M. Tech.

in

Energy & Environment Technologies and Management

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

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CONTENTS

S. No.	Description		Page No.
1.	**PREAMBLE**		v
2.	**PROPOSED PROGRAMME STRUCTURE**		vii
3.	**COURSE TEMPLATES**		1
	PROGRAMME CORE COURSES		
3.1.	ESL711	Fuel Technology	1
3.2.	ESL715	Electrical Energy Management	5
3.3.	ESL727	Energy and Environment	9
3.4.	ESL740	Non-Conventional Sources of Energy	13
3.5.	ESL774	Quantitative Methods for Energy Management and Planning	18
3.6.	ESL776	Industrial Energy and Environment Analysis	22
3.7.	ESL784	Cogeneration and Energy Efficiency	26
3.8.	ESP728	Energy &Environment Laboratory	30
	CUMPULSORY AUDIT COURSES		
3.9.	ESN704	Basic Thermal Engineering	34
3.10.	ESN712	Basic Electrical Engineering	38
	PROGRAMME ELECTIVE COURSES		
3.11.	ESL724	Energy Audit	41
3.12.	ESL733	Organic Waste to Energy Conversion Technology	45
3.13.	ESL735	Hazardous Waste Management	49
3.14.	ESL738	Power System Planning and Operation	53
3.15.	ESL742	Economics and Financing of Renewable Energy Systems	57

3.16.	ESL743	Optimal Design of Energy Systems	61
3.17.	ESL744	Plasmas for Energy and Environment	65
3.18.	ESL745	Environmental Audit and Impact Assessment	69
3.19.	ESL749	Developing Energy Efficiency and Renewable Energy Projects	73
3.20.	ESL752	Carbon Audit and Management	78
3.21.	ESL754	Nanomaterials for Energy Applications	82
3.22.	ESL756	Energy Policy and Planning	87
3.23.	ESL758	Carbon Capture and Storage	91
3.24.	ESL764	Environmental Economics	96
3.25.	ESL766	Environmental Regulations	100
3.26.	ESL771	Instrumentation and Control in Energy Systems	104
3.27.	ESL772	Energy Storage	109
3.28.	ESL773	Battery Storage	113
3.29.	ESL778	Industrial Waste Management and Recycling	117
3.30.	ESL780	Zero Emission Vehicles	121
3.31.	ESL782	Emission Control in Internal Combustion Engines	125
3.32.	ESL796	Operation and Control of Electrical Energy Systems	129
3.33.	ESL797	Operation of Electrical Energy Systems with Large Scale Integration of Renewable Energy Sources	132
3.34.	ESL798	Distributed and Decentralized Energy Systems	136
3.35.	ESL804	Pollution Control in Power Plants	140
3.36.	ESL875	Alternative Fuels for Transportation	144
3.37.	ESV891	Special Topics on Emerging Trends of Energy & Environmental Technologies	148

Courses from other departments

3.38.	CLL723	Hydrogen Energy and Fuel Cell Technology	
3.39.	CLL724	Environmental Engineering and Waste management	

3.40.	CLL725	Air Pollution Control Engineering
3.41.	CLL706	Petroleum Production Engineering
3.42.	CLL794	Petroleum Refinery Engineering
3.43.	CVL820	Environmental Impact Assessment
3.44.	CVL822	Emerging Technologies for Environmental Management
3.45.	CVL823	Thermal Techniques for Waste Management
3.46.	CVL824	Life Cycle Analysis & Design for Environment
3.47.	CVL721	Solid Waste Engineering
3.48.	CVL720	Air Pollution and Control
3.49.	CVL847	Transportation Economics
3.50.	MCL812	Combustion
3.51.	MCL825	Design of Wind Power Farms
3.52.	PYL727	Energy Materials and Devices
3.53.	ELL765	Smart Grid Technology

PREAMBLE

(M.Tech. in Energy & Environment Technologies and Management)

Energy is a basic need of the modern economy as all of its sectors critically depend on energy for growth and even for continued sustenance. Energy is, in fact, an inevitable part of well being, prosperity and the growth of humans. Rapid urbanization and economic growth, improvement in living standards, new demographic trends and constraints due to anthropogenic climate change are key challenges being faced by the emerging economic countries including India. Several factors including the growing demand for energy to fuel economic development, the urgent need to diversify into environmentally sustainable sources of energy supply, ensuring energy security, and climate change considerations have accelerated the need for a comprehensive understanding of all the complex issues involved and also for developing and trying out a variety of energy sector solutions. As indicated earlier, the challenge of sustainable global energy supply is an urgent one primarily due to population growth, improvement in standard of living, gradual depletion of fossil fuel reserves and climate change. Finite fossil energy supply, growing population and energy demand and the risk of anthropogenic climate change pose the important challenge of providing sufficient energy for everyone in a sustainable manner. The country must strive to meet its increasing demand in a sustainable manner without any concerns for energy security and volatility of fuel prices in future. Thus, it is imperative for all countries, emerging economies in particular, to ensure security of energy supply while maintaining competitiveness and proactively striving towards a transition to low carbon energy supply. These and other challenges call for an all-out effort towards human resource development in the country at all levels.

With global population heading towards 10 billion, ensuring that there is sufficient energy for everyone is likely to be the greatest challenge for humanity. It is even greater than the food and water related challenges as availability of sufficient sustainable energy supply would be necessary to solve the food and water related challenges. Global energy consumption is expected to increase by over 50% by 2040 mostly due to increased demand from emerging nations such as China and India. In fact, in recent years, there has been a significant shift in the dynamics of energy consumption in the Non-OECD countries (especially China and India) on the path of rapid growth in their energy consumption.

In order to contribute towards solving the challenges in preparing competent manpower in the field of energy, it is necessary that the same be reduced to their essentials by going deeply into the core of each problem to understand the same holistically and then focusing on the specific elements necessary for arriving at the solution(s). This would also require a clear comprehension of relative importance of each of the facets of the challenge and to be able to explicitly delineate and prioritize the action points.

Increasing accumulation of greenhouse gases in the atmosphere represents quite a serious threat for the sustainability of life on earth. Moreover, the extraction, conversion, storage, transport, and utilization of energy carriers also have adverse impacts at micro level. Though several mitigation measures have been proposed and implemented, the efforts in this direction should accelerate and become stronger in the next decade. A comprehensive understanding of all environmental emissions from energy sector and also of technological and policy/regulatory matters are necessary to decide and implement appropriate combinations of energy resources and technologies.

It is, therefore, critically important that each energy strategy must be tuned with the corresponding strategy for environmental emissions co-produced within the strategy

primarily due to their rather close interdependence. Thus, on capacity building front in the country, at the postgraduate level, there is a need for a programme at M. Tech. level that provides:

i. Holistic approach of global energy demand, supply and security challenges.
ii. Knowledge and understanding of environmental aspects of various energy supply options with discussion on the entire chain of each path of energy demand satisfaction, impact on local and global environments.
iii. In depth treatment of technological solutions towards mitigating environmental emissions from the energy sector.
iv. Engineering solution to the industries those are functioning using energy and environment technologies.
v. Exposure to various facets of energy management.
vi. Exposure to policy, regulatory and other measures to facilitate development and deployment of effective and efficient interventions in the energy sector to ensure sustainable and affordable energy supply in future.
vii. Training in communicating problems and issues pertaining to energy sector and its environmental and climate change related effects besides developing capability to develop innovative and creative solutions to energy sector driven environmental problems through team work and projects

As a modest attempt towards the above-mentioned requirements, the proposed M. Tech. programme is designed to provide deeper understanding of the interrelationships between energy sector and environmental challenges being faced by the mankind. The proposed programme is aimed at refining and strengthening academic competence in a variety of interdisciplinary backgrounds and provides an applied focus for postgraduates with a strong professional and industrial orientation. The programme aims to equip students with the necessary knowledge and skills to contribute towards energy and environment management strategies that can be implemented at different levels depending on the importance of energy (and associated environmental emissions) in comparison with other factors of production. The proposed M. Tech. programme is directed at students interested in acquisition of knowledge and skills with in depth understanding of environmental aspects of all energy supply options, as well as corresponding technological developments for achieving efficient and effective energy management and mitigation of environmental emissions. Several courses under the category of programme Electives have been included in the proposed M. Tech. programme to provide knowledge and skills for managing adverse environmental impacts of the energy sector (including those offered by other academic units of the Institute). The students are also expected to gain ability to develop and implement strategies to address important issues in energy regulation and policy. In addition, the students will be able to critically evaluate management options in carbon reduction from the energy sector and also the corresponding policies.

The M. Tech. programme is targeted on students with bachelor degree in engineering (mechanical, electrical, chemical, energy and other relevant branches) or Master's degree in Physics and Chemistry with a strong interest in energy industry and its environmental dimensions. Both public and private sector organizations require manpower with knowledge and skills about environmental implications of energy sector activities so as to help take and implement decisions towards minimizing cost of energy demand satisfaction and also to reduce carbon footprint of the same. The likely professional profiles of these students on successful completion of the programme include Energy & Environment Technocrat, Energy & Environment Engineer, Energy Manager, and Energy Efficiency Consultant.

PROPOSED PROGRAMME STRUCTURE

Programme Code**: ESN**

Master of Technology in Energy & Environment Technologies and Management

Interdisciplinary Programme

The overall credits structure

Category	PC	PE	OE	Total
Credits	30	18	06	54

Programme Core (PC): ESN					Programme Electives (PE)/Open Electives (OE): ESN			
ESL711	Fuel Technology	3-0-0	3		ESL773	Battery Storage	3-0-0	3
ESL715	Electrical Energy Management	3-0-0	3		ESL778	Industrial Waste Management and Recycling	3-0-0	3
ESL727	Energy and Environment	3-0-0	3		ESL780	Zero Emission Vehicles	3-0-0	3
ESL740	Non-conventional Sources of Energy	3-0-0	3		ESL782	Emission Control in Internal Combustion Engines	3-0-0	3
ESL774	Quantitative Methods for Energy Management and Planning	3-0-0	3		ESL796	Operation and Control of Electrical Energy Systems	3-0-0	3
ESL776	Industrial Energy and Environment Analysis	3-0-0	3		ESL797	Operation of Electrical Energy Systems with Large Scale Integration of Renewable Energy Sources.	3-0-2	4
ESL784	Cogeneration and Energy Efficiency	3-0-0	3		ESL798	Distributed and Decentralized Energy Systems	3-0-0	3
ESP728	Energy &Environment Laboratory	0-0-6	3		ESL804	Pollution Control in Power Plants	3-0-0	3
JTD801	Major Project Part – 1 (ESN)	0-0-12	6		ESL875	Alternative Fuels for Transportation	3-0-0	3
	Total PC		***30***		ESV891	Special Topics on Emerging Trends in Energy and Environmental Technologies	1-0-0	1
Compulsory Audit Courses (CA): ESN					JTD799	Minor Project (ESN)	0-0-6	3
ESN704	Basic Thermal Engineering	1-0-0	0		JTD802	Major Project Part – 2 (ESN)	0-0-24	12
ESN712	Basic Electrical Engineering	1-0-0	0		JTS801	Independent Study (ESN)	0-3-0	3
Programme Electives (PE)/Open Electives (OE): ESN								
ESL724	Energy Audit	3-0-0	3			**Programme Electives (other Departments)**		
ESL733	Organic Waste to Energy Conversion Technology	3-0-0	3		CLL723	Hydrogen energy and fuel cell technology	3-0-0	3
ESL735	Hazardous Waste Management	3-0-0	3		CLL724	Environmental Engineering and Waste management	3-0-0	3
ESL738	Power System Planning and Operation	3-0-0	3		CLL725	Air Pollution Control Engineering	3-0-0	3
ESL742	Economics and Financing of Renewable Energy Systems	3-0-0	3		CLL706	Petroleum Production Engineering	3-0-0	3
ESL743	Optimal Design of Energy Systems	3-0-0	3		CLL794	Petroleum Refinery Engineering	3-0-0	3
ESL744	Plasmas for Energy and Environment	3-0-0	3		CVL820	Environmental Impact Assessment	3-0-0	3
ESL745	Environmental Audit and Impact Assessment	3-0-0	3		CVL822	Emerging Technologies for Environmental Management	3-0-0	3
ESL749	Developing Energy Efficiency and Renewable Energy Projects	3-0-0	3		CVL823	Thermal Techniques for Waste Mgmt.	3-0-0	3
ESL752	Carbon Audit and Management	3-0-0	3		CVL824	Life Cycle Analysis & Design for Environment	3-0-0	3
ESL754	Nanomaterials for Energy Applications	3-0-0	3		CVL721	Solid Waste Engineering	3-0-0	3
ESL756	Energy Policy and Planning	3-0-0	3		CVL720	Air Pollution and control	3-0-0	3
ESL758	Carbon Capture and Storage	3-0-0	3		CVL847	Transportation Economics	3-0-0	3
ESL764	Environmental Economics	3-0-0	3		ELL765	Smart Grid Technology	3-0-0	3
ESL766	Environmental Regulations	3-0-0	3		MCL812	Combustion	3-0-0	3
ESL771	Instrumentation and Control in Energy Systems	3-0-0	3		MCL825	Design of Wind Power Farms	3-0-0	3
ESL772	Energy Storage	3-0-0	3		PYL727	Energy Materials and Devices	3-0-0	3

Proposed Semester wise Course Distribution: ESN

SEMESTER	Courses (Number, abbreviated title, L-T-P, Credits)						Lecture Courses	Contact h/week				Credits
								L	T	P	Total	
I	**ESL740** Non-Conventional Sources of Energy (3-0-0) 3	**ESL711** Fuel Technology (3-0-0) 3	**ESL715** Electrical Energy Management Systems (3-0-0) 3	**ESL727** Energy and Environment (3-0-0) 3	**PE-1** (3-0-0) 3	**ESN704** Basic Thermal Engineering / **ESN712** Basic Electrical Engineering (1-0-0) 0	6	16	0	0	16	**15**
II	**ESL776** Industrial Energy and Environment Analysis (3-0-0) 3	**ESL784** Cogeneration and Energy Efficiency (3-0-0) 3	**ESP728** Environment Laboratory (0-0-6) 3	**ESL774** Quantitative Methods for Energy Management and Planning (3-0-0) 3	**PE-2** (3-0-0) 3		4	12	0	6	18	**15**
SUMMER	JTD801 Major Project Part-1 (ESN) (0-0-12) 6											
III	**JTD801** Major Project Part-1 (ESN) (0-0-12) 6	**OE-1** (3-0-0)3	**OE-2** (3-0-0)3				2	6	0	12	18	**12**
IV	**JTD802**Major Project Part-2 (ESN) (0-0-24) 12						0	0	0	24	24	**12**
	PE-3 (3-0-0)3	**PE-4** (3-0-0)3	**PE-5** (3-0-0)3	**PE-6** (3-0-0)3			4	12	0	0	12	
												Total 54

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COURSE TEMPLATES

PROGRAMME CORE COURSES

1.	**Department/Centre/School proposing the course**	Centre for Energy Studies		
2.	**Course Title**	Fuel Technology		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL 711		
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, ESN
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**	----

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

11.	**Faculty who will teach the course** Prof. D. K. Sharma, Prof. M. G. Dastidar, Prof. K. A Subramanian, Prof. Kaushik Saha

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

13.	**Course objectives** The course will provide knowledge and understanding of various solid, liquid and gaseous fuels which are conventional energy sources in use today for meeting the primary needs. The course also aims at making the students aware of various techniques for inter-conversion of fuels as well as holistic exposure to the issues related to clean fuels for guarding the environment.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Solid, liquid and gaseous fuels, Coal as a source of energy and chemicals in India, Coal preparation and refining, Carbonization, Gasification and liquefaction of coal and lignite, Principle of combustion, Petroleum and its derived products, Testing of liquid fuels, Petroleum refining processes, Inter-conversion of fuels, Natural gases and its derivatives, sources, classes, potential, Gas hydrates, Combustion appliances for solid, liquid and gaseous fuels, Introduction to nuclear fuels, RDF, Bio-fuels, etc.

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

Module no.	Topic	No. of hours
1	Principles of Combustion	2
2	Solid, liquid and gaseous fuels	4
3	Coal as a Source of Energy and Chemicals in India	3
4	Coal Preparation	5
5	Carbonization	2
6	Gasification	3
7	Liquefaction of coal and lignite	4
8	Petroleum, properties and its derived products	4
9	Inter-conversion of fuels	3
10	Gaseous fuels including natural gas and uses	3

11	Combustion of solid, liquid and gaseous fuels	5
12	Types of combustion	2
13	Introductionto nuclear fuels	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	Liquefaction & Gasification of coal & lignite
9	Inter-conversion of fuels
11	Kinetics of combustion
(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. Mal I.D., Petrolium Refining technolgy, CBS Publishers and distributors, 2015.
2. Indra D.M., Petrolium Refining technolgy, CBS Publishers and distributors, 2015.
3. Speight J. G., Chemistry and Technology of Coal, CRC Press, 2012.
4. Speight J. G., Chemistry and Technology of Petroleum, CRC Press, 2012.
5. Sarkar S., Fuels and Combustion, Orient Longman, 2009.
6. Peter F., Fuels and Fuel Technology, Wheatan& Co. Ltd., 2002.

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**	Electrical Energy Management		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL715		
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
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	ESL 796 (< 10 %)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	EEL 896 (<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. A. Verma, Prof. T. S. Bhatti, Prof. Sumit Chattopadhyay

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

13.	**Course objectives** The course will enable the students • Understand the importance of electrical energy management, energy auditing and energy conservation. • Methods to improve electrical energy efficiency in Industrial/commercial/domestic sectors. • Use of micro grids and decentralized power, advantages and operational aspects/challenges in energy management

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Importance of energy management, Electrical energy auditing methods, demand control, load scheduling/shifting, Energy management centres and their functions, Economic operation of power system, Unit commitment, Supervisory control and scada systems, Optimal resource management in micro grid/decentralized environment, Power factor improvement, Energy efficient motors, Pumps, Variable frequency drives, Energy efficient lighting, Energy conservation in various electrical devices.

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

Module no.	Topic	No. of hours
1	Introduction to energy management, energy auditing methods	04
2	Demand control, demand shifting	03
3	Operation of interconnected and restructured power system	04
4	Energy management centers and their functions	02
5	Economic operation of power system	05
6	Unit Commitment	05
7	Supervisory control and SCADA systems	02
8	optimal resource management in micro grid/decentralized environment	04
9	Power factor improvement	03
10	Energy efficient motor, pumps, Variable frequency drives	04
11	Energy efficient lighting	03

12	Energy conservation in electrical devices	03
	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
3	Steady state modelling of various power system components, p.u. system, deregulation in power system
4,5 & 6	Various types of generating systems, their cost characteristics, gestation period, operational constraints, power flow analysis
7	KKT conditions, basics of optimization techniques
8	Resource characteristics of various renewable energy sources
9&10	Calculations of active, reactive power, motor efficiency, capability chart of synchronous generator
(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. Green J. N., Wilson R., Control and Automation of Electric Power Distribution Systems, Taylor and Francis, 2007.
2. Wood A. J., Wollenberg B. F., Power Generation Operation and Control, 2nd Edition John Wiley and Sons, 2003.

3. Handschin I.E., Petroianu I.A., Energy Management (Operation & Control of Electric Energy Transmission Systems), Springer Verlag, 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	PC LAB for running the software
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	25%
21.4	Open-ended laboratory work	25%
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**	Energy and Environment		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	----
5.	**Course number**	ESL727		
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
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	ESL 710 (≤ 50%) ESL330 (≤ 40%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	CLL725 (≤ 15%) CLL212 (≤ 10%) CVL483 (≤ 5%)
8.2	Supersedes any existing course		---

9.	**Not allowed for**	Students who have passed ESL710, ESL330

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

11.	**Faculty who will teach the course** Prof. M. G. Dastidar, Prof. K. A. Subramanian, Prof. R. Narayanan, Prof. R. Uma, Prof. S. Kar, Prof. D. Sahu, Prof. K. Ravi Kumar

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

13.	**Course objectives** The student will be able to identify • the detrimental effects of energy utilization on environment • the burning environmental issues

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction (Basic definitions, link with ecology, resource classifications), Energy Transfer and Nutrient cycling, Environmental Impact of conventional resources, Alternate mitigation aspects using non-conventional resources, air pollution, water pollution, soil pollution, thermal pollution, e-waste pollution, radioactive degradation, global effects and climate change.

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

Module no.	Topic	No. of hours
1	Introduction a) Basic definitions b) link with ecology c) resource classifications	3
2	Energy Transfer and Nutrient cycling	3
3	Environmental Impact of conventional resources	3
4	Alternate mitigation aspects using non-conventional resources	3
5	Air Pollution	
	a) Mobile and Stationary sources	1
	a) Impact of criteria pollutants	1
	b) Temperature inversions	2
	c) Plume models	2
6	Water (surface, ground and marine) Pollution	
	a) Water quality, treatment, use and disposal	3
	b) Biochemical oxygen demand(BOD)	3
7	a) Thermal pollution	2
	b) Radioactive waste	2
	c) e-waste pollution	2
8	Soil pollution	
	a) Types of source pollutants	2
	b) its causes and effects	2
	c) remedial solutions	2
9	Global effects and climate change	
	a) Greenhouse gases	2

	b) Ozone depletion concepts	2
	c) Effects on oceans	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
1-9	Basic radioactive decay concepts (Radioactivity Law, alpha-,beta- and gamma-rays)
1-9	Basic concepts of Heat transfer (Conduction, Convection and Radiation Laws)
3-4	General Knowledge of different energy sources (conventional and unconventional)
5-9	Basic Chemistry (Classification of Organic and Inorganic Compounds, Concept of pH, ppm and ppb)
(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. Kok K. D., Nuclear Engineering Handbook, 2nd Edition, CRC Press, 2017.
2. Behari J., Sustainability, Green Energy and Climate Change: Revisited, Capital Publishing Company, 2016.
3. Gilbert M. M., Wendell P. E., Introduction Environmental Engineering and Science, Prentice Hall of India, 2008.
4. Nag P. K., Power Plant Engineering, Tata McGraw Hill, 2001.

5. Sarkar S., Fuel and Combustion, Orient Longman Limited, 2001.
6. Rao C. S., Environmental Pollution Control Engineering, Wiley Eastern Ltd., 1991.
7. Etherington H., Nuclear engineering handbook, McGraw Hill, 1958.

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**	Non-Conventional Sources of Energy		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL740		
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, ESN
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	ESL340 (≤50%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	MCL241 (≤20%) PYL350 (≤15%) RDL722 (≤15%)
8.2	Supersedes any existing course		---
9.	**Not allowed for**	Students who have passed ESL340	

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

11.	**Faculty who will teach the course** Prof. K. A. Subramanian, Prof. R. Narayanan, Prof. V. K. Komarala, Prof. V. Dutta, Prof. V. Kumar, Prof. S. Karak, Prof. D. Rakshit, Prof. K. Ravi Kumar

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

13.	**Course objectives** The course will provide the students an • Understanding of the various non-conventional energy resources and technologies. • Estimation of the potential power based on the resources.

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, Efficiency of solar thermal and PV systems, Biomass: generation, Characterization, Biogas: aerobic and anaerobic bio-conversion processes, Mini/micro hydro power: classification of hydropower schemes, classification of water turbine, Turbine theory, Essential components of hydroelectric system, system efficiency, Fusion: Basic concepts, fusion reaction physics, Thermonuclear fusion reaction criteria, Confinement schemes, Inertial and magnetic confinement fusion, current status; Wind Energy: Origins, Basic principles of aerodynamics, Measurement and distribution, Power extraction; Geothermal, Tidal, Wave, and Ocean Thermal Energy sources.

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

Module no.	Topic	No. of hours
1	Solar Energy: a) Introduction b) Solar energy basics c) Solar thermal systems	5
2	Solar heating/ cooling of buildings	3
3	Solar thermal power generation, Solar Photovoltaic	5
4	Biomass and Biofuels: a) Generation b) Characterization and Conversion processes	3
5	Tidal energy a) Cause and enhancement of tides a) Flow and range power	3
6	Wave energy a) Wave motion and patterns b) Power extraction	2
7	Wind Energy: a) Origins	5

	b) Measurement and distribution c) Basic principles of aerodynamics d) Power extraction e) Technological and economical aspects	
8	Fusion:	
	a) Introduction	1
	b) Basic concepts	1
	c) Fusion reaction physics	1
	d) Thermonuclear reaction criterion	1
	e) Confinement schemes	1
	f) Inertial confinement fusion (ICF)	1
	g) Magnetic confinement fusion (MCF)	1
9	Mini/micro hydro power: a) Classification of hydropower schemes b) Essential components of hydroelectric system c) Hydro-turbines d) Classification of water turbine e) Constraints of hydropower systems	5
10	Geothermal: a) Geothermal regions and Types of geothermal resources b) Analysis of geothermal resources and geothermal energy conversion technologies.	3
11	OTEC	1
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	Electronic states in semiconductors, Impurities and doping, Semiconductor under equilibrium and bias, Drift and Diffusion

2, 10, 11	Basic concepts of conduction, convection and radiation heat transfer
3,4	Characteristics of organic and inorganic compounds
5,6, 7, 9	Bernoulli's equation, viscosity, turbulence and friction in fluid flows
8	Plasma, single particle motion in uniform electric and magnetic fields, drifts
(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., Weir T., Renewable Energy Resources, Taylor and Francis, 3rd edition, 2015.
2. Duffie J. A., Beckman W.A., Solar Engineering of Thermal Processes, John Wiley and Sons, 4th edition, 2013.
3. Boyle G., Renewable Energy: Power for a Sustainable Future, Oxford University Press, 3rd edition, 2012.
4. Weston M. S., Fusion-An Introduction to the Physics and Technology of Magnetic Confinement Fusion, 2nd edition, Wiley-VCH Publications, 2010.
5. Chen F. F., Introduction to Plasma Physics and Controlled Fusion: Volume 1: Plasma Physics, Springer, 2nd edition, 2006.
6. Nelson J., Physics of Solar Cells, World Scientific, 2003.
7. Gross R. A., Fusion Energy, John Wiley and Sons, 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**	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, 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	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** Prof. A. Ganguli, Prof. R. Narayanan, Prof.D. Rakshit, Prof. A. Verma, Prof. K. Ravi Kumar, Prof. D. Sahu, Prof. 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**

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
	------	------
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)

20.1	Software	TORA
20.2	Hardware	----
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	----
20.5	Equipment	Computer for solving problems in TORA
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**	Industrial Energy and Environment Analysis		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL776		
6.	**Course Status** (Course Category for Program):			

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:	Cogeneration and Energy Efficiency
Programme Core for:	ESN
Programme Elective for:	JEN
Open category Elective for all other programs (No if InstituteCore)	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** Prof. D. K. Sharma, Prof. M. G. Dastidar, Prof. K. A. Subramanian, Prof. R. Uma, Prof. T. C. Kandpal, Prof. D. Rakshit

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

13.	**Course objectives** To introduce basic techniques for energy and environmental analysis of industrial processes, further, to take a holistic exposure of the practical issues and challenges involved relevant case studies will be undertaken and analyzed. The course will also dwell upon various approaches towards appropriate utilization of energy as well as the emissions from the industrial sectors that are detrimental for the environment.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Industrial energy use and its disaggregation (in terms of production dependent, weather dependent and independent etc. components), Energy intensity, Pinch analysis, Lean energy analysis, Thermodynamics and energy analysis, Life cycle energy analysis, Energy analysis and energy management, Energy audits, Managing energy efficiency in the industry. Basic approaches and tools for environment analysis, life cycle analysis and environmental impact assessment of industrial products and processes, Inventory of materials and energy inputs and environmental emissions, Emission factors, Relevant ISO standards (such as ISO 14040 and ISO 14044), Potential of energy and materials recovery, Case studies.

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

Module no.	Topic	No. of hours
1	Industrial energy use and its disaggregation (in terms of production dependent, Weather dependent and independent etc. components), Energy intensity.	2
2	Pinch analysis, Lean energy analysis	5
3	Thermodynamics and energy analysis	3
4	Life cycle energy analysis, Energy analysis and energy management	5
5	a) Energy audits, Quantifying non-productive energy use	2
	b) Identifying opportunities for improving energy efficiency in industrial energy systems (involving electric motors, pumps, compressed air, ventilation, space heating and cooling, lighting, water heating etc.)	4

6	Estimating energy efficiency potential, Managing energy efficiency in the industry, Policies for promoting energy efficiency in the industrial sector, Barriers to energy efficiency	5
7	Basic approaches and tools for environment analysis: (life cycle analysis and environmental impact assessment of industrial products and processes)	5
8	Life cycle analysis (life cycle inventory, life cycle costing) and environmental impact assessment of industrial products and processes	4
9	Inventory of materials and energy inputs and environmental emissions,	3
10	Relevant ISO standards (ISO 14040,ISO 14044 etc.)	2
11	Potential of energy and materials recovery, 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	Combustion of fuels and pollution caused by it.
3	Basics of thermodynamics.
7-9	Policies for promote energy efficiency and encouraging life cycle analysis based decision.

11	ISO standards on environmental analysis.
(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. Blok K., Nieuwlaar E., Introduction to Energy Analysis, 2nd Edition, Routledge, 2017.
2. Kreith F., Goswami D.Y., Energy Management and Conservation Handbook, 2ndEdition, CRC Press, 2016.
3. Socolow R., Andrews C., Berkhout F., Thomas V., Industrial Ecology and Global Change, Cambridge University Press, 2010.
4. Sincero A.P., Sincero G.A., Environmental Engineering, Prentice Hall, 2007.
5. Barrow C. J., Developing the Environment, Longman Scientific and Technical, 1995.
6. Paul O. C., Energy Management, McGraw Hill Book Company, 1993.
7. Bousted I. and Hancock G.F., Handbook of Industrial Energy Analysis, Ellis Horwood 1979.
8. Thomas A.G., Energy Analysis, IPC Science and Technology Press Ltd. 1977.

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 theCentre)

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Cogeneration and Energy Efficiency		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL784		
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:	Cogeneration and Energy Efficiency
Minor Area / Interdisciplinary Specialization Elective for:	---
Programme Core for:	ESN
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	ESL 714 (≤ 10%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	MCL811 (≤ 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** Prof. K. A. Subramanian, Prof. D. Rakshit, Prof. T. C. Kandpal, Prof. S. C. Kaushik, Prof. K. Ravi Kumar

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

13.	**Course objectives** The students will be able to understand the importance of cogeneration in improving the overall efficiency and emission reduction in thermal power plants. The course will impart knowledge of practical cogeneration possibilities through case studies in process and other industries.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): The cogeneration concept, Main design parameters for cogeneration, Cogeneration alternatives, cogeneration efficiency, Steam turbine plants, Gas turbine plants, Spark ignition engine and compression ignition engine power plant, Combined cycle power plant, Sterling engine, Industry/Utility cogeneration, Tri-generation, polygeneration, Cogeneration in sugar, textile, paper and steel industry, Case studies.

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

Module no.	Topic	No. of hours
1	Cogeneration concept, Basics of Energy efficiency improvement in heat engines	3
2	Design parameters for cogeneration, Concept of tri-generation and polygeneration	3
3	Cogeneration alternatives	3
4	Steam turbine plants	
	(a) Introduction	1
	(b) Boiler, Turbine, Condenser, Economizer, Super heater	3
	(c) Reheating, Methods to improve power output and efficiency	4
5	Gas turbine plants	
	(a) Introduction	1
	(b) Compressor, Combustors, Turbine, Closed and Open type gas turbine system	3
	(c) NOx emission reduction techniques, Sequential combustion in multi combustors	4
6	Spark Ignition engines and compression ignition power plants:	
	(a) Introduction	1
	(b) Indicated power, Brake power	2
	(c) Supercharger, Turbocharger, Exhaust Recirculation,	3

	(d) Back pressure in exhaust system	2
7	Combined cycle power plants: combined Gas turbine and steam turbine power plants, internal combustion engines and sterling engine	3
8	(a) General application of cogeneration in industries	2
	(b) Cogeneration in sugar, textile, paper and steel industry	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	Basic thermodynamic cycles
3	Analysis of cogeneration systems using first and second laws of thermodynamics
4	Thermo-physical properties of steam, air and flue gases
(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. Gupta M. K., Power Plant Engineering, Prentice Hall India, 2012.
2. Kolanowski B. F., Small-Scale Cogeneration Handbook, 4th Edition, TheFairmont Press, 2011.
3. Meherwan P., Boyce, Handbook for Cogeneration and Combined Cycle PowerPlants, Second Edition, ASME, 2010.
4. Nag P. K., Power Plant Engineering, Tata McGraw-Hill Education, 2002.

5. EI-WakilM. M., Power Plant Technology, McGraw Hill, 2001.
6. PolimerosG., Energy Cogeneration Hand Book for Central Plant Design, Industrial Press Inc., 1981.

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**	Energy & Environment Laboratory		
3.	**L-T-P structure**	0-0-6		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESP728		
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
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** This laboratory course being an interdisciplinary course in energy and environment would deal with students across different academic background. The main focus of this laboratory would therefore be to make students aware of the various energy saving measures in different areas of energy utilization. Besides these the message of environmental sustainability is also conveyed through these laboratories. This awareness would help the students to make significant innovative contributions to environmental related issues. This will in turn give them a holistic idea of improving technologies through innovation and thus cater to the development of an energy efficient society by addressing global issues. Some of the experiments also include case studies and simulations in addition to the practical component.

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. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
1	Introduction of experiments by concerned faculty.	6
2	Determination of Combustion Efficiency of cook stoves.	6
3	Proximate and ultimate analysis of a solid fuel.	6
4	Determination of calorific value of solid fuel.	6
5	Evaluation of COP for earth air heat exchanger.	6
6	Electron density and temperature measurement of Argon/ Nitrogen plasma using Langmuir probe.	6
7	Measurement of Solar Radiation on horizontal and tilted surface and comparison with estimated values.	6
8	Measurement of pollutants due to combustion process.	6
9	Experimental study on effects of biodiesel fuel on performance and emissions characteristics of a compression ignition engine.	6
10	Experimental study on effects of alcohol fuels (methanol / ethanol / butanol) on performance and emissions characteristics of a spark ignition engine.	6
11	Experimental study of emissions characteristics of hydrogen fuelled spark ignition engine.	6
12	Utilization of waste biomass for waste water treatment.	6
13	Paschen Curve of a planar DC discharge.	6
14	Carbon, hydrogen analysis for solid fuels (Demonstration).	6
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. Kothari D. P., Sharma D. K., Energy Engineering: Theory and Practice, S. Chand Publisher, 2000.
2. Garg H. P., Kandpal T. C., Laboratory Manual on Solar Thermal Experiments, Narosa Publishing, 1999.
3. Plasma Lab (Experiments 6 and 13) will provide hand-outs during the introductory lectures.

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

20.1	Software	Transys, MATLAB, DDA
20.2	Hardware	Required as appropriate in experiments
20.3	Teaching aids (videos, etc.)	----
20.4	Laboratory	All CES Laboratories
20.5	Equipment	Required as appropriate in experiments
20.6	Classroom infrastructure	----
20.7	Site visits	PV Substation
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)

CUMPULSORY AUDIT COURSES

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		
4.	**Credits**	0	**Non-graded Units**	---
5.	**Course number**	ESN704 **(a course offered under the basket of Compulsory Audit for non-Mechanical Engineers)**		
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**	Nil

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

11.	**Faculty who will teach the course** Prof. Dibakar Rakshit, Prof. Ravi Kumar, Prof. S. K. Tyagi, Prof. 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. Michael A. Boles and Yungus A. Cengel, Thermodynamics: An Engineering Approach, McGraw-Hill Education, 2014.
2. Frank P. Incropera, David p. Dewitt, Theodore l. Bergman, Adrienne S. Lavine, Fundamentals of heat and mass transfer, John Wiley & Sons, 2005.
3. Frank. M White, Fluid mechanics, McGraw-Hill Education, 2011.

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**	Basic Electrical Engineering			
3.	**L-T-P structure**	1-0-0			
4.	**Credits**	0	**Non-graded Units**	---	
5.	**Course number**	ESN712 **(a course offered under the basket of Compulsory Audit for non-Electrical Engineers)**			
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**	Nil

10.	**Frequency of offering**	☒ Every semester ☐ I sem ☐ II sem ☐ Either semester
11.	**Faculty who will teach the course** Prof. Ashu Verma, Prof. T.S Bhatti, Prof. 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 Del Toro, Principles of Electrical Engineering, EEE.

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)

PROGRAMME ELECTIVE COURSES

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Energy Audit		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	----
5.	**Course number**	ESL724		
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
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** Prof. D. Rakshit, Prof. K. Ravi Kumar, Prof. T. C. Kandpal, Prof. K. A. Subramanian	

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

13.	**Course objectives:** The primary aim of the course is to provide in-depth and directly relevant energy concepts, technologies and methods to the students to carry out successful energy audits, identify energy conservation opportunities and to implement the same. On successful completion of the course the students will be able to identify the potential sub-energy systems for further optimization of specific electrical and thermal energy consumption, and energy intensity with comparison to national and international benchmark, improvement of energy conservation or energy saving measures, perform quantitative analysis to estimate the energy savings expected as well as the economic and environmental benefits likely to accrue and measure and verify the performance of the energy saving measures upon implementation.

14.	**Course contents:** Need for energy audit; Energy Conservation Act 2001 and other legislative frameworks; Types of energy audit; energy accounting and analysis; Instrumentation and measurement techniques for energy audit; Energy audit of buildings; HVAC audit; Energy audit of lighting and other electrical systems, motors, lifts, pumps, fans, and blowers; Energy audit of diesel or gas or alternative fuel based captive power generation systems; Energy audit for gas turbine power plant, Energy auditing of boilers, steam distribution systems, furnaces, stoves and burners, compressed air networks, heat exchangers, cooling towers etc.; Identification and assessment of energy saving opportunities; Preparing energy audit reports.

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

Module no.	Topic	No. of hours
1	Introduction to energy audit, Requirement of energy audit, Energy Conservation Act 2001 and other legislative frameworks, Importance of energy efficiency act "Performance, Achieve and Trade (PAT)"	2
2	Types of energy audit – Preliminary energy audit, Detailed energy audit, Questionnaire for preliminary data collection	2
3	Energy accounting and analysis – Sankey diagram, load profiles	3
4	Performance measurement and verification protocols, Instrumentation for energy audit – Combustion analyzers, lux meters, leak detectors, speed meters, fluid flow measuring equipment, temperature measuring sensors and meters, pressure measuring equipment, instruments to	5

	measure frequency, current, voltage, power and power factor etc.	
5	Energy audit of buildings – energy efficiency in electrical and thermal systems in the buildings, HVAC audit, lighting audit and alternative options for lighting, Energy consumption measurement of lifts and escalators.	5
6	Energy efficiency of electrical distribution systems, Procedures of measuring and improving power quality.	3
7	(a) Energy auditing of diesel, natural gas and alternative fueled internal combustion engine generator system,	2
	(b) Specific fuel and energy consumption with respect to load change, heat balance diagram, thermal efficiency and specific emissions.	3
	(c) Energy auditing of gas turbine power plants: compressor, combustor and turbine, heat rate, supplementary firing, heat recovery system and combined cycle power plant.	2
8	(a) Energy auditing of boilers, steam distribution systems,	2
	(b) Furnaces, stoves and burners, compressed air networks	3
	(c) Heat exchangers, cooling towers etc.	2
9	Identification of energy management opportunities based on an energy audit, Calculation of energy and monetary savings due to implementation of the findings of an energy audit, Estimation of life cycle carbon emissions mitigation.	5
10	Assessment and evaluation of implementation potential of the finding of an energy audit, Follow up activities, Preparation of an energy audit report.	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
1	Energy Conservation Act 2001
2	Walk through inspection for energy audit
4	Error and uncertainty analysis in measurements
5	Illumination, energy consumption and other characteristics of incandescent lamps, fluorescent tubes, compact fluorescent lamps, LED lamps
(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. Thumann A., Niehus T., Younger W. J., Handbook of Energy Audits, 9th Edition, Fairmont Press (2012).
2. Turner W. C., Energy Management Handbook, Seventh Edition, Fairmont Press, (2007).
3. Abbi Y. P., Shashank J., Handbook on Energy Audit and Environment Management, TERI Press (2006).
4. www.beeindia.gov.in

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**	Organic Waste to Energy Conversion Technology		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL733		
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
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	CVL723 (≤ 5%)
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**	Prof.Dibakar Rakshit, Prof.K.Ravi Kumar, Prof. K. A Subramanian, Prof. Kaushik Saha

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

13.	**Course objectives** This course will provide the knowledge to students for understanding of various technologies which can convert organic waste to energy / electrical power. As the waste from industrial and other sectors leads to severe problem of air / water / soil pollution, waste disposal and environment, this course would be useful to the students who can understand and develop appropriate technologies to address these problems to attain the sustainable energy and environment system.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Different sources of organic and synthetic waste from residential sectors, Commercial sectors, municipal sectors, Industrial sectors, and agriculture and forest residues, Estimation of energy potential of organic waste from these sectors, GHG emission reduction potential with waste, material efficiency, Concept of zero effluent based eco-industrial park, Lifecycle assessment (LCA) and its application to sustainable waste management, Classification of the organic wastes based on incinerable, Land fillable and recyclable, Various technologies for segregation of organic matter from the waste, Physico-chemical properties of the organic matter, Various technologies for conversion from the organic waste to energy: Thermo-chemical conversion (incineration, combustion, gasification / plasma gasification, pyrolysis / plasma pyrolysis, and esterification), Bio-chemical conversion (anaerobic digestion, dark fermentation, microbial system). Conversion of energy/fuels derived from waste to electrical power: steam turbine power plant, Internal combustion engines, Microbial fuel cell, Solid oxide fuel cell, Technologies for emission reduction for waste to energy systems, Future technologies for zero effluent industrial parks, Government policies and norms for waste to energy, and case studies / numerical Problems for the industries including sugar, cement and paper.

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

Module no.	Topic	No. of hours
1	Introduction to concept of waste to energy, Different sources of organic wastes from industrial and other sectors	4
2	Estimation of energy potential of organic waste from these sectors, GHG emission reduction potential with waste	3
3	Overview of concept of industrial ecology and zero effluent based eco-industrial park	3
4	Impact of organic waste through life-cycle analysis on energy and environment system (air / water / soil)	3
5	Various technologies for segregation of organic matter from the	3

	waste, Physico-Chemical properties of the organic matter	
6	Analysis of Physico-Chemical properties of organic waste / pre-processed organic waste	2
7	(a) Various technologies for conversion from the organic waste to energy: Thermo-chemical conversion, esterification incineration, combustion	3
	(a) Gasification / plasma gasification, pyrolysis / plasma pyrolysis	4
8	Bio-chemical conversion (anaerobic digestion, dark fermentation, microbial system)	3
9	(a) Conversion of energy/fuels derived from waste to electrical power	1
	(b) Steam turbine power plant, internal combustion engines, microbial fuel cell	3
	(c) Technologies for emission reduction for waste to energy systems	3
10	Future technologies for zero effluent industrial parks, Government policies and norms for waste to energy system	3
11	Case studies / numerical problems for the industries including sugar, cement and paper	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

2	Calculation of CO_2 emission using carbon balance method, energy efficiency, carbon content, estimation of CO_2 equivalent GHG emission, specific thermal and electrical energy, energy intensity
9	Thermodynamic cycles for power plants
(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. Naomi Klinghoffer Marco Castaldi, Waste to Energy Conversion Technology, Woodhead Publishing, 2013.
2. Efstratios N. Kalogirou, Waste-to-Energy Technologies and Global Applications, CRC Press, 2017
3. Branchini, Lisa, Waste-to-Energy: Advanced Cycles and New Design Concepts for Efficient Power Plants, Springer, 2015.

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**	Hazardous Waste Management		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL735		
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, 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	CVL821 (≤ 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** Prof. M. G. Dastidar, Prof. D. K. Sharma, Dr. R. Uma, Prof. Kaushik Saha	

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

13.	**Course objectives** To impart knowledge about hazardous waste generation and various treatment techniques with an overview of waste management problems, highlighting transport, storage and disposal of hazardous waste for avoiding environmental efforts. It is also aimed to undertake case studies that provide the awareness about the issues and challenges involved in treating potential hazardous waste including biomedical waste.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Sources and classification of hazardous wastes, Assessment of exposure potential: Transport processes, Overview of waste management problems, Guidelines for handling hazardous wastes, Energy from organic hazardous wastes, Chemical waste treatment processes, Physical waste treatment processes, Biological waste treatment processes, Thermal waste treatment processes, Nuclear waste treatment processes, Waste elimination option, Domestic hazardous waste, Hazardous waste management options, Toxic metallic waste, Biomedical waste, Remediation of hazardous waste contaminated soils, Engineering issues in waste remediation, case studies.

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

Module no.	Topic	No. of hours
1	Sources and classification of hazardous wastes	3
2	Assessment of exposure potential, transport processes	3
3	Overview of waste management problem	3
4	Energy from organic wastes	3
5	Physical and chemical waste treatment processes	4
6	Biological waste treatment processes	4
7	Nuclear waste treatment processes	2
8	Waste elimination option	3
9	Domestic hazardous waste	3
10	Hazardous waste management option	2
11	Toxic metallic wastes	4
12	Biomedical wastes	4
13	Remediation of hazardous waste contaminated soils	2
14	Engineering issues in waste remediation 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	Location of hazardous waste landfill sites
3-4	Handling and disposal of chemical wastes
(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. Cliff V. G., Hazardous Waste Management, Mercurary Learning and Information, 2012.
2. Paul R., Lydia F., Risks of Hazardous Wastes, Elsevier, 2011.
3. Eddy M., Tchobanoglous G., Burton F. L., Stensel H. D., Waste Water Engineering, Mc-Graw Hill Publishing Company, 2002.
4. Commelt D., Environmental Engineering, Mc-Graw Hill Publishing Company, 1998.
5. Rao C. S., Environmental Pollution Control Engineering, New Age International Publishers, 1997.
6. Lagrega H. D., Buckingham P. L., Evans J. C., Hazardous Waste Management, McGraw Hills, 1994.

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**	Power System Planning and Operation		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL738		
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, 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	ELL 874 (≤ 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** Dr. A. Verma, Prof. T.S. Bhatti, Prof. Sumit Chattopadhyay

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

13.	**Course objectives** Upon successful completion of this course the students will be able to • Formulate power system operation and planning problems for a particular objective(s) subject to the given constraints. • Implement various optimization techniques for solving these problems.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Reliability Indices: Unit availability, Capacity outage probability tables, Loss of load indices, operation of interconnected systems, Restructured power system operation. Applications of optimization techniques for power system planning, Generation expansion planning, Transmission expansion planning, Reactive power planning, combined generation, Transmission, reactive expansion planning, Generation /transmission/reactive planning in the presence of renewable energy sources.

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

Module no.	Topic	No. of hours
1	Basic probability theory, planning procedures	2
2	Various reliability indices, loss of load expectation (LOLE),Loss of load probability (LOLP), Equivalent forced outage rate (EFOR), system risk indices	3
3	Operation of interconnected and restructured power system	4
4	Applications of various conventional optimization techniques to planning: Linear/non-linear programming, gradient methods, Interior point methods, dynamic programming etc.	5
5	Applications of various meta-heuristic optimization techniques to planning: genetic algorithm, particle swarm optimization, bacteria foregoing, harmony search, ant colony etc.	5
6	Hybrid techniques for power system planning	2
7	Formulation of generation expansion planning problem (for different types of generating units thermal, hydro, nuclear, renewable etc.), objectives, constraints etc.	5
8	Transmission network expansion planning (TNEP) problem formulation (with/without security constraints, generation rescheduling)	4
9	TNEP in the presence of renewable energy sources, TNEP in a deregulated environment	5
10	Combined TNEP and reactive power planning	4
11	Combined generation and transmission planning	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	Calculation of probability of occurrence of an event
4,5,6	KKT conditions
7,8	Basics of power system operations: power flow analysis with NR method, DC load flow methods
9	Electrical characteristics of various renewable energy sources
10	Basics of reactive support devices: shunts, taps, FACT devices (STATCOM, SVC, TCSC) 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. Billinton R., Karki R., Verma A. K., Reliability and risk evaluation of wind integrated power systems, Springer, 2013.
2. Wenyuan L., Probabilistic Transmission system Planning, Wiley Interscience, 2011.
3. Kwang Y. L., El-Sharkawi Md. A., Modern Heuristic Optimization Techniques, Wiley Interscience, 2008.
4. Billinton R., Allan R. N., Reliability Evaluation of Power Systems, Plenum Press, 1996.
5. WangX., MacDonaldJ. R., Modern Power System Planning, McGraw Hill Book Company, 1994.

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	PC LAB for running the software
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)

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:	Renewable Energy
Programme Core for:	---
Programme Elective for:	ESN, 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** Prof. T. C. Kandpal, Prof. K. Ravi Kumar, Prof. S. Karak, Prof. S. Kar, Prof. 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	5
5	Social cost -Benefit analysis of renewable energy projects	4
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. CampbellH., BroronR., Benefit- Cost Analysis, Cambridge University Press, 2003.
2. Kandpal T. C., GargH. P., Financial Evaluation of Renewable Energy Technologies, Macmillan India Ltd., 2003.
3. ParkC. S., Contemporary Engineering Economics, Prentice Hall Inc., 2002.
4. ThuesenG. J., FabryckyW. 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)

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Optimal Design of Energy Systems		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL743		
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
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** Prof. D. Rakshit, Prof. K. Ravi Kumar

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

13.	**Course objectives** Upon successful completion of the course the student will have the ability to undertake tasks related to: • Steady and dynamic state simulation of large energy systems • Analysis led design • Inverse problem solving techniques

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Engineering design and optimization definitions, Concepts pertaining to system design and simulations, Information flow diagrams, Optimization techniques- Curve fitting, Lagrange multipliers, Search methods, Dynamic programming, Geometric programming, Linear programming, Modelling of energy systems, Steady-state simulation and Dynamic behaviour Analysis of large energy systems like heat exchangers, Power plants, Components optimization for maximum efficiency, Energy storage optimization.

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

Module no.	Topic	No. of hours
1	Design and Optimization Introduction	3
2	Analysis led design	3
3	System Design and Simulations a) Steady state system simulation	2
	b) Dynamic system simulations	2
	c) Mass and Energy balance diagrams	1
	d) Information flow diagrams	1
4	Non-traditional optimization techniques a) Unconstraint optimization	2
	b) Optimization sensitivity coefficients	2
	c) Inequality constraint	2
5	Power plant accessories optimization a) Boiler, Condenser optimization	2
	b) Turbine, Pump and motors optimization	3
	c) HRSG optimization	1

6	Heat exchanger optimization	3
7	Industrial heating and cooling systems a) Cement industry	2
	b) Sugarcane and textile industry	2
	c) District heating	2
8	Optimization of cogeneration plants a) Energy, Entropy optimization	2
	b) Seasonal variation optimization	2
9	Design and optimization of turbine blade cooling	2
10	Optimization of thermal storage systems	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
5-9	(a) Basics of Rankine cycle, Brayton cycle (b) Basics of cogeneration (c) Basics of heat exchanger design (d) Basics of heating and cooling systems
(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. Taha H. A., Operations Research: An Introduction, Prentice-Hall of India Pvt. Ltd., 8th Edition,

2007.
3. Bejan A., Tsatsaronis G., Moran M., Thermal Design and Optimization, Wiley Publications, 1996.
4. Stoecker W. F., Design of Thermal Systems, Mc-Graw Hill International Editions, 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	----
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**	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** Prof. A Ganguli, Prof. R. Narayanan, Prof. D.Sahu, Prof. 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)

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Environmental Audit and Impact Assessment		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL745		
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, 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	----
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	CVL737 (≤ 5%) CVL820 (≤ 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** Prof. Vamsi K. Komarala, Prof. R. Uma, Prof. S. Karak, Prof. K. Ravi Kumar, Prof. S. Kar, Prof. 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 understanding of the: • Concept of environment sampling methods for air, surface and ground water etc. • Method of environmental impact studies. • Importance of environmental audit in industries.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Environmental setting-air, water etc., Sampling and monitoring-Design, Types and objectives; Ambient and stack/source air quality monitoring and analysis; Waste water monitoring and analysis; Environmental audit-detailed procedure; National environmental policy; Methods of impact identification; Methodology of environmental impact studies;

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

Module no.	Topic	No.of hours
1	Environmental setting-air, water etc.	5
2	Environmental sampling and monitoring-Design, types and objectives	4
3	Ambient and stack/source air quality monitoring and analysis	5
4	Waste water sampling and analysis	4
5	Environmental audit-detailed procedure	4
6	Energy interaction with environment	5
7	National environmental policy	5
8	Methods of impact identification	5
9	Methodology of environmental impact assessment	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
2	The guidelines for Environmental Audit, as given by the Central Pollution Control Board, Ministry of Environment & Forests, Govt. of India.
3-5	The environment auditing of various industries in India.
(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. Raman N. S. and Gajbhiye A. R., Environmental Impact Assessment, 2014.
2. Eccleston C. H., Environmental Impact Assessment: A guide to best professional practices, 2011.
3. Glasson J., Therivel R., Introduction to environmental impact assessment, Natural Built and environment series 22, 2011.
4. Khopkar S. M., Environmental Pollutions Monitoring and Control, New-age publications, 2005.
5. Reddy S. J., Analytical Techniques in Environmental Monitoring, B. S. Publications, 2002.
6. Anjaneyulu Y., Environment Impact Assessment Méthodologies. B. S Publishers, 2002.
7. Canter L. W., Impact Prediction Auditing, McGraw Hill Publication, 1996.
8. Deith L. H., Environmental Sampling and Analysis - A practical Guide, Lewis Publishers, 1991.
9. Lawrence H. K., Principles of Environmental Sampling. American Chemical Society (Washington), 1988.
10. Programme Objective Series Probe/50/1993-94, Central Pollution Control Board, Ministry of Environment & Forests, Govt. of India, Parwesh Bhawan, East Arjun Nagar, Delhi-110032.
11. Ministry of Environment and Forests: Notification, New Delhi, April 22nd 1993(Central Pollution Control Board, Ministry of Environment and Forests, Govt. of India, New Delhi).

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**	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)			

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:	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** Prof. T. C. Kandpal, Prof. 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 (not exceeding 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, 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	5
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, 16 Case Studies on the Deployment of Photovoltaic technologies in Developing Countries, International Atomic Energy Agency (IEA), IEA-PVPS.T9-07 (2003).
3. IEA, How2 Guide for Wind Energy Roadmap Development and Implementation, International Energy Agency (IEA), Vienna (2014).
4. Federal Energy Management Program, US Department of Energy, Developing Renewable Energy Projects Larger than10MWe at Federal Facilities, Report DOE/GO-102013-3915 (2013).
5. Springer R., A Framework for Project development in the Renewable Energy Sector, National Renewable Energy Laboratory, USA, Technical Report, NREL/TP-7A40-57963 (2013).
6. CEC, Guide to Developing a Community Renewable Energy Project in North America, Commission for Environmental Cooperation (CEC), Montreal, Canada (2010).
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)

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** Prof. T. C. Kandpal, Prof. K. Ravi Kumar, Prof. K. A. Subramanian, Prof. 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
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, transport, water and wastewater, manufacturing, information and communication technology etc.	3
	(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)

COURSE TEMPLATE

1.	**Department / Centre / School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Nanomaterials for Energy Applications		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL754		
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
Open category Elective for all other programs (No if Institute Core)	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	None
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	EEL 312 (≤ 15%), PYL 105 (≤ 10%) ELL 744 (≤ 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. Sandeep Pathak

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

13.	**Course objectives** The purpose of this course is to develop a broader understanding on the properties and applications of nanomaterial. The intended course covers the whole spectrum of nanomaterials ranging from synthesis, properties, and characterization to various device fabrications routs and culminates into Nano-photonics and optoelectronic devices and other energy related applications such as energy storage systems, super capacitor etc. The course will also dwell upon the importance of Nano materials in the field of high importance such as biomedical, air pollution, aerospace and defence technologies.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): **1.Nano-material Synthesis and Characterization Techniques** Synthesis of nanomaterial with 0D, 1D, 2D and 3D structures. Basic characterization techniques of nanomaterial; X-ray characterization (X-ray sources; wide angle and extended x-ray absorption technique), Electron microscopy: high resolution imaging (SEM/TEM), defects in nano-materials. Spectroscopy; electron energy-loss mechanisms, electron filtered imaging and optical spectroscopy of metal/semiconductor nanoparticles. **2.Nanolithography and Device Fabrication Techniques** EUV lithography, Phase-shifting photolithography, X-ray lithography, Electron Beam Direct Writing System, Focused ion beam (FIB) lithography, Neutral atomic beam lithography, Plasma-aided nanofabrication, Soft Lithography, Nano sphere Lithography etc. Nanofabrication Using a de Broglie Wave-Electron Beam Holography, Atomic Beam Holography and Nanometer Lithography Using Organic Positive/Negative Resists. **3. Nano-photonics and optoelectronic devices** Advanced photonics and optoelectronic devices; Photo-voltaic, LEDs and Lasers. Spin tunneling devices, Magnetic tunnel junctions, Tunneling spin polarization, Tunnel-based spin injectors, Magnetic tunnel transistor, Memory devices and sensors and spintronic biosensors. **4. Nanotechnology in other energy related Fields:** Application of Nanotechnology in other Advanced Energy Related Fields; Energy storage systems, Fuel Cells, Battery, Super-capacitors, air/water purification, and removal of domestic and outdoor air pollutants, Biomedical application, Aerospace and defense technology.

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

Module no.	Topic	No. of hours
1	Introduction of nanomaterial and nanotechnology	1
2	Methods of nanomaterial synthesis nanomaterial with 0D, 1D, 2D and 3D structures)	3
3	X-ray characterization (X-ray sources; wide angle and extended x-ray absorption technique)	2
4	Electron microscopy: high-resolution imaging (SEM/TEM), atomic force microscopy and defects analysis in Nano-materials.	3
5	Nanolithography (EUV lithography, Phase-shifting photolithography, X-ray lithography, Electron beam direct writing system, Focused ion beam (FIB) lithography, Neutral atomic beam lithography, etc.)	4
6	Introduction to Advanced photonics and optoelectronic devices	1
7	Nano materials for photovoltaics devices	5
8	Nano materials for LEDs and Lasers.	5
9	Nano-materials for Memory devices and sensors	4
10	Application of nanotechnology in energy storage devices	3
11	Application of nanotechnology in fuel cell and super capacitor	3
12	Application of nanotechnology in green building	2
13	Application of nanotechnology in dealing with domestic and outdoor air pollutants	2
14	Application of nanotechnology in medical fields	2
15	Application of nanotechnology in high performance materials for aerospace and defense technology	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	Basics of nanotechnology
8	Basics of photonics and optoelectronic devices
9	Updated information on the cutting edge applications of nanotechnology in various fields
(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. He J., Nanomaterials in Energy and Environmental Applications, Pan Stanford 2016, ISBN 9789814463782.
2. Vollath D., Nanomaterials: An Introduction to Synthesis, Properties and Applications, 2nd Edition, Wiley-VCH, 2013, ISBN: 978-3-527-33379-0.
3. Gaponenko S. V., Introduction to Nanophotonics, Cambridge University Press, 2010, ISBN 978-0-521-76375-2.
4. Hornyak G. L., Tibbals H. F., Dutta J., Moore J. J., Introduction to Nanoscience and Nanotechnology, CRC Press, 2008, ISBN 9781420047790.

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**	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:	ESN, 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** Prof. T. C. Kandpal, Dr. K. Ravi Kumar, Dr. S. Karak, Dr. S. Kar, Dr. 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**	Carbon Capture and Storage		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	---
5.	**Course number**	ESL758		
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		
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	CLL725 (≤ 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**	Prof.Dibakar Rakshit, Prof. K. A Subramanian, Prof. Kaushik Saha

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

13.	**Course objectives** This course will provide knowledge and understanding of CO_2 capture and storage from power plants / thermal energy systems. The global warming and climate change due to steep increase in CO_2 concentration in the atmosphere is a major environmental issue. The content of this course is designed to understand how to capture, storage or sequestrate CO_2 using the advanced technologies. A student, who acquired the information and academic skill through this course, could develop appropriate technologies to minimize or eliminate CO_2 emission from the thermal energy system as well convert it into useful products which results in strengthening of sustainable energy and environment.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to source of CO_2 (Greenhouse gas) from thermal energy systems and their Global warming potential (GWP), carbon and CO_2 cycle, Scenario of CO_2 concentration in atmosphere, Relationship between radiative forcing and greenhouse gas concentration, Estimation of the equilibrium surface temper change, and global warming and climate change. Mechanism of CO_2 emission formation during combustion in power plants (steam turbine, gas turbine and internal combustion engines), CO_2 emission reduction by use of alternative fuels and energy efficiency improvement in thermal energy system, Measurement and analysis of CO_2 emission in heat engines / power plants / thermal energy system. Carbon capture: different methods (physical / chemical / biological) of Carbon capture from power plants, CO_2 capture through pre-combustion methods, Oxygen-combustion method, Post-combustion methods (physical solvents/sorbents, membranes, cryogenic fractionation), and Chemical-looping combustion, and algae species. Carbon storage under empty oil well, Ocean storage, etc. Carbon sequestration: mineral carbonation, Photosynthesis of plants, Fuel production, refrigerant, Dry ice, Fertilizer, Working fluid for power plants, Industrial applications (textile, paint, mining, oil etc.) and Case studies / numerical calculations for energy input requirement for CCS system.

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

Module no.	Topic	No. of hours
1	Introduction to source of CO_2 from energy systems, discussion of a scenario of increasing its concentration in the atmosphere, GWP, carbon and CO_2 cycle	3
2	Relationship between radiative forcing with Greenhouse gases, estimation of equilibrium surface temperature, consequences of GHG emissions on global warming and climate change	3

3	Mechanism of CO_2 emission formation during combustion in power plants (steam turbine, gas turbine and internal combustion engines) / thermal energy systems	3
4	Measurement and analysis of CO_2 emission in heat engines / power plants / thermal energy systems, carbon balance method to calculate CO_2 emission	3
5	(a) CO_2 emission reduction by use of alternative fuels and	3
	(b) Energy efficiency improvement in thermal energy system	3
6	Different methods (physical / chemical / biological) of Carbon capture from power plants /thermal energy system	3
7	(b) CO_2 capture through pre-combustion methods, oxygen-combustion method, post-combustion methods (physical solvents/sorbents, membranes, cryogenic fractionation	3
	(c) Chemical-looping combustion, algae species etc.	3
8	Carbon storage under empty oil well, ocean storage, etc.	3
9	Carbon sequestration: mineral carbonation, photosynthesis of plants, fuel production, refrigerant, dry ice, fertilizer, etc.	4
10	Application of supercritical CO_2 in industries including textile, paint, oil recovery, oil extraction, dyeing, power plants etc.	5
11	Case studies / numerical calculations for energy input requirement for CCS system.	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
3	Basics of working fluid properties used in thermal power plants, air/fuel ratio, reactants, ignition and combustion
10	Phase change properties of carbon dioxide with respect to temperature and pressure
3, 4, 5, 11	Fundamentals of thermodynamics, fluid mechanics, and chemical kinetics
(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. Steve Rackley, Carbon Capture and Storage, Elsevier Publisher, 2010.
2. Rao.Y, Surampalli, Tian.C.Zhang, et al, Carbon Capture and Storage: Physical, Chemical and Biological methods, American Society of Civil Engineer (ASCE), 2015.
3. Ibrahim Dincer, Calin Zamfirescu, Sustainable Energy Systems and Applications, Springer, 2011

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**	Environmental Economics		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL764		
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, 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** Prof. T. C. Kandpal, Dr. K. Ravi Kumar, Dr. S. Karak, Dr. S. Kar, Dr. D. Sahu

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

13.	**Course objectives** To introduce the concept and analysis of environmental economics to an energy policy maker.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Economic development and the environment, Relevance of environmental economics, Economic efficiency and markets, The economics of environmental quality, Frameworks for environmental cost and benefit analysis, criteria for evaluating environmental initiatives, Command and control strategies, Risk and uncertainty, Incentive based strategies - emission taxes and subsidies, Transferable discharge permits, Environmental policies, International environmental agreements.

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

Module no.	Topic	No. of hours
1	Economic development and environment	3
2	Relevance of environmental economics	2
3	Supply of energy and associated environmental impacts	3
4	Estimation of environmental benefits and costs	2
5	Economic efficiency and markets	3
6	Economics of environmental quality	3
7	Evaluation criteria for projects	5
8	Risk and uncertainty	4
9	Command and control strategies	4
10	Emission taxes and subsidies	3
11	Environmental policies	3
12	International agreements	3
13	Case studies	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
1-3	Environmental emissions from energy sector
4-8	Discount rate and its value for environmental analysis
9-13	Global initiatives on climate change related issues
(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. Goldin I., Winters L. A., The Economics of Sustainable Development, Cambridge University Press, 1995.
2. Field C. B., Environmental Economics, McGraw Hill Inc., 1994.

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**	Environmental Regulations		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL766		
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, 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** Prof. K. A. Subramanian, Prof. R. Uma, Prof. K. Ravi Kumar, Prof. S. Karak, Prof. S. Kar, Prof. D. Sahu

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

13.	**Course objectives** Upon successful completion of this course the student will have a detailed knowledge of environmental regulations in the country.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Environmental legislation and strategies to control pollution, Standards and setting criterion, Role of national and international agencies in dealing with environmental aspects. Standards developed by ministry of environment and forest, Sampling and analysis techniques, Data interpretations and relationships for the design of treatment facilities. Regulations for pollution controls of water, air industrial, automobile, Noise and hazardous waste environmental audit, Public liability insurance, Environment management systems, Catalytic converters in vehicles in metropolitans, EURO standards, Bharat standards.

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

Module no.	Topic	No. of hours
1	Environmental legislation and strategies to control pollution	5
2	Standards and setting criterion	3
3	Role of national and international agencies in dealing with environmental aspects.	4
4	Standards developed by ministry of environment and forest.	5
5	Sampling and analysis techniques, Data interpretations and relationships for the design of treatment facilities	5
6	Regulations for controlling a) water pollution	3
	b) air pollution	3
7	Regulations for pollution controls of automobile, Noise and hazardous waste	4
8	Environment management systems	5
9	a) Catalytic converter b) Emission norms	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	Environment norms throughout the world
3-5	General methodologies of formulation of environment norms
6-9	Development of driving cycles for automotive sector and loading cycles for stationary 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. Daniel B. B., Keller E. A., Environmental Sciences (Earth as a living planet), Wiley Publications, 2014.
2. Miller Jr. G. R., Spoolman S., Environmental Science, Wadsworth Publishing Co., 2013.
3. Environmental Regulations and Related Programs, EPA, United States, 2010. http://www2.epa.gov/sites/production/files/documents/EnvRegSC_Hndbk.pdf
4. Irwin I., Comprehensive Industry Documents Series (COINDS), Resources, 1995.
5. Jacob I. B., Kenneth M. M., Environmental Regulations Handbook, Lewis Publishers, 1992.
6. Lohani B. N., Environmental Quality Management, South Asian Publishers, 1984.

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**	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, 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	----
	(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, frequency, temperature, phase sequence measurement, current transformers, potential transformers, phase difference measurements other measuring devices	5
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)

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**	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** Prof. D. Rakshit, Prof. S. C. Kaushik, Prof. A. Verma, Prof. T. S. Bhatti, Prof. K. A. Subramanian, Prof. K. Ravi Kumar, Prof. Sumit Chattopadhyay, Prof. 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 Vassallo, 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)

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**	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**	Prof. K. Ravi Kumar, Prof. Sandeep Pathak, Prof. Sumit Chattopadhyay, Prof. 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 G. Pistoa G., Lithium Batteries, Science and Technology, Kluwer Academic Publisher, 2003. Rand D.A.J., Woods R., and Dell R.M., "Batteries for Electric Vehicles".
4. Berndt D., "Maintenance-Free Batteries", John Wiley & Sons, New York, 1997.

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**	Industrial Waste Management and Recycling		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL778		
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, 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	CVL821 (≤ 5%)
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. M. G. Dastidar, Prof. D. K. Sharma,Prof. R. Uma, Prof. K. Ravi Kumar, Prof. S. Karak,Prof. S. Kar, Prof. D. Sahu, Prof. Kaushik Saha

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

13.	**Course objectives** The major objective of the course is to impart sufficient knowledge on generation and management of solid waste, water and air pollution from the industrial sector. Solid waste disposal through landfills and various water treatment techniques are the important components of the course. Study on various case studies on industrial waste management and recycling further strengthen the course objectives.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Solid waste treatment and disposal. Sanitary Landfills. Leachate and gaseous emissions estimation from landfills. Energy resource recovery from waste, life cycle of waste materials, Waste management in different industries-steel, aluminium, chemical, paper, petroleum, and Petro-chemical. Waste water treatment techniques. Agricultural pollution. Application of air pollution control devices in industries.

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

Module no.	Topic	No. of hours
1	Introduction to solid waste management	3
2	Composting of waste	2
3	Landfills-design, construction and types	5
4	Estimation of leachate and gaseous emissions from landfills	2
5	Energy resources recovery from waste	3
6	Life cycle analysis of waste materials	3
7	Waste management in steel and aluminium industries	5
8	Waste management in chemical, petroleum, Petro-chemical industries	5
9	Waste management in paper and distillery industries; Energy from waste	5
10	Waste water treatment techniques	4
11	Agricultural pollution-causes and impact on environment	3
12	Application of air pollution control devices in industries	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	Basics of organic and inorganic wastes
4	Landfills
(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. John P., Waste Management-Municipal Hazardous Industries, CRC Press, 2014.
2. Larry P. J., Alan R. R., Hazardous Industrial Waste Management and Testing, ASTM, 2003.
3. Nicholas P. C., Handbook of Solid Waste Management and Waste Minimization Technologies. An Imprint of Elsevier, 2003.
4. Vesilind P. A., Worrell W. A., Reinhart D. R., Solid Waste Engineering, Thomson Asia Pvt. Ltd., 2002.
5. Birute V., Guide for Industrial Waste Management, U.S.-EPA, 2000.
6. Dutta M., Parida B. P., Guha B. K., Sreekrishnan T. R., Industrial Solid Waste Management and Landfilling practice, Narosa Publishing House, 1999.
7. Bagchi A., Design, Construction and Monitoring of Landfills, John Wiley and Sons, 1994.

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**	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** Prof. K. A. Subramanian, Prof. 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,	5

	Accessories of battery operated vehicles, battery recharging systems, Variable frequency drive	
7	Fuel cell vehicles: overall efficiency, power output, comparison of fuel cell and internal combustion engines at same conditions for their efficiency and transient performance.	5
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)

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**	Emission Control in Internal Combustion Engines		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	----
5.	**Course number**	ESL782		
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
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	ESL780 (≤ 10%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	CLL 725 (≤ 15%)
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. K.A. Subramanian, Prof. Kaushik Saha

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

13.	**Course objectives** This course is mainly aimed at dissemination of the vital information to the students who need to have • Basic understanding of the emission formation and its control mechanism in internal combustion engines. • Increase in energy efficiency with emission reduction.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Introduction to IC Engine Emissions; IC Engine's Regulated emissions (CO, HC, NOx, PM and CO_2) and Greenhouse gas emissions (CO_2, CH_4, and N_2O), Transient emissions; Formation mechanism of these emissions(soot morphology, PM's size and count etc.) in IC Engines, Effect of combustion characteristics on emissions of IC engine, Effect of alternative and renewable fuels on emissions of IC engine, Control strategies of emission at source level: Exhaust Gas Recirculation (EGR), Water injection, Use of gaseous fuels including hydrogen and natural gas, Control strategies for exhaust gas emissions with after-treatment devices: Catalytic control technologies, Oxidation Catalysts, Reduction catalysts, Three way Catalysts (TWC), Nonselective catalytic reduction (NSCR), Selective catalytic reduction (SCR), Diesel oxidation catalysts (DOC), Particulate emission control, Diesel particulate filter (DPF), Emission reduction of IC engine with renewable energy system under hybrid mode, National (Bharat Stage, CPCB etc.) and International (EPA, EURO etc.) Current and future national and international emission regulations of IC engines/vehicles and emission testing procedures (ESC, ETC, 5-mode, 8-mode and 13 mode tests).

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

Module no.	Topic	No. of hours
1	Introduction to IC Engine emissions (regulated and unregulated (GHG) emissions), basics and Quantification of emissions from internal combustion engines.	5
2	Effect of physico-chemical properties of alternative and biofuels on fuel economy and emission reduction. Relationship between octane and cetane number on emission formation and its control.	5
3	Effect of combustion characteristics on emissions of IC Engine: ignition delay, Heat release rate, Combustion duration, Indicated power,	5

	indicated mean effective pressure, Knocking, Rate of pressure rise, Mass fraction burned rate.	
4	Mechanism of emission formation in IC engine: effect of molecular structure (single bond and double bond) and composition (aromatic, paraffin, olefin, etc.) on emissions formation in IC engine, effect of design and operating parameters on emission formation in IC engines	5
5	Emission control at source level in IC engine using exhaust gas recirculation, spark timing, injection timing, etc.	5
	Emission reduction using optimization of engine design and operating parameters	5
6	Emission control technologies with after treatment devices	4
7	Emission reduction of IC engine with renewable energy system under hybrid mode	3
8	Current and Future National and international Emission regulations and emission testing procedures	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	Air standard cycles (Otto cycle, Diesel cycle and dual cycle), Pressure-volume and temperature-entropy diagrams
2	In-cylinder pressure-crank angle, In-cylinder temperature-crank angle, Heat release rate and Cumulative heat release rate
3	Analysis of heat release rate in IC engine using first law and second law of thermodynamics
4, 6	Emission conversion from volume basis to mass basis

(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. Adachi M., Nakamura H., Engine Emissions Measurement Handbook, SAE International, 2014.
2. Babu M. K. G., Subramanian K. A., Alternative Transportation Fuels: Utilization in Combustion Engines, CRC Press, 2013.
3. Willard W. P., Engineering Fundamentals of the Internal Combustion Engine, Pearson Prentice Hall, 2008.
4. Zhao F., Technologies for Near-Zero-Emission Gasoline-Powered Vehicles, SAE International, 2006.
5. Addy M. W., Khair M. K., Diesel Emissions and Their Control, SAE International, 2006.
6. Ferguson C. R., Allan T. K., Internal Combustion Engines Applied Thermo sciences, John Wiley & Sons, Inc. 2001.
7. Degobert P., Automobiles and Pollution, Editions Technip, 1995.
8. Heywood J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, Inc. 1988.

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**	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, JES, JEN, 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	≤ 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** Prof. Ashu Verma, Prof. T.S. Bhatti, Prof. 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. Jones, Renewable Energy Integration, Practical Management of Variability, Uncertainty, and Flexibility in Power Grids, Elsevier Publications, 2016.
2. Kirschen Goran Strbac, Fundamentals of Power System Economics, WILEY , 2014
3. John J. Grainger, William D. Stevenson, 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)

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, 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)		**---**
	(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		ESL 796

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, Prof. T.S. Bhatti, Prof. 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. Jones, Renewable Energy Integration, Practical Management of Variability, Uncertainty, and Flexibility in Power Grids, Elsevier Publications, 2016.
2. Kirschen Goran Strbac, Fundamentals of Power System Economics, WILEY, 2014.
3. John J. Grainger, William D. Stevenson, Power System Analysis, Mc Graw 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. S.S. Sastry, 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)

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**	ESL 798		
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, 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)		**---**
	(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. FunabashiToshihisa, Integration of distributed resources in power systems, Academic Press, 2016.
2. Acha Salvador, Modelling Distributed Energy Resources in Energy Service Networks, IET Press, Renewable Energy Sources,2013.
3. HossainJhangir, Hemanshu Roy Pota, "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)

COURSE TEMPLATE

1.	**Department/Centre/School proposing the course**	**Centre for Energy Studies**		
2.	**Course Title**	Pollution Control in Power Plants		
3.	**L-T-P structure**	3-0-0		
4.	**Credits**	3	**Non-graded Units**	------
5.	**Course number**	ESL804		
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, 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	ESL710 (≤ 10%) ESL330 (≤ 10%) ESL727 (≤ 10%)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	CLL725 (≤ 20%)
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. D. K. Sharma, Dr. K. A. Subramanian, Prof. S. C. Kaushik, Dr. D. Rakshit, Prof. Kaushik Saha

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

13.	**Course objectives** Upon successful completion the course, the student will be able to identify and apply different methods of controlling pollutants released in operation of power plants.

14.	**Course contents** (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Coal and nuclear based power plants-Fly ash generation, utilization, disposal and environmental impact; Nuclear fuel cycle; radioactive waste-treatment and disposal; Instrumentation; Pollution control methods-(i) Pre combustion control (ii) Combustion control during combustion clean coal technologies, advanced combustion control technologies (iii) Post-combustion Control; Gaseous pollutants control-Flue gas desulfurization (FGD) Systems, SO_x and NO_x treatments; Electrostatic precipitators; Thermal Pollution and its impact on aquatic life.

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

Module no.	Topic	No. of hours
1	Coal based power plants-Fly ash generation utilization, disposal and environmental impact	5
2	Nuclear power plants-Nuclear fuel cycle; radioactive waste-treatment and disposal	5
3	Thermal Pollution and its impact on aquatic life.	3
4	Pollution control methods	4
5	Pre combustion control	5
6	Combustion control-clean coal technologies	5
7	Post-combustion Control; Gaseous pollutants control-Flue gas desulfurization (FGD) Systems, SO_x and NO_x treatments; ESP;	5
8	During combustion clean technologies (Fluidized bed combustion, Boiler tuning etc.)	5
9	Advanced clean coal technologies	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
1-4	Thermal pollution and its control
5-6	Post combustion controls-Flue gas desulfurization and NO_x 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. Kok, K. D., Nuclear Engineering Handbook, 2nd Edition, CRC Press, 2017.
2. Speight J. G., Chemistry and Technology of Coal, CRC Press, 2012.
3. Gilbert M. M., Wendell P. E., Introduction Environmental Engineering and Science, Prentice Hall of India, 2008.
4. TIFAC (Technology Information Forecasting and assessment Councill) Home page http://www.tifac.org.in/news/flyindia.html 2005.
5. Nag P. K., Power Plant Engineering, Tata McGraw Hill, 2001.
6. Sarkar S., Fuel and Combustion, Orient Longman Limited, 2001.
7. Rao C. S., Environmental Pollution Control Engineering, Wiley Eastern Ltd., 1991.
8. Etherington H., Nuclear Engineering Handbook, McGraw Hill, 1958.

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**	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:	ESN, 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	---
	(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** Dr. K. A. Subramanian, Prof. 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 andhydrogen.

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**	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
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
	-------	-------
		-------

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)