3.	Lithium batteries	4
4.	Beyond lithium batteries, Nickel metal hydride battery	3
5.	Lead-acid battery, High temperature batteries for back-up applications	4
6.	Flow batteries for load leveling and large scale grid application, Ni-Hydrogen batteries for space and marine applications,	4
7.	Manufacturing technologies of batteries, Sustainable design of batteries	3
8.	Hybridization of battery	3
9.	Battery recycling technologies	2
10.	Battery applications for stationary and secondary use, Battery chargers and battery testing procedures	3
11.	Battery management	3
12.	Regulations and safety aspects of high voltage batteries	2
13.	Super capacitors	3
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
--	--	------
Total Tutorial hours (14 times 'T')		------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	------
Total Practical / Practice hours (14 times 'P')		------

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Linden D. and Reddy T.S., Handbook of Batteries, 3rd Edition, McGraw-Hill (2002).
2. Kiehne H.A., Battery Technology Handbook, Marcel Dekker, NYC(2003).
3. Nazri G-A. and Pistoa G., Lithium Batteries, Science and Technology, Kluwer Academic Publisher (2003).
4. Rand D.A. J., Woods R. and Dell R.M., Batteries for Electric Vehicles, Research Studies Press (1998).
5. Berndt D., Maintenance-Free Batteries, John Wiley & Sons, New York(1997).

20. Resources required for the course(itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	-----
5	Equipment	----
6	Classroom infrastructure	---
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	-----
2	Open-ended problems	-----
3	Project-type activity	-----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Quantitative Methods for Energy Management and Planning		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL774		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESN, JEN
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	MTL103 (≤ 25%) MCL261 (≤ 15%) MCL366 (≤ 10%) MCL765 (≤ 15%) MTL704 (≤ 5%) APL771 (≤ 10%)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Profs. A. Ganguli, R. Narayanan, D. Rakshit, A. Verma, K. Ravi Kumar, D. Sahu, S. Kar

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course will enable students to tackle optimization issues in energy management systems which deal with both deterministic and non-deterministic problems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): The necessity and the levels of optimization of energy systems: synthesis, design and operation, Laws of probability and Probability distribution function; Basics principles of calculus methods, Mathematical methods for solution of the optimization problem; Classes of mathematical optimization methods, Sensitivity analysis, Special methods for optimization of energy systems, Environment considerations in the optimization of energy systems,Meta-heuristic techniques (genetic algorithms, particle swarm optimization).

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Necessity of energy management and formulation of the problem	1
2	Quantifying optimal conditions through:	
	a) Graphical method	2
	b) Simplex method	2
	c) Matrix method	2
3	Sensitivity analysis, primal and duality	5
4	Basic principles of probability and calculus of variations	3
5	Curve fitting, Lagrange multipliers (gradient and Newton's method), search methods, secant method, steepest ascent and steepest descent along with local and global optimum	4
6	Introduction to different classes of optimization through simple problems:	
	a) Linear and nonlinear programming	2
	b) Deterministic and stochastic programming	2
	c) Quadratic and geometric programming	2
	d) Integer and real-valued programming	2
	e) Single- and multiple-objective programming	2
	f) Constrained and unconstrained programming	2
7	Sequencing, queuing theory, networks, PERT and CPM	4
8	Levels of optimization of energy systems: single-level and multi-level optimization	3
9	Environment considerations in the optimization of energy systems	4
	Course Total	**42**

6. Brief description of tutorial activities:

Module no.	Description	No. of hours
	------	------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	------
Total Practical / Practice hours (14 times 'P')		------

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
2	Matrices and its basic operations, Transformations (primarily Gauss-Jordan)
4, 5	Basics of set theory representations and their notations, Differentiation and partial differential equations
8,9	Knowledge of impact of energy resources on environmental pollution
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Jaluria Y., Design and Optimization of Thermal Systems, CRC Press, 2nd edition (2008).
2. TahaH. A., Operations Research: An Introduction, Prentice-Hall of India Pvt. Ltd., 8th Edition (2007).
3. VohraN. D., Quantitative Techniques in Management, Tata McGraw-Hill (1997).
4. Bejan A., Tsatsaronis G., Moran M., Thermal Design and Optimization, Wiley Publications (1996).
5. Stoecker W. F., Design of Thermal Systems, McGraw Hill International Editions (1989).
6. Wagner H. M., Principles of Operations research with Application to Managerial Decisions, Prentice Hall(1969).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	TORA
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	----
5	Equipment	Computer for solving problems in TORA
6	Classroom infrastructure	----

7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Zero Emission Vehicles		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL780		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL782 (≤ 10%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	MCL345 (≤ 10%)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Profs. K. A. Subramanian, Kaushik Saha

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course covers the details of various transportation vehicles with zero/near-zero emissions. This course will aid students in development of sustainable transportation vehicle.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to various zero emission vehicles; Fundamentals of Internal combustion (IC) engines (Spark ignition and Compression ignition engines); Emission and its formation mechanism (UHC, CO, NO_x, N_2O, PM etc.); Emission control strategies including EGR; Exhaust gas after treatment devices (TWC, SCR, LNT, DOC, DPF); Lean burn combustion (PCCI and HCCI): Controlled auto ignition, Homogeneous charge preparation strategies; Hydrogen fuelled vehicle: Back firing, Power drop, Fuel induction techniques; Battery operated vehicles: Introduction, Types, Batteries, Accessories; Hybrid vehicles: Introduction, Classification, Advantages and disadvantages; Fuel cell vehicles: Introduction, Fuel cell system, Classification, Speed-Torque and Speed-power characteristics, Operational issues; Well to wheel analysis of zero emission vehicles, Net impact (including embodied energy) of zero emission vehicles on Environment for assessment of CO_2 emission.

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to zero emission vehicles, different type of power train / vehicles	4
2	Emissions formation mechanisms in internal combustion engines, overview of technologies for achieving zero emission	5
3	Hydrogen fueled IC engines, advanced technologies for achieving zero NOx emission, Technologies for improvement of power and thermal efficiency.	5
4	Oxides of nitrogen emission reduction strategies: Exhaust gas recirculation, water injection, after treatment devices (selective catalyst reduction, Lean NOx Trap, particulate trap, oxidation catalyst, etc.)	5
5	Hybrid vehicles: internal combustion engines with electrical motor system, regeneration of energy through breaking, power-torque characteristics, fuel economy improvement for urban driving cycle	5
6	Battery operated vehicles: type of battery for vehicle applications, Accessories of battery operated vehicles, battery recharging systems, Variable frequency drive	5
7	Fuel cell vehicles: overall efficiency, power output, comparison of fuel cell	5

	and internal combustion engines at same conditions for their efficiency and transient performance.	
8	Well to Wheel analysis of Zero emission vehicles: well to tank and tank to wheel efficiency, Greenhouse gases.	4
9	Environment impact of zero emission vehicles	4
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	------	------
Total Tutorial hours (14 times 'T')		------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	------
Total Practical / Practice hours (14 times 'P')		------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Fundamentals of design and operating parameters of IC engine
1, 2	Types of emissions (Regulated and unregulated emissions)
2	Molecular structure of fuels (hydrocarbon and hydrogen), fuel physical and chemical properties
3, 4	Fundamentals of fuel chemistry (chemical equilibrium, stoichiometric conditions)
6	Basic concept of battery and electrochemical devices
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Babu M. K. G., Subramanian K. A., Alternative Transportation Fuels: Utilization in Combustion Engines, CRC Press(2013).
2. Willard W. P., Engineering Fundamentals of the Internal Combustion Engine, Pearson Prentice Hall(2008).
3. Addy M. W., Khair M. K., Diesel Emissions and Their Control, SAE International (2006).
4. Ferguson C. R., Allan T. K., Internal Combustion Engines Applied Thermosciences, John Wiley & Sons, Inc. (2001).
5. Turns S. R., An Introduction to Combustion, McGraw-Hill Companies(2000).
6. Heywood J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, Inc. (1988).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	-----
5	Equipment	----
6	Classroom infrastructure	----
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	-----
2	Open-ended problems	-----
3	Project-type activity	-----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Policy and Regulatory Aspects of Power System Operation with Increasing Renewable Energy Share		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL790		
6.	**Course Status** (Course Category for Program) (list program codes: eg., EE1, CS5, *etc*.)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	Nil

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL 757 (<20%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		No

9.	**Not allowed for**	Nil

10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course:** Profs. T. C. Kandpal, Ashu Verma, Sumit K Chattopadhyay

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** After sucessfully completing this course the student will be able to understand 1) Factors and tools effecting the policy and regulatory decisions for energy sector 2) Reulatory framework for promotion of RE sector across the globe 3) Key policy challenges for large scale integration of renewable energy sources

14.	**Course contents**: Overview of the global renewable energy sector, Role of various international energy organizations and government bodies, Country wise organizational structure for regulatory deployment of various schemes for RE integration at transmission and distribution level, Electricity Act of various countries and their comparison Overview of global solar energy policies, Regulatory Issues with the Deployment of Variable Renewable Energy Sources, Policy and regulatory Framework for rural electrification, Particular case studies for rural electrification in India/solar alliance countries, International Grid Codes, Amendments for renewable energy integration, Specific requirements for solar and wind integration, Comparative study of Indian grid code with Nordic, European Network of Transmission System Operators for Electricity (ENTSO-E's) network codes and other country wise grid codes. Distribution system operator: countryside mechanism for DSO operations, EV scheduling, Demand side management. Time of Use (ToU)/Time of Demand (ToU) price regulation, factors influencing them.

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Overview of the global renewable energy sector: installed capacity, accessed potential, plans for next 20 years. UN sustainable development goals. Role of various international energy organizations and government bodies, REN21, IRENA Country wise organizational structure for regulatory deployment of various schemes for RE integration at transmission and distribution level	04
2	Electricity Act of various countries, Tariff determination (basis, country specific factors influencing), country specific case studies such as: Electricity Act 2003, National Electricity Policy 2005, National Tariff policy 2006, Draft Renewable Energy Act-2015	04
3	Overview of global solar energy policies: Part A: Renewable Energy credit systems deployed in various countries like Renewable purchase obligations (RPO), Renewable energy credit (REC) mechanism	04
4	Overview of global solar energy policies: Part B: Country-wise targets, subsidies and incentive-mechanism, renewable portfolio standard, production tax credit etc.	04
5	Regulatory Issues with the Deployment of Variable Renewable Energy Sources: Balancing, grid Flexibility, Fault ride through (FRT) requirements for solar and wind energy systems	04
6	Need for accurate forecasting, methods, challenges, regulatory requirements of various countries	03
7	Need and advantages for decentralized and distributed solutions, Status, technical requirements, economic feasibility and targets of grid-connected/ off-grid distributed	03

	generation in the world	
8	Scope and challenges in implementing off grid solutions in the world, Policy and regulatory Framework for rural electrification: Various programmes for rural electrification in the world. Particular case studies for rural electrification in some of the countries.	04
9	International Grid Codes, Amendments for renewable energy integration, Specific requirements for solar and wind integration.	04
10	Comparative study of various grid codes e.g. Indian grid code, Nordic, European Network of Transmission System Operators for Electricity (ENTSO-E's) network codes etc.	04
11	Distribution system operator: country wise mechanism for DSO operations, EV scheduling, Demand side management. Time of Use (ToU)/Time of Demand (ToU) price regulation, factors influencing them	04
Course Total		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
All	Basics of various renewable energy technologies
3	Basics of Solar PV, area required, operating conditions, plant load factor etc.
5	Load generation balance, active, reactive power sharing its impact on system voltages, and frequency
9	Basics of regression, time series techniques, study of artificial intelligence algorithms, implementation on simple regression/classification problems
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Chernyakhovskiy, I., Tian, T., McLaren, J., Miller, M. and Geller, N., US Laws and Regulations

for Renewable Energy Grid Interconnections (No. NREL/TP--6A20-66724), National Renewable Energy Lab.(NREL), Golden, CO (United States) (2016).
2. Michalena E., Hills J. M., Renewable Energy Governance Complexities and Challenges, Springer (2013).
3. Kumar A. and Chatterjee S., Electricity Sector in India: Policy and Regulation, Oxford University Press (2012)
4. ENTSO-E Network Codes. https://electricity.network-codes.eu/network_codes/
5. The Grid Code, NERC. https://www.nerc.com/comm/PC/Integration%20of%20Variable%20Generation%20Task%20Force%20IVGT/Sub%20Teams/Interconnection/UK_Grid_Code.pdf
6. Indian Electricity Grid Code, http://www.cercind.gov.in/2016/regulation/9.pdf
7. Nordic Grid Code, https://www.entsoe.eu/fileadmin/user_upload/_library/publications/nordic/planning/070115_entsoe_nordic_NordicGridCode.pdf
8. Review of International Grid Codes, Ciaran Roberts, Lawrence Berkeley National Laboratory, https://certs.lbl.gov/sites/default/files/international_grid_codes_lbnl-2001104.pdf

20. Resources required for the course (itemized student access requirements, if any)

1	Software	MATLAB
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	Blackboard, LCD projector, OHP
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Renewable Energy Integration and Power Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL791		
6.	**Course Status** (Course Category for Program) (list program codes: eg., EE1, CS5, *etc*.)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	Nil	
8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL 797 (< 30%) ESL 860 (< 20%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	EEL 770 (<10%) EEL 776 (< 10%)
8.2	Supersedes any existing course		No

9.	**Not allowed for**	Nil

10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course:** Profs. Ashu Verma, Sumit K Chattopadhyay, T.S. Bhatti

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** On successful completion of this course, a student will have detailed knowledge of various major renewable energy resources and their effect on power system. State of the art and emerging technologies for efficient penetration and integration of renewable energy resources on power system. Power system optimization techniques for optimal dispatch and unit commitment with renewable integrated systems. Challenges of renewable energy integration at transmission and distribution level, stability and security assessment of power system, Congestion management, ancillary services need and mechanisms to fulfil.

14.	**Course contents**: Integration of solar photovoltaic (PV) based and wind based generation systems to power system at different voltage levels, Integration of small- hydro, biomass gasifier based generations systems to LV distribution networks, Modelling of various types of storages in power systems, Power electronic based power flow controllers for transmission and distribution systems, Power flow analysis and State estimation, Security and Stability Analysis of renewable integrated transmission and distribution system, Optimal operational dispatch and Unit commitment, TSO-DSO Interaction, alancing, Congestion management, Ancillary services for frequency support, voltage support, balancing and inertial with different reserve types (attery, PV derating, Pumped storage, thermal, HVAC etc).

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Integration of solar photovoltaic energy resources to power system	5
2	Integration of wind energy to power system	5
3	Integration of hydro and other renewable energy sources to power system	4
4	Different kind of storage for renewable energy systems	4
5	Power flow controllers for transmission and distribution systems	4
6	Power flow analysis and State estimation	4
7	Optimal operational dispatch and Unit commitment	4
8	Security and Stability Analysis of Integrated Energy Systems	4
9	TSO-DSO Interaction	4
10	Balancing, Congestion management, Ancillary services (reserve types: Battery, Pumped storage, Inertia)	4
Course Total		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
1&2	Basic modelling of various power system components like transformers, generators, transmission lines, loads etc.
4&5	Characteristics of various power electronic components like thyristors, IGBTs, MOSFETs etc. Understanding of full wave/half wave rectifiers
6	Basic idea of numerical analysis methods like Newton Raphson, Gauss Seidel, Least square estimates
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Lawrence E. J., Renewable Energy Integration, Practical Management of Variability, Uncertainty, and Flexibility in Power Grids, Elsevier Publications, (2016).
2. Kirschen G. S., Fundamentals of Power System Economics, WILEY (2014).
3. Grainger J. J., Stevenson W. D., Power System Analysis, , Mc Graw Hill, (2003).
4. Teodorescu R., Liserre M. and Rodríguez P., "Grid Converters for Photovoltaic and Wind Power Systems" ISBN:9780470057513, John Wiley & Sons, Ltd
5. "Utility-Scale Solar Photovoltaic Power Plants, AProject Developer's Guide" Available online: https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbbe54d141794/IFC+Solar+Report_Web+_08+05.pdf?MOD=AJPERES
6. NPTEL Video Lecture on Energy Resources and Technologies, Available Online: https://nptel.ac.in/courses/108105058/

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----

3	Teaching aids (videos, etc.)	----
4	Laboratory	NO
5	Equipment	----
6	Classroom infrastructure	Blackboard, LCD projector, OHP
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	25%
2	Open-ended problems	50%
3	Project-type activity	25%
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Advanced Energy Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL792		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JES, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		No
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL770 (< 5%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	No
8.2	Supersedes any existing course		No

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. S. K. Tyagi, D. Rakshit, K. Ravi Kumar, S. C. Kaushik

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** The advance power & energy cycles are the technologies that promise reduced pollution & higher efficiencies. An engineer should have basic knowledge of these systems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Latest topics on energy, Integrated Gasification Combined Cycle (IGCC), Fuels for power generation, Advanced Energy Storage Systems, Hydrogen Power, Clean Coal Technologies, Pressurized fluidized bed combustion, Natural gas cycles, Integrated generation, Fuel cells, Energy conservation in power plant, Battery vehicles, Electric vehicles, Algal biofuels, Metal hydrates, Geological CO_2 sequestering.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Fuels for power generation	02
2	Combined Cycles	05
3	IGCC	02
4	PFBC	02
5	AFBC	02
6	Advanced combustion systems	04
7	Advance Energy storage	04
8	Hydrogen Power	04
9	Natural Gas Cycles	04
10	Energy Conservation in Power Plants	04
11	Fuel Cells	03
12	Heavy Fuel based Power Generation	03
13	Algal Biofuels	01
14	Geological CO_2 sequestering	02
	Course Total	**42**

16. Brief description of tutorial activities:

Nil

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Nikolai Khartekenko, Advanced Energy Systems, Taylor & Frances (1988)
2. Hodge B. K., Analysis and Design of Energy Systems, Prentice Hall (1985)
3. Mitchell W. J., Energy Engineering, John Wiley & sons (1983)
4. Hunt V. D., Handbook of Energy Technology, Van Nostrand Reinbold (1982)

20. Resources required for the course (itemized student access requirements, if any)

1	Software	No
2	Hardware	No
3	Teaching aids (videos, etc.)	Yes
4	Laboratory	No
5	Equipment	----
6	Classroom infrastructure	LCD Projector, OHP and Black Board Facilities
7	Site visits	No
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----

5	Others (please specify)	25% Assignment / Tutorials/ Presentation of one concept

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Operation and Control of Electrical Energy Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL796		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	----
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR, JES, JEN
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	≤ 10%
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	≤ 10%
8.2	Supersedes any existing course		---

9.	**Not allowed for**	
10.	**Frequency of offering**	☐ Every semester ☐ I sem ☒ II sem ☐ Either semester
11.	**Faculty who will teach the course** Profs. T.S. Bhatti, Ashu Verma, Sumit Chattopadhyay	

12.	**Will the course require any visiting faculty?**	No
13.	**Course objectives** This course will introduce students with the operational structure of power system, challenges with high penetration of RE sources, various control and operational aspects of power system at transmission level as well as distribution level incorporating variable/intermittent RE generation.	

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): General structure of Indian power system, roles of various organizations like RLDCs, SLDCs, REMCs, ISO, CERC, SERC, GENCO, TRANSCO, DISCOs, RESCOs, in power supply chain. Peculiarities of Indian power systems (geographical, political constraints etc), challenges with large scale Integration of RE sources, scheduling practices followed in Indian/International scenarios. Power flow analysis, state estimation, optimal operational dispatch, unit commitment, demand side management, security and stability analysis of integrated energy systems, DSO operations, restructuring in power systems, market mechanisms to buy/sell power, balancing, congestion management, ancillary services for large scale integration of RE sources.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Basic structure of power systems, Roles of various organizations	02
2	Peculiarities of Indian power systems (geographical, political constraints etc), Challenges with large scale Integration of RE sources, Scheduling practices followed in Indian/International scenarios.	05
3	Power flow analysis	03
	State estimation	03
4	Optimal operational dispatch	03
	Unit commitment	03
5	Demand side management	04
6	Security and Stability Analysis of Integrated Energy Systems	05
7	Restructuring	03
	Market Mechanisms to Buy/Sell Power	03
	TSO-DSO Interaction	03
8	Balancing, Congestion management, Ancillary services (reserve types: Battery, Pumped storage, Inertia)	05
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	-------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
-------	-------
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Lawrence E. J., Renewable Energy Integration, Practical Management of Variability, Uncertainty, and Flexibility in Power Grids, Elsevier Publications, (2016).
2. Kirschen G. S., Fundamentals of Power System Economics, WILEY(2014).
3. Grainger J. J., Stevenson W. D., Power System Analysis, , Mc Graw Hill, (2003).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	MATLAB, Optimization Software
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	NO
20.5	Equipment	----
20.6	Classroom infrastructure	Blackboard, LCD projector, OHP
20.7	Site visits	Visit to NRLDC, REMCs to understand the power system operations in Indian Context
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	25%
21.2	Open-ended problems	50%

21.3	Project-type activity	25%
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Operation of Electrical Energy Systems with Large Scale Integration of Renewable Energy Sources.		
3.	**L-T-P structure**	3-0-2		
4.	**Credits**	4	**Non-graded Units**	---
5.	**Course number**	ESL797		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	----
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR, JES
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		ESL796

9.	**Not allowed for**	

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course** Profs. Ashu Verma, T.S. Bhatti, Sumit Chattopadhyay	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course aims to introduce students with the operational structure of power systems, challenges with high penetration of renewable energy (RE) based electricity , various control and operational aspects of power system both at transmission as well as distribution level incorporating variable/intermittent RE based power generation.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): General structure of Indian power system, roles of various organizations like RLDCs, SLDCs, REMCs, ISO, CERC, SERC, GENCO, TRANSCO, DISCOs, RESCOs, in power supply chain. Challenges with large scale Integration of RE sources, Scheduling practices followed in Indian/International scenarios. Power flow analysis, State estimation, Optimal operational dispatch, Unit commitment, Demand side management, Security and stability analysis of integrated energy systems with high penetration of Renewable Energy Systems, DSO operations, Market mechanisms to buy/sell power, Balancing, Congestion management, Ancillary services for large scale integration of RE sources, Smart Grid/Micro grid operations.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Basic structure of power systems, Roles of various organizations	02
2	Peculiarities of Indian power systems (geographical, political constraints etc), challenges with large scale Integration of RE sources, scheduling practices followed in Indian/International scenarios.	03
3	Power flow analysis	03
	State estimation	03
4	Security and stability analysis of integrated energy systems	05
5	Optimal operational dispatch, unit commitment,	05
6	Strategies for demand side management, demand response, participation of Electric Vehicles in DSM	05
7	Market mechanisms to buy/sell power in a deregulated environment	05
8	Balancing, congestion management	03
	Ancillary services (reserve types: battery, pumped storage, inertia)	03
9	Smart Grids/Micro Grid Operations	05
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
2	Power flow analysis for a) transmission and b) unbalanced distribution networks with solar photovoltaic and wind integration system: observe the effect of integration of these resources	04 + 04
3	Overload and voltage security analysis	04
5	Optimal operation dispatch (with economic dispatch as special case), and unit commitment with solar photovoltaic and wind integration system	06
6	Load shaping with demand side management, demonstration of DSM and Demand Response (DR) at distribution/building load time of demand (TOD) management	04
7	Students will take three problems from existing topics and will solve it by making their own programming modules	06
Total Practical / Practice hours (14 times 'P')		28

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1 & 2	Basics and modelling of various power system components,
3	Numerical Analysis Methods NR, FDLF, Least square estimation
4	Optimality conditions, basics of optimization theory
9	Load frequency control (single area/multi area): controlled/uncontrolled cases, Automatic Voltage Control
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Lawrence E. J., Renewable Energy Integration, Practical Management of Variability, Uncertainty, and Flexibility in Power Grids, Elsevier Publications(2016).
2. Kirschen G. S., Fundamentals of Power System Economics, WILEY (2014).
3. John J. G., William D. S., Power System Analysis, McGraw Hill (2003).
4. Peer reviewed journals such as IEEE Transaction on Power System, IEEE Transaction on Smart Grid, IET Generation Transmission Distribution, IET Renewable Power Generation.

5. SastryS.S., Introductory Methods of Numerical Analysis, Prentice Hall (2005) (For self-study component only).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	MATLAB, ETAP
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	------
20.4	Laboratory	Simulation Laboratory
20.5	Equipment	----
20.6	Classroom infrastructure	Board, Projector
20.7	Site visits	Visit to Load Dispatch Centre, Solar power plants
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**			Centre for Energy Studies	
2.	**Course Title**	Distributed and Decentralized Energy Systems			
3.	**L-T-P structure**	3-0-0			
4.	**Credits**	3	**Non-graded Units**	---	
5.	**Course number**	ESL798			
6.	**Course Status** (Course Category for Program):				

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	----
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR, JES
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	NIL
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	NIL
8.2	Supersedes any existing course		

9.	**Not allowed for**	

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course** Prof. Ashu Verma, T.S. Bhatti, Prof. Sumit Chattopadhyay	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course aims to equip the students with the knowledge, understanding and application oriented skills pertaining to operational and control aspects of decentralized and distributed energy system, micro grids, in islanded/grid connected modes with particular emphasis on large scale integration of renewable energy based power systems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities):Operation and control of various distributed energy resources (DERs) such as roof top photovoltaic, wind, small hydro, fuel cell and battery energy storage systems, smart grid and distributed energy systems, inverter control, parallel operation of inverters in distributed energy resources (DERs), voltage and current control of a three phase four wire distributed generator (DGs) inverters in islanded/grid connected modes. Operation and control of biogas and biodiesel based electricity generation systems. Distribution power flow, operational aspects of distribution systems with multiple DGs and energy storage. Multi generation frequency control, voltage and reactive power management in integrated systems with DGs sand energy storage, stability analysis of DERs integrated energy systems, distribution system reconfiguration, effect of DERs on protection, operation and control of rural/urban/industrial micro grids.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Operation of Distributed Generation Sources: roof top photovoltaic systems, wind, small hydro systems, biomass/biogas based generation sources	04
2	Operation and control of inverters for distributed energy resources	04
3	Stand-alone operation of renewable distributed energy resources	04
4	Unbalanced Distribution power flow, State estimation, Harmonic power flow	04
5	operational aspects of distribution system with multiple DERs and energy storage devices	03
6	Multi generation frequency control	05
7	Voltage/reactive power management in integrated systems	04
8	Distribution system reconfiguration	04
9	Role of ICT in integration of Distributed energy sources	02
10	Operation and Control of Rural/Urban/Industrial Micro Grids	04
11	Discussions regarding actual case studies from the field	04
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1 & 2	Basics and modelling of various electrical components,
4	Numerical Analysis Methods NR, Least square estimation
6	Basics of Load frequency control (single area/multi area): controlled/uncontrolled cases
7	Automatic Voltage Control
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Toshihisa F., Integration of distributed resources in power systems, Academic Press (2016).
2. Salvador A., Modelling Distributed Energy Resources in Energy Service Networks, IET Press, Renewable Energy Sources (2013).
3. Jhangir H., Pota H. R., Robust control of grid voltage stability: high penetration of renewable energy: Interfacing conventional and renewable power generation resources, Springer (2014).
4. Peer reviewed journals such as IEEE Transaction on Smart Grid, IET Renewable Power Generation.
5. Sastry S.S., Introductory Methods of Numerical Analysis, Prentice Hall, 2005 (For self-study component only).
6. Elgerd O.I., Electrical Energy Systems Theory: An Introduction, Indian Edition (Reprint), 2017 (For self-study component only).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	MATLAB
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	------
20.4	Laboratory	Simulation Laboratory
20.5	Equipment	----
20.6	Classroom infrastructure	Board, Projector

20.7	Site visits	Visit to Load Dispatch Centre, Solar power plants
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Essentials of Electrical Power Generation by Renewable Energy Sources		
3.	**L-T-P structure**	2-0-2		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL799		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		No
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	No
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	ELL 751 (< 5 %) ELL 758 (< 10 %)
8.2	Supersedes any existing course		No

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. T. S. Bhatti, A. Verma, S. Chattopadhyay

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course should serve as a basic course for M.Tech students imparting the knowledge about various types of green and renewable energy sources, generators used for power generation, electrical characteristics, operation and control of power electronic devices in renewable energy, power quality issues and mitigation, introduction to microgrids, smartgrids, and decentralized power generation.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Basics power electronic converters for renewable energy integration to power system, basics of wind power generation, wind turbines, generators (SCIG, DFIG, PMSG) and topologies, small hydro systems, control of wind power system, processing of solar power, power quality issues, power quality control , control of inverter output impedance, harmonic filters, control and protection issues with renewable solar/wind, parallel operation of inverters, power flow control, synchronverters, operation of inverters in islanded/grid connected modes, basic controllers for RE sources, PI, PID, intelligent controllers, synchronization techniques, conventional, PLL , sinusoid-locked loops, need for micro grids, architecture and communication infrastructure for smart grids, Importance and challenges for decentralized energy generation, peculiarities related to integration of roof top PV and autonomous energy storage devices. Basic requirement of PV inverters and source of leakage current

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Basics power electronic converters for renewable energy integration to power system	02
2	Basics of wind power generation, wind turbines, generators (SCIG, DFIG, PMSG) and topologies, small hydro system	04
3	Power quality issues with integration of renewable energy sources, power quality control, control of inverter output impedance, bypassing harmonic current components,	05
4	Control and protection issues with renewable solar/wind, parallel operation of inverters, power flow control, synchronverters, operation of inverters in islanded/grid connected modes,	05
5	Basic controllers for RE sources, PI, PID, intelligent controllers, synchronization techniques, conventional, PLL, sinusoid-locked loops	04
6	Need for micro grids, architecture and communication infrastructure for smart grids	02

7	Need and challenges for decentralized energy generation, peculiarities related to integration of roof top PVand autonomous energy storage devices.	03
8	Basic requirement of PV inverters and source of leakage current	03
	Course Total	**28**

16. Brief description of tutorial activities:

Nil

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
1	Introduction	1
2	Solar photovoltaic generation systems in islanded/grid connected modes, leakage current analysis	6
3	Various types of wind generators (SCIG, DFIG, PMSG)	6
4	Power quality measurement and improvement for power systems with significant penetration of renewable energy	9
5	DC-DC converters for renewable energy integration	3
6	Parallel operation of two inverters	3
Total Practical / Practice hours (14 times 'P')		**28**

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	State of the art and emerging power electronic devices
2	Present scenario of wind and small hydro power generation in India and over the world
3	Power rating and features of grid connected and off grid power converters for wind and solar power generation
6	Case study of existing smart grids and micro grids
8	Basic characteristics of solar PV cell, array and modules under different conditions.
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Zhong Q-C. and Hornik T., Control of Power Inverters in Renewable Energy and Smart Grid Technology, IEEE Press, & WILEY Publications (2013).
2. Ned M., Power Electronics: A First Course, WILEY Publications (2011)
3. Remus T., Marco L., and Pedro R., Grid Converters for Photovoltaic and Wind Power Systems, John Wiley & Sons, Ltd (2011)
4. http://indiasmartgrid.org/

20. Resources required for the course (itemized student access requirements, if any)

1	Software	MATLAB, Optimization Software
2	Hardware	Solar PV system, DC-DC converters, Inverters, SCIG,DFIG and PMSG with prime movers, Loads Resistive/Inductive, Power Quality Analyzer, Capacitor Bank, Synchronization Panel, Various measuring devices (AC/DC ammeter, AC/DC voltmeter, multimeters, power meter, phase sequence meters etc).
3	Teaching aids (videos, etc.)	Yes
4	Laboratory	Yes
5	Equipment	----
6	Classroom infrastructure	Blackboard, LCD projector, OHP
7	Site visits	2 site visits to Tata power/ NISE for various solar installations
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	25%
2	Open-ended problems	50%
3	Project-type activity	25%
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Solar Architecture		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL840		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JES, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		No
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL770 (< 5%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	No
8.2	Supersedes any existing course		No

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. S. K. Tyagi, D. Rakshit, K. Ravi Kumar, S. C. Kaushik

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course has objectives to elaborate PG students regarding current trends in solar architecture and following key concepts: Solar Radiation, Sun Angles, and Importance of Sun Angles for Building Fenestration/day lighting, Solar Passive Architecture, heat transfer in buildings, Natural Heating/Cooling concepts for Building, Earth to Air Heat Exchanger, Thermal Comfort Requirements, Energy Conservation, and Concept of Zero Energy Buildings.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Thermal comfort, sun motion, Building orientation and design, passive heating and cooling concepts, thumb rules, heat transfer in buildings: Thermal modeling of passive concepts, Evaporative cooling, Energy efficient windows and day lighting, Earth air tunnel and heat exchanger, Zero energy building concept and rating systems, Energy conservation building codes, Software for Building Simulation, Automation and Energy Management of Buildings.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Solar Radiation Concept	02
2	Sun Angles	01
3	Building Orientation and Design	02
4	Passive Heating	04
5	Passive Cooling	04
6	Basics of Heat Transfer in Buildings	06
7	Thermal Modeling of Passive Concepts	06
8	Evaporative Cooling	04
9	Day lighting through Windows	05
10	Earth air tunnel and heat exchanger	02
11	ZEBC, Building rating system, Simulation Tools, Codes	06
	Course Total	**42**

16. Brief description of tutorial activities:

Nil

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
2	Sun-earth angle and motion
2	Fourier Analysis
1, 6	Transient heat conduction analysis
3	Building materials and their energy density and greenhouse effect
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

5. Tiwari G. N., Solar Energy, CRC Press (2002).
6. Sodha M. S., Bansal N. K., Bansal P. K., Kumar A., and Malik M. A. S., Solar Passive Building, Science and Design, Pergamon Press (1986).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	No
2	Hardware	No
3	Teaching aids (videos, etc.)	Yes
4	Laboratory	No
5	Equipment	----
6	Classroom infrastructure	LCD Projector, OHP and Black Board Facilities
7	Site visits	No
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	50%
2	Open-ended problems	25%
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	25% Assignment / Tutorials/ Presentation of one concept

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**			Centre for Energy Studies	
2.	**Course Title**	Negative CO_2 Emission Technologies			
3.	**L-T-P structure**	3-0-0			
4.	**Credits**	3	**Non-graded Units**	---	
5.	**Course number**	ESL842			
6.	**Course Status** (Course Category for Program)				
Institute Core for all UG programs				---	
Programme Linked Core for:				---	
Departmental Core for:				---	
Departmental Elective for:				---	
Minor Area / Interdisciplinary Specialization Core for:				---	
Minor Area / Interdisciplinary Specialization Elective for:				---	
Programme Core for:				---	
Programme Elective for:				ESR	
Open category Elective for all other programs (No if Institute Core)				Yes	
7.	**Pre-requisite(s)**	Nil			

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant overlap with any UG/PG course of the Dept./Centre/ School	ESL758 (<15%)
	(b)	Significant overlap with any UG/PG course of other Dept./Centre/ School	CVL 875 (10%)
8.2	Supersedes any existing course		Nil

9.	**Not allowed for**	Nil

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester
11.	**Faculty who will teach the course** Profs. K. A. Subramanian, S. K. Tyagi, Dibakar Rakshit, K. Ravi Kumar, Kaushik Saha	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** On successful completion of this course the students will gain an understanding of various CO_2 emission reduction technologies as well as understanding of integrated approaches of CO_2 removal / sequestration using renewable energy systems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to Negative Emissions; Paris climate summit on limiting average global temperature rise; Future projected concentration of Carbon dioxide (CO_2) in atmosphere and consequences of Climate change and global warming; Carbon budget; Overview of CO_2 emission from industrial sectors, transport sectors, power generating sectors; formation mechanism of CO_2 emission in combustion engines; Radiative forcing of climate change; Global warming potential (GWP); Stabilization of CO_2 emission in the atmosphere by renewable energy systems; Renewable energy system with carbon sequestration technologies. Different methods / technologies of Carbon dioxide removal from the atmosphere: Ocean Liming; Enhanced Weathering; Ocean Fertilization; Forestation; Soil Carbon Management; Direct Air Capture; Artificial trees; Bioenergy with Carbon Capture & Storage; Pyrolysis process and Biochar; CO_2 emission reduction through Energy efficiency improvement in energy devices / power plants; Integration of different renewable energy systems (solar photo-voltaic, solar thermal, wind, bioenergy, geothermal, tidal) with the carbon sequestration technologies; Analysis of energy intensity of carbon dioxide removal system; Different scenario of CO_2 emission reduction; Exploration of possible Sequestration of CO_2 at source level in industries; Issues and control measures of CO_2 removal system; Carbon tax and credit; Case studies.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to Negative Emissions and Paris climate summit on limiting average global temperature rise	2
2	Analysis of effect of future projected concentration of Carbon dioxide (CO_2) in atmosphere on global temperature rise and other consequences of climate change	2
4	Overview of CO_2 emission from industrial sectors, transport sectors, power generating sectors; formation mechanism of CO_2 emission in combustion engines	3
5	Radiative forcing of climate change; Global warming potential (GWP); Calculation of average temperature rise using radiative forcing and climate sensitivity factor	2
6	Stabilization of CO_2 emission in the atmosphere by renewable energy systems; Renewable energy system with carbon sequestration technologies	3
7	Ocean Liming; Enhanced Weathering; Ocean Fertilization; Forestation for CO_2 removal from the atmosphere	4
8	Soil Carbon Management; Direct Air Capture; Artificial trees for CO_2 emission removal from the atmosphere	2
9	Bioenergy with Carbon Capture & Storage	3
10	Pyrolysis process and Biochar, Characterisation of biochar	3

11	CO_2 emission reduction through Energy efficiency improvement in energy devices / power plants	2
12	Integration of different renewable energy systems (solar photo-voltaic, solar thermal, wind, bioenergy, geothermal, tidal) with the carbon sequestration technologies	4
13	Analysis of energy input to carbon dioxide removal system	2
14	Analysis of different scenario of CO_2 emission reduction potential using different technologies	2
15	Exploration of possible Sequestration of CO_2 at source level in different industries	2
16	Issues and control measures of CO_2 removal mechanism	2
17	Carbon tax and credit	1
18	Case studies	2
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	-------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Carbon cycle and basics of ecology
4	Air-fuel ratio calculation for different fuels and carbon balance method for CO_2 emission calculation
9	Phase diagram of CO_2 with critical pressure and temperature
11	Relationship between CO_2 with energy efficiency and carbon content in fuels
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Negative Emissions Technologies and Reliable Sequestration : A Research Agenda, The National Academies Press, (2018).
2. Pachauri R. K. and Meyer L., Climate Change 2014 Synthesis Report, IPCC (2018).
3. Dincer I. and Zamfirescu C., Sustainable Energy Systems and Applications, Springer (2011).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	----
4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	----
7	Site visits	----
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATES

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Net Zero Energy Buildings		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL845		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	Heat Transfer

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant overlap with any UG/PG course of the Dept./Centre/ School	ESL 720 (< 5 %)
	(b)	Significant overlap with any UG/PG course of other Dept./Centre/ School	MCL 380 (< 5 %)
8.2	Supersedes any existing course		**---**

9.	**Not allowed for**	

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course** Profs. T. C. Kandpal, Ashu Verma, Dibakar Rakshit	

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course will give an in-depth understanding of the different definitions of NZEBs and the different steps involved in achieving NZEB goals. Detailed examples of NZEBs from the world over will further reinforce the understanding of the concept. Salient objectives of the course include the following: • A thorough understanding of Zero Energy Building definitions • Understanding solar energy utilization in buildings • Solar PV versus Solar Thermal for renewable power • Understanding of other Renewable sources of power generation for buildings • Energy conservation studies in building perspective • Study of transient building heat transfer and its impact on thermal comfort • Study of contemporary HVAC equipment and possible integration of renewable energy • Introduction to novel materials and designs for NZEB construction • Tangible strategies for reducing energy demands in different climatic zones

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to Net Zero Energy Buildings (NZEBs) and its Concepts; Different Definitions of NZEBs; Relevance of Such Systems; Steps to Achieve NZEBs; Challenges Involved in the Design of Such Systems, Sources of Renewable Power for NZEBs; Thermal Loads and Energy Use in Buildings; Design Considerations in NZEBs: Building fabric/ envelope, HVAC and Lighting Systems, Integration with Solar/ Renewable Energy Systems, Building Management Systems; Optimal resource dispatch (thermal and electrical), demand side management with NZEB operation including HVAC, lighting control Operation of building microgrids in grid connected/islanded modes, provision of ancillary services or peer to peer sharing among the various buildings Comfort considerations in NZEBs: Thermal Comfort, Visual Comfort, Acoustic Comfort, Indoor Air Quality; Carbon Footprint Mitigation; NZEB Case Studies, Future Directions

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours (<5 hours per topic)
1	Introduction to Net Zero Energy Buildings (NZEBs) and its Concepts; Different Definitions of NZEBs; Relevance of Such Systems	4
2	Steps to Achieve NZEBs; Challenges Involved in the Design of Such Systems; Sources of Renewable Power for NZEBs	4
3	Thermal loads and energy use in buildings	2
4	Design Considerations in NZEBs:	4
	Building fabric/ envelope	4
	HVAC and Lighting Systems	4
	Integration with Solar/ Renewable Energy Systems	4
	Building Management Systems	4
	Optimal resource dispatch (thermal and electrical), demand side management with NZEB operation including HVAC, lighting control	4

	Operation of building microgrids in grid connected/islanded modes, provision of ancillary services or peer to peer sharing among the various buildings	4
5	Comfort considerations in NZEBs: Thermal Comfort, Visual Comfort, Acoustic Comfort, Indoor Air Quality	4
6	NZEB Case Studies: Carbon Footprint Mitigation, Economics of NZEBs; Future Directions	4
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	----	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	----	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
	Basic Thermodynamics and Heat Transfer, Basics of AC Motors and Solid State Transformers
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Arora, C. P., *Refrigeration and Air Conditioning,* McGraw Hill Education (2017).
2. Athienitis A. and O'Brien W., *Modeling, Design, and Optimization of Net-Zero Energy Buildings,* Ernst & Sohn, (2015).
3. Goswami, D. Y., *Principles of Solar Engineering*, CRC Press Taylor & Francis Group (2015).
4. Chwieduk, D., *Solar Energy in Buildings*, Elsevier (2014).
5. Holman, J. P., *Heat Transfer*, McGraw Hill Education (2010).
6. Duffie, J. A., Beckman, W. A., *Solar Engineering of Thermal Processes*, John Wiley & Sons (2006).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----
2	Hardware	----
3	Teaching aids (videos, etc.)	Projector and screen
4	Laboratory	----
5	Equipment	----
6	Classroom infrastructure	Yes
7	Site visits	Yes (Proposed Visit to NISE)
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Solar Refrigeration and Air Conditioning		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL850		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JES, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		No
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	No
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	No
8.2	Supersedes any existing course		No

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. S. K. Tyagi, D. Rakshit, K. Ravi Kumar, S. C. Kaushik

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** This course will contain Basic Thermodynamic Modelling, Design Studies and Evaluation Methods for Solar Cooling Systems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Potential and scope of solar cooling, Types of solar cooling systems, Solar collectors and storage systems for solar refrigeration and air-conditioning, Solar operation of vapour absorption and vapour compression refrigeration cycles and their thermodynamic assessment, Rankine cycle, sterling cycle based solar cooling systems, Jet ejector solar cooling systems, Fuel assisted solar cooling systems, Solar desiccant cooling systems, Open cycle absorption / desorption solar cooling alternatives, Advanced solar cooling systems, Thermal modeling and computer simulation for continuous and intermittent solar refrigeration and air-conditioning systems, Refrigerant storage for solar absorption cooling systems, Solar thermoelectric refrigeration and air-conditioning, Solar thermo acoustic cooling and hybrid air-conditioning, Solar economics of cooling systems.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Scope of Solar Cooling	01
2	Solar Collection and Storage Options	03
3	Types of Solar Cooling	02
4	Vapour Compression Refrigeration	03
5	Photovoltaic Refrigeration	01
6	Rankine cycle solar cooling	03
7	Gas cycle solar cooling systems	01
8	Steam Jet Ejector Cooling	02
9	Thermo compression systems	02
10	Vapour Absorption Cooling	03
11	Types of Absorption cooling	02
12	Open cycle Absorption cooling cycle	02
13	Vapour Absorption cooling cycle	02
14	Solid and Liquid Desicant cooling	03
15	Hybrid Solar Air Conditioning cycle	02
16	Solar Thermoelectric cooling	03
17	Solar Thermo acoustic cooling	02
18	Corporative study of cooling systems	02

19	Solar economics of cooling systems	02
20	Advanced Solar Cooling Concepts	02
	Course Total	**42**

16. Brief description of tutorial activities:

Nil

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Unit of Refrigeration cooling (TR) and Compression work (Horse Power)
2	History of Refrigeration, Traditional cooling options
3	Heating/Cooling load calculations
3	Building materials and their energy density and greenhouse effect
4	Types of compression based Refrigeration system, Air compression based Refrigeration, Traditional Refrigerants, Problems with conventional Refrigerants, Ozone Depletion Potential and Global warming Potential of various Refrigerants
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Kaushik S. C., Solar Refrigeration and space conditioning, Divyajyoti Publications, 1989.

20. Resources required for the course (itemized student access requirements, if any)

1	Software	No
2	Hardware	No
3	Teaching aids (videos, etc.)	Yes
4	Laboratory	No
5	Equipment	----

6	Classroom infrastructure	LCD Projector, OHP and Black Board Facilities
7	Site visits	No
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	25% Assignment / Tutorials/ Presentation of one concept

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATES

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Emerging Materials for Next Generation Photovoltaic Applications		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL852		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		---
	(a)	Significant overlap with any UG/PG course of the Dept./Centre/ School	ESL 360 (< 5%) ESL755 (< 10%)
	(b)	Significant overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---
10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course** Profs. Supravat Karak, Sandeep Pathak, Vamsi Krishna, Viresh Dutta	

12.	**Will the course require any visiting faculty?**	NO

13.	**Course objectives** Upon successful completion of the course students will have profound understanding on various recent developments in emerging 4th generation photovoltaic materials in terms of their processing technologies and applications. The course has been designed in separate sections covering a broad range of impending topics in emerging PV materials including Silicon & beyond (such as: metal chalcogenides, dye-sensitized solar cells, organic photovoltaic, perovskite, Quantum dot solar cell etc.). Thus, it will bring together a wealth of information that will serve as a valuable resource for students, researchers, scientists and engineers engaged in PV research and development.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Wide range of non-conventional emerging materials for next generation photovoltaic applications will be discussed in details. In the first part, fundamental photo-physics of different materials such as organic, inorganic and hydride semiconductors, comparison of their specific optical and electrical properties and basic characterisations for solar cells will be introduced. The second part will be dedicated for new emerging materials such as, Organic semiconductors, hybrid perovskite, metal chalcogenides and ferroelectrics for PV application. Their fundamental properties, technologies and device applications will be discussed in details. In the next part, carbon based nano-materials and quantum dot based highly efficient devices will be discussed. In the last part various technologies and material processing for the production of low-cost Si cell and their recycling processes will be emphasized.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours (<5 hours per topic)
1	Scope of PV in world energy scenario	01
2	Basic fundamentals of different semiconductors (Energy band, charge carriers and their motion, generation, recombination, doping)	
	a) (i) Inorganic semiconductors	03
	b) (ii) Organic semiconductors/polymers	03
	c) (iii) Hybrid semiconductors	02
3	Solar cell characterisation (generation of photocurrent and photovoltage, I-V equation and different parameters like η, I_{SC}, V_{OC}, FF etc., External quantum efficiency, equivalent model)	02
4	Organic Solar Cells (Fundamentals, technologies and applications)	04
5	Dye-Sensitized Solar Cells (DSSC)	03
6	Perovskite Solar Cells (promises and challenges, $CH_3NH_3PbI_3$, Pb free: Bi, Sn etc)	04

7	Metal Chalcogenides based photovoltaic devices (SnS, SnSe, SnTe)	04
8	Photovoltaics in Ferroelectric Materials	02
9	Nano-Photovoltaics (CNT, ZNO, TIO_2, ITO, FTO, organics etc)	04
10	Quantum Dot Photovoltaics/ Near-IR responsive QD photovoltaics	04
11	Low-Cost Silicon Photovoltaics (crystalline, multicrystalline, PERC, PESC, HIT, IBC, SHJ solar cells)	04
12	Recycling Crystalline Silicon Photovoltaic Modules	02
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	----------	-------
Total Tutorial hours (14 times 'T')		-------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	----------	-------
Total Practical / Practice hours (14 times 'P')		-------

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
2	P-N junction under dark (diode) and illumination(solar cell)
4	Design of solar cells and modules
5	Si production, Si wafer based solar cell technology
5,8,9,11	Thin film solar cell technology (CVD, PECVD, MBE, Thermal evaporation, spin and spray deposition etc)
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Ikhmayies S. J. A., Advances in Silicon Solar Cells, Springer (2018).
2. Chen G., Ning Z., Agren H., Nanostructured Solar Cells, MDPI AG (2017).
3. Park N. G., Grätzel M., Miyasaka T., Organic-Inorganic Halide Perovskite Photovoltaics, Springer (2016).

4. Tress W., Organic solar cell, Springer (2014).
5. Huang J., Huang H., Organic and Hybrid Solar Cells, Springer (2014).
6. Sze S. M., Ng K. K., Physics of Semiconductor Devices, Willey (2006).
7. Nelson J., The Physics of Solar Cells, Imperial college press (2003).
8. Brendel R. and Goetzberger A., Thin Film Crystalline Si Solar cells, Wiley VCH (2003).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	----------
2	Hardware	----------
3	Teaching aids (videos, etc.)	----------
4	Laboratory	----------
5	Equipment	----------
6	Classroom infrastructure	----------
7	Site visits	----------
8	Others (please specify)	----------

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----------
2	Open-ended problems	----------
3	Project-type activity	----------
4	Open-ended laboratory work	----------
5	Others (please specify)	----------

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**		Centre for Energy Studies	
2.	**Course Title**	Solar Photovoltaic Power Generation		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	Not Applicable
5.	**Course number**	ESL855		
6.	**Course Status** (Course Category for Program)(list program codes: eg., EE1, CS5, *etc.*)			

Institute Core for all UG programs	No
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	No
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	No
8.2	Supersedes any existing course		-

9.	**Not allowed for**	-

10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course:** Profs. Sumit K Chattopadhyay, Ashu Verma, V. Dutta, T. S. Bhatti

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives:** On successful completion of this course, a student will have detailed knowledge about photovoltaic power generation at different power level, using different technologies in all components of photovoltaic power generation. Addition to this emerging and future trends in photovoltaic power generation will also be discussed. A student successfully undergoing this course should be able to execute design, development or any similar assignment related to photovoltaic plants of any power rating.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Components of Photovoltaic Power Generation with Cost-Breakup (Present and Projected). Various kinds of PV modules and their features, IV-Characteristics and Electrical Equivalent Circuits under various conditions. Effect of partial shading, Local and global MPPT. Mounting structures and earthing for various kind of Solar PV plants. Cables and cable-layout, maintenance and standards for various kind of Solar PV plants. MPPT algorithms and tuning parameters. Review of basic power electronics and control systems. Charge controllers and Inverter configurations. Off-grid power converter configurations and operation (features). Grid connected central inverter: Configuration, performance and features. Synchronization and other control requirements for grid connected power converters. Leakage current and transformer-less power converters. Transformers for utility scale solar PV power plants. Power quality and related standards. Power Purchase agreements. Emerging trends for PV power generation: Converter topology, Ancillary support and SCADA

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of Classes
1	Introduction to the course	1
2	Components of Photovoltaic Power Generation with Cost-Breakup (Present and Projected)	2
3	Various kinds of PV modules (based on type of PV Cell and based on Envelope materials) and their features, Module degradation and life expectancy, Preventive measures to prevent degradation, IV-Characteristics and Electrical Equivalent Circuits. Effect of temperature, irradiance, air-speed, air-density on I-V Characteristics. Strings and Array characteristics under partial shading, Local and global MPPT	5
4	Mounting structures and earthing for Utility-Scale, roof-Top and Floating Solar PV plants and related standards	2
5	Cables and cable-layout, maintenance and standards for Utility-Scale, roof-Top and Floating Solar PV plants and related standards	2
6	MPPT algorithms: various reference-cell-based and non-reference-cell based algorithms, Effect of tuning parameters on MPPT efficiency	3
7	Review of basic power electronics and control systems	4

8	Charge controllers, Inverter configurations (central, multi-string and string) with power rating	2
9	Off-grid power converter configurations and operation (features)	1
10	Grid connected central inverter: Configuration, performance, features	3
11	Grid Synchronization (Phase-locked-loops) and other control requirements for grid connected power converters	4
12	Leakage current and evolution of transformer-less power converter topologies	3
13	Evacuation transformers for utility scale solar PV power plants	2
14	Power quality and related standards	1
15	Power Purchase agreements and various standards	2
16	Emerging trends for PV power generation: Active compensation techniques to enhance energy yield, Ancillary services to power systems like frequency support, reactive power support, unbalance compensation, harmonic compensation using PV inverters. Fault ride through and anti-islanding requirement. SCADA and monitoring parameters	5
Total Lecture hours(14 times 'L')		**42**

16. Brief description of tutorial activities:

NA

17. Brief description of Practical / Practice activities

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
1	Present scenario of PV power generation
6	Implementation of MPPT algorithm using MATLAB/Simulink
8	Simulation of Charge-Controllers along with MPPT using Simulink
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Teodorescu R., Liserre M. and Rodríguez P., "Grid Converters for Photovoltaic and Wind Power Systems" ISBN:9780470057513, John Wiley & Sons, Ltd
2. "Utility-Scale Solar Photovoltaic Power Plants, AProject Developer's Guide" Available online: https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbbe54d141794/IFC+Solar+Report_Web+_08+05.pdf?MOD=AJPERES
3. Esram T. and Chapman P. L., "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," in IEEE Transactions on Energy Conversion, vol. 22, no. 2, pp. 439-449, June 2007.

4. Chattopadhyay S. K. and Chakraborty C., "A New Asymmetric Multilevel Inverter Topology Suitable for Solar PV Applications With Varying Irradiance," in **IEEE Transactions on Sustainable Energy**, vol. 8, no. 4, pp. 1496-1506, Oct. 2017.
5. Grid Connected Solar Rooftop Programme In India, Available online:file:///E:/IITD%20TEACHING/Solar%20Photovoltaic%20Power%20Generation/rooftop%20govt%20of%20india.pdf
6. https://www.pveducation.org/Welcome
7. NPTEL Video Lecture on Energy Resources and Technologies, Available Online: https://nptel.ac.in/courses/108105058/
8. http://www.solarhub.com/

20. Resources required for the course (itemized student access requirements, if any)

1	Software	-
2	Hardware	-.
3	Teaching aids (videos, etc.)	Power Point Projectors
4	Laboratory	-
5	Equipment	-
6	Classroom infrastructure	Required
7	Site visits	-
8	Others (please specify)	-

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	NA
2	Open-ended problems	NA
3	Project-type activity	NA
4	Open-ended laboratory work	NA
5	Others (please specify)	NA

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Alternative Fuels for Transportation		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL875		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JEN, ESN, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	----

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester

11.	**Faculty who will teach the course** Profs. K. A. Subramanian, Kaushik Saha

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** Upon completing the course, the student will be able to: • Understand the current availability of petroleum based fuels, their progress and influence on environment. • Realize the need, production and technology of utilizing different alternative liquid and gaseous fuels for transportation including alcohol, biodiesel, Compressed Natural Gas, Liquefied Petroleum Gas, Di-methyl ether, Di-ethyl ether and hydrogen.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): An introduction to hydrocarbon fuels-their availability and effect on environment, Resources such as shale gas and petroleum, Gasoline and Diesel self-ignition characteristics of the fuel, octane number, Cetane number, Alternative fuels -liquid and gaseous fuels, Physico-chemical characteristics, Alternative liquid fuels, Alcohol fuels -ethanol and methanol, fuel composition, Fuel induction techniques, Fumigation, Emission of oxygenates, Applications to engines and automotive conversions, Biodiesel formulation techniques, Transesterification, Application in diesel engines, , Dimethyl ether(DME), properties fuel injection consideration general introduction to Liquefied Petroleum Gas(LPG) and Liquefied Natural Gas(LNG), Compressed natural gas (CNG) components, mixtures and kits, Fuel supply system and emission studies and control, Hydrogen combustion characteristics, Flashback control techniques, Safety aspects and system development, NO_x emission control, Biogas, Producer gas and their characteristics, System development for engine application.

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to alternative fuels and emissions from internal combustion engines, resources such as shale gas and petroleum	4
2	Physic-chemical properties fuels: self-ignition temperature, octane number, cetane number, distillation characteristics, Sulphur, density, viscosity, copper corrosion number, iodine number	5
3	Ethanol resources, Production technologies, ethanol utilization in spark ignition engines / vehicles, improvement of thermal efficiency and power output by optimization of compression ratio	5
4	Biodiesel Production and Utilization in compression ignition engines, Emissions reduction techniques (optimization of injection timing,	5

	exhaust gas recirculation, water injection, after treatment devices)	
5	Hydrogen Production, Storage and Utilization in spark ignition engines, power drop, backfire, NOx emission formation and reduction strategies	5
6	Compressed Natural gas Production and Utilization in spark ignition engines, performance and emissions characteristics of spark ignition engines fueled with natural gas	5
7	Dimethyl ether: induction / injection strategies, Power output improvement techniques, Optimization of design and Operating parameters of compression ignition engines for Dimethyl Ether.	5
8	Methanol Production and Utilization	4
9	Production Biogas, LPG and LNG gaseous fuels, their storage, Utilization of these fuels in spark ignition engines.	4
	Course Total	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	------	------
Total Tutorial hours (14 times 'T')		------

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	------	------
Total Practical / Practice hours (14 times 'P')		------

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1	Molecular structures and Physico-chemical properties of hydrocarbon fuels and biofuels
2	Worldwide Fuel Quality and emissions norms for internal combustion engines
3-9	Basic working principle of internal combustion engines
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Babu M. K. G., Subramanian K. A., Alternative Transportation Fuels: Utilization in Combustion Engines, CRC Press, 2013.
2. Willard W. P., Engineering Fundamentals of the Internal Combustion Engine, Pearson Prentice Hall, 2008.
3. Addy M. W., Khair M. K., Diesel Emissions and Their Control, SAE International, 2006.
4. Bechtold R. L., Alternate Fuels-Transportation Fuels for Today and Tomorrow, Society of Automotive Engineers (SAE), 2002.
5. Ferguson C. R., Allan T. K., Internal Combustion Engines Applied Thermosciences, John Wiley & Sons, Inc. 2001.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	----
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	-----
20.5	Equipment	----
20.6	Classroom infrastructure	----
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	-----
21.2	Open-ended problems	-----
21.3	Project-type activity	-----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Solar Thermal Power Generation		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL880		
6.	**Course Status** (Course Category for Program)			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	JES, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		No
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL340 (<10%) ESL740 (<10%) ESL770 (<20%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	No
8.2	Supersedes any existing course		No

9.	**Not allowed for**	---

10.	**Frequency of offering**	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** Profs. S. K. Tyagi, D. Rakshit, K. Ravi Kumar, T. C. Kandpal, S. C. Kaushik

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** To provide knowledge, understanding and application oriented skills on various solar thermal power generation technologies and their components/subsystems (solar concentrators, thermal storage and power conversion options) towards their effective utilization for meeting electricity demand with minimum environmental emissions.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Relevance of solar thermal power generation; Design and performance characteristics of different solar concentrator types suitable for thermal power generation; Tracking of solar concentrators; performance characterization of solar concentrators ,Storage option for solar thermal power plants; Modes of power generation in solar thermal power plants; Sizing solar thermal power plants; Operation and maintenance issues; Emerging trends in solar thermal power generation; Economics of solar thermal power generation; Case studies.

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Electricity demand in the country, Challenges with conventional power generation option, Need and relevance of renewable energy based power generation, suitability of solar thermal power generation for India	02
2	Solar thermal power generation, Components of solar thermal power plant	02
3	Solar concentrators, Parameters characterizing solar concentrators,Solar radiation availability for solar concentrators and its dependence on tracking modes	03
4	Optical design and concentration characteristics of Parabolic Through, Parabolic Dish, Fresnel Lens, Linear Fresnel Reflector, Compound Parabolic Concentrator, and Central Tower Receive System, optical performance and durability characterization	07
5	Thermal performance of solar concentrators, Receiver designs,Thermal performance characterization	04
6	Tracking of solar concentrators	02
7	Power generation block of solar thermal power plants, Oil-Indirect steam generation, Organic Rankine cycle, Brayton cycle, Stirling engine, air and water cooling arrangements, Choice of heat transfer fluids	05
8	Storage of heat in solar thermal power plants, Storage media and heat transfer fluids	03
9	Sizing solar thermal power plants for stand alone, with storage, with auxiliary, and with storage and auxiliary mode of operation, Field layout, Site selection	04
10	Issue in manufacture and use of (a) reflectors for use in solar thermal power plants (II) absorbers (III) support structures (IV) tracking	03

	systems and other components	
11	Operation and maintenance of solar thermal power plants, water requirement etc.	02
12	Economics of solar thermal power generation	02
13	Case studies on existing solar thermal power plants	03
	Course Total	**42**

16. Brief description of tutorial activities:

Nil

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component
(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
1-3	Solar radiation, Sun-earth geometry, Basic optics of solar collection-reflection, refraction, and absorption from a glass, Equations of parabola, cylinder, sphere, circles etc. in Cartesian and polar coordinates
4-5	Basics of heat transfer, Materials aspects of solar thermal collection-glass, metals, selective coatings, Basics of power cycles, Carnot, Rankine, Bryton, Stirling cycles
6-10	Solar thermal power generation module of the software "System Advisor Model"
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. Lovegrove K. and Stein W., Concentrating solar Power Technology: Principles Development and Applications, Woodhead Publishing Ltd.(2012).
2. Duffie J. A. and Beckman W. A., Solar Engineering of Thermal Processes, John Wiley and Sons (2006).
3. Kalogirous S. A., Solar Energy Engineering, Academic Press (2009).
4. Kreider J. F., Medium and High Temperature Solar Processes, Academic Press (1979).

5. Mathur S. S. and Kandpal T. C., Solar Concentrators in "Reviews of Renewable Energy Resources", Wiley Eastern Limited, New Delhi (1984).
6. Vogel W. and Kolb H., Large Scale Solar Thermal Power, Wiley-VCH Verlag GmbH&Co. KGaA Weinheim (2010).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	Sizing software for solar thermal power plants
2	Hardware	No
3	Teaching aids (videos, etc.)	Yes
4	Laboratory	No
5	Equipment	----
6	Classroom infrastructure	LCD Projector, OHP and Black Board Facilities
7	Site visits	Visit to system and facilities installed in and around Solar Energy Centre of Ministry of New and Renewable Energy
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	20%
2	Open-ended problems	20%
3	Project-type activity	10%
4	Open-ended laboratory work	----
5	Others (please specify)	50% Assignments on niche area identification, site selection and choice of CSP technology

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Solar Industrial Process Heating		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	Not Applicable
5.	**Course number**	ESL885		
6.	**Course Status** (Course Category for Program) (list program codes: eg., EE1, CS5, *etc*.)			

Institute Core for all UG programs	No
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute	Yes

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		(course number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	ESL770 (~15%) ESL880 (~10%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	Nil

10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester

11.	**Faculty who will teach the course** (Minimum 2 names for core courses / 1 name for electives) Profs. K. Ravi Kumar, Dibakar Rakshit, T.C. Kandpal

12.	**Will the course require any visiting faculty?**	No

13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to…"): The course will provide the knowledge to the students on fundamentals of solar thermal energy systems, various components of solar thermal energy systems, applications of solar thermal energy systems for various industrial applications and challenges involved in integration of thermal energy system with industrial applications, thermal energy storage system.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Basics of Solar Radiation, classification of solar thermal energy systems, Non-Concentrating solar collectors: Flat plate and evacuated tubular solar collector, Concentrating solar collectors: Compund parabolic concentrator, parabolic trough collector, linear Fresnel collector, parabolic dish collector, Optics of solar collectors, Tracking systems solar concentrators, receivers for concentrators; Designing thermal storage for industrial application; Applications of solar thermal energy system for various industrial applications such as pulp and paper, textile, oil upstream and downstream, food and beverage, pharmaceutical, leather, automobile industries, etc. Basics of economics.

15. Lecture Outline(with topics and number of lectures)

Module no.	**Topic**	**No. of hours** (< 5h per topic)
1	Basics of solar radiation: Solar- earth geometry, insolation	3
2	Basics of industrial process heat: Temperature requirements, consumption pattern.	4
3	Solar thermal energy systems: Basic concepts & parameters, flat plate collectors, evacuated tube collectors.	3
4	Concentrating Collector Systems: Concentrating collector designs, Optics of solar concentrators, Tracking systems.	4
5	Design of parabolic trough concentrators, Linear Fresnel reflector, Parabolic dish collector and its comparison.	4
6	Thermal energy storage systems: Classifications, Design of sensible, latent and thermochemical energy storage.	4
7	Solar process heating in pulp and paper, oil upstream and downstream, textile industries.	4
8	Solar process heating in food and beverage and pharmaceutical industries.	3
9	Solar process heating in leather, automobile and painting industries.	3
10	Energy transport system: Piping, Heat transfer fluids, Heat exchangers.	3
11	Challenges involved in integration of thermal energy system with industrial applications.	3
12	Economics of solar industrial process heating, cost reduction possibilities.	4
Course Total		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
4	Basic optics of solar collection
5-11	Basics of heat transfer
6	Basics of energy storage technologies
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Garg H.P., Prakash J., Solar Energy: Fundamentals and Applications, Tata McGraw-Hill, 1st Revised Edition (2016).
2. Goswami D. Y., Principles of Solar Engineering, CRC Press, 3rd Edition (2015).
3. Duffie J. A., Beckman W.A., Solar Engineering of Thermal Processes, John Wiley and Sons, 4th edition (2013).
4. Kalogirou S. A., Solar Energy Engineering: Processes and Systems, Academic Press, 2nd Edition (2013).
5. Lovegrove K., Stein, W., Concentrating Solar Power Technology: Principles, Developments and Applications, Woodhead Publishing (2012).
6. Sukhatme S., Nayak J: Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 3rd edition (2008).
7. Rabl, A. Active solar collectors and their applications. Oxford University Press (1985).

20. Resources required for the course (itemized student access requirements, if any)

1	Software	---
2	Hardware	---
3	Teaching aids (videos, etc.)	---
4	Laboratory	---
5	Equipment	---
6	Classroom infrastructure	---
7	Site visits	---

8	Others (please specify)	---

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	---
2	Open-ended problems	
3	Project-type activity	
4	Open-ended laboratory work	
5	Others (please specify)	

Date: (Signature of the Head of the Department/ Centre / School)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time.

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**			Centre for Energy Studies	
2.	**Course Title**	Renewable Energy Simulation Laboratory			
3.	**L-T-P structure**	0-0-6			
4.	**Credits**	3	**Non-graded Units**	------	
5.	**Course number**	ESP706			
6.	**Course Status** (Course Category for Program)				

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	---
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESR
Open category Elective for all other programs (No if Institute Core)	No

7.	**Pre-requisite(s)**	---

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	----
8.2	Supersedes any existing course		---

9.	**Not allowed for**	

10.	**Frequency of offering** (check one box)	☐Every semester ☐I sem ☐II sem ☒Either semester
11.	**Faculty who will teach the course**	Profs. Ashu Verma, Dibakar Rakshit, K. Ravi Kumar, Kaushik Saha, Sumit Chattopadhyay

12.	**Will the course require any visiting faculty?**	No

13.	**Course objectives** In order to supplement various topics related to energy aspects in class-room lectures, some utility software are needed as a part of curriculum development of energy studies, programmed for better understanding of the subjects. The software gives in detail information on all probable data using science/engineering principles, are so designed so as to provide students enough stimulation for further investigation. This course will introduce various software and associated approach for simulation of different types of energy systems to the systems. These include software such as MATLAB, IDA ICE, ANSYS, eQuest, EnergyPlus, Trnsys, SolTrace, COMSOL, etc. Hence, students would be exposed to the applications as well as limitations of the different software used for the purpose of energy conservation.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Simulation experiments related to Renewable Energy Systems

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours

Total Lecture hours (14 times 'T')		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
1	Thermal Comfort Assessment of a Building using IDA Indoor Climate and Energy (IDA ICE) Software	6
2	Energy Savings Assessment through Energy Efficiency Measures using eQuest Software	6
3	To model a building using DesignBuilder software to be used for simulations	6
4	Assessment of heating and cooling loads on a typical building model using EnergyPlus software	6
5	Energy savings determination through wall insulation for a residential room under local weather conditions using TRNSYS software	6
6	Numerical modelling of heat transfer across building walls using MATLAB	6
7	Heat transfer analysis of insulating material embedded building walls using ANSYS	6
8	Battery Thermal Management System in Electric Vehicles	6
9	Numerical simulation training for modelling of fuel spray using alternative fuel	6

10	Numerical simulation training for modelling internal combustion engine using alternative fuel.	6
11	Study of transients of power system consisting Modular Multilevel Converter based HVDC grid.	6
12	Study of various faults and protection mechanism in Power System having Modular Multilevel Converter based HVDC grid.	6
13	Flux distribution analysis of concentrated solar thermal collectors using SolTrace	6
14	Heat transfer analysis of a receiver tube of parabolic trough solar collector using ANSYS Workbench	6
15	Modeling of thermal energy storage system using COMSOL Multiphysics®	6
16	Performance comparison between the System Advisory Model (SAM) model output and measured performance data of a roof top solar water heating system.	6
Course Total (any 14 experiments will be offered as per student's background)		**96 (84)**

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	**Description**
1-16	Basic MATLAB, ANSYS, COMSOL, IDA ICE, Design Builder, EnergyPlus, eQuest, SAM and Soltrace
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

1. EQUA, "Documentation," 2018. [Online]. Available: http://www.equaonline.com/iceuser/new_documentation.html. [Accessed 10 December 2018].
2. Hirsch J. J., "eQUEST Introductory Tutorial eQUEST Introductory Tutorial, version 3.63," 2009. [Online]. Available: doe2.com/download/equest/eQ-v3-63_Introductory-Tutorial.pdf. [Accessed 20 January 2019].
3. GARD Analytics, Inc. and University of Illinois at Urbana-Champaign under contract to the National Renewable Energy Laboratory, "User Support," [Online]. Available: https://energyplus.net/support. [Accessed 10 December 2018].
4. Palm III W. J., Introduction to MATLAB for Engineers, II edition, McGraw-Hill Education, 2010
5. Solar Energy Laboratory, University of Wisconsin-Madison, "TRNSYS 18 User resources," November 2018. [Online]. Available: http://sel.me.wisc.edu/trnsys/user18-resources/index.html. [Accessed 10 December 2018].
6. Stolarski T., Nakasone Y., Yoshimoto S., Engineering Analysis with ANSYS Software, II edition, Butterworth-Heinemann, 2018
7. "ANSYS FLUENT 12.0 User's Guide." [Online]. Available: http://www.afs.enea.it/project/neptunius/docs/fluent/html/ug/main_pre.htm. [Accessed: 21-Jan-2019].
8. "ANSYS FLUENT Theory Reference Release 5.6." [Online]. Available: http://research.me.udel.edu/lwang/teaching/MEx81/ansys56manual.pdf. [Accessed: 21-Jan-2019].
9. "ANSYS Tutorials." [Online]. Available: https://web.engr.uky.edu/~jbaker/ansystutor.html. [Accessed: 21-Jan-2019].
10. Comsol, "User´s Guide Comsol Multiphysics®," 2012. [Online]. Available: http://people.ee.ethz.ch/~fieldcom/pps-comsol/documents/User%20Guide/COMSOLMultiphysicsUsersGuide.pdf. [Accessed: 24-Jan-2019].

11. Comsol, "Introduction to COMSOL Multiphysics®," 2017. [Online]. Available: https://cdn.comsol.com/documentation/5.3.0.316/IntroductionToCOMSOLMultiphysics.pdf. [Accessed: 24-Jan-2019].
12. For experiments, hand-outs will be provided during the introductory lectures.
13. System Advisory Model (SAM) Available: https://sam.nrel.gov/[Accessed: 24-Jan-2019]

20. Resources required for the course (itemized student access requirements, if any)

1	Software	• IDA Indoor Climate and Energy (IDA ICE) 4.8 • eQuest 3.65 • DesignBuilder Version 5 • EnergyPlus 9.0.1 • MATLAB 9.5 • TRNSYS 18 • ANSYS 19.0 • SolTrace Version 3.0 • COMSOL Multipysics® 5.4 (At least 5 licences of each of the software for 5 different desktop systems)
2	Hardware	Intel(R) Core(TM) i7-4790S CPU @3.20GHz, RAM 8.00GB, 64-bit OS
3	Teaching aids (videos, etc.)	Projector and screen
4	Laboratory	Yes
5	Equipment	----
6	Classroom infrastructure	Yes
7	Site visits	---
8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

1	Design-type problems	----
2	Open-ended problems	----
3	Project-type activity	----
4	Open-ended laboratory work	----
5	Others (please specify)	----

Date: (Signature of the Head of the Centre)

Date of Approval of Template by Senate	

The information on this template is as on the date of its approval, and is likely to evolve with time

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Special Topics on Emerging Trends of Energy & Environmental Technologies		
3.	**L-T-P structure**	1-0-0		
4.	**Credits**	1	**Non-graded Units**	---
5.	**Course number**	ESV891		
6.	**Course Status** (Course Category for Program):			

Institute Core for all UG programs	---
Programme Linked Core for:	---
Departmental Core for:	----
Departmental Elective for:	---
Minor Area / Interdisciplinary Specialization Core for:	---
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	---
Programme Elective for:	ESN, ESR
Open category Elective for all other programs (No if Institute Core)	Yes

7.	**Pre-requisite(s)**	NIL

8.	**Status vis-à-vis other courses**		
8.1	List of courses precluded by taking this course (significant overlap)		**---**
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	---
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	---
8.2	Supersedes any existing course		---

9.	**Not allowed for**	

10.	**Frequency of offering**	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	**Faculty who will teach the course** Personnel from industry and academia and faculty from other departments of IIT Delhi	

12.	**Will the course require any visiting faculty?**	

13.	**Course objectives** This course will cater to specialised topics in area of current interest on emerging topics in the field of energy and environmental technologies

14.	**Course contents**

15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
2		
3		
4		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
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17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description

19. Suggested texts and reference materials

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	----
20.6	Classroom infrastructure	----
20.7	Site visits	----
20.8	Others (please specify)	----

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	----
21.2	Open-ended problems	----
21.3	Project-type activity	----
21.4	Open-ended laboratory work	----
21.5	Others (please specify)	----

Date: (Signature of the Head of the Department/ Centre / School)