Himachal Pradesh University

Dr. A.P.J. Abdul Kalam Bhawan, H. P. University, Shimla-171005

(NAAC accredited “A-Grade” University)

Centre
for
Green Energy and Nanotechnology

Course Work Syllabus

For

Doctor of Philosophy (Ph.D.)

in

Energy Science and Engineering

(Effective for the Batch 2026 and onwards)

Vision of University:

The vision of the University is to disseminate and advance knowledge, wisdom and understanding by teaching and research, and by the example and influence of its corporate life.

Mission of University:

To work towards its vision, the University is committed to its mission to:

1. Advance learning and knowledge by teaching and research and by extension programs so as to enable a student to obtain advantages of university education.
2. Provide the right kind of leadership in all walks of life
3. Promote in the students and teachers an awareness and understanding of the social needs of the country and prepare them for fulfilling such needs
4. Take appropriate measures for promoting inter-disciplinary studies in the University
5. Foster the composite culture of India and establish such departments or institutions as may be required for the study and development of the languages, arts and culture of India
6. Make such provision for integrated courses in Humanities, Sciences and Technology in the educational programs of the University.

Vision of Centre:

To advance sustainable and resilient energy systems through innovation, research, and collaboration in renewable energy and nanotechnology

Mission of Centre:

1. To support Himachal Pradesh's transition to clean energy.
2. To build research excellence in solar energy, green hydrogen, and electric mobility.
3. To promote indigenous technology development and sustainable rural energy models.

Program's Vision:

To achieve excellence in research & technology and human resource development in sustainable energy.

Program's Mission:

1. To provide multidisciplinary education, research & development solutions with focus on clean energy sources.
2. To identify energy, environmental concerns & policy issues to provide local and global solutions towards sustainability.
3. To promote energy education, environmental awareness, entrepreneurship development, and National & International collaboration for technology transfer.
4. To provide high-quality trained professionals for the Institutions/ Industry in the country and worldwide.

Ph.D. Coursework Requirements

- All candidates must complete **a minimum of 12 credits**.
- The coursework shall consist of:
    - **Research and Publication Ethics (RPE-PhD)**

- **Research Methodology (ESE-RM-PhD-101)**

- **At least one elective** from the approved list Coursework must normally be completed within the **first semester** of registration **[ESE-PhD-103(i-xi)].**
- Evaluation in each course shall comprise internal assessment and end-semester examination, with minimum passing marks/grade as per HPU norms.

Outline of the Course Work for Ph.D. in Energy Science and Engineering

Code	Title of Paper	Max Marks	Credits
RPE-PhD	Research and Publication Ethics	50	2
ESE-RM-PhD-101	Research Methodology	100	5
ESE-AC-PhD-102	Audit Course (Online Courses offered from SWAYAM, MOOC, NPTEL, or other online platforms)	0	0
Elect any one of the following i.e. ESE-PhD-103 (i-xi) (Elective)		100	5
ESE-PhD-103(i)	Wind & Small Hydro Energy Systems		
ESE-PhD-103(ii)	Distributed Generation and Microgrid		
ESE-PhD-103(iii)	Economics & Planning of Energy System		
ESE-PhD-103(iv)	Integrated Energy Systems		
ESE-PhD-103(v)	Renewable Energy Resources		
ESE-PhD-103(vi)	Solar Photovoltaic Systems		
ESE-PhD-103(vii)	Electric Vehicle Technology		
ESE-PhD-103(viii)	Sustainable Buildings		
ESE-PhD-103(ix)	Modeling and Optimization of Energy Systems		
ESE-PhD-103(x)	Energy Storage Systems		
ESE-PhD-103(xi)	Biofuel and Bio Energy		
Total Marks/Credits		**250**	**12**

Name of the Course	**Research And Publication Ethics**	
Course Code: RPE-PhD	**Credits-2, MM-50**	**Duration-3 Hrs**

Course Description

This course has a total of 6 units focusing on the basics of philosophy of science and ethics, research integrity, and publication ethics. Hands-on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open-access publications, research metrics (citations, h-index, Impact Factor, etc.), and plagiarism tools will be discussed in this course.

Course Objectives

a. Promote the importance of research integrity.
b. Discuss the principles of publication ethics.
c. Educate on identifying research misconduct and predatory publishing.
d. Discuss indexing and citation databases.
e. Provide information on open-access publications and research metrics.
f. Introduce various plagiarism detection tools.

Evaluation

Continuous assessment will be conducted through tutorials, assignments, quizzes, and group discussions. At the end of the course, a final written examination of 50 Marks will be conducted.

1. Students who have at least 75% attendance in classes will be considered eligible for the final written examination.
2. The exam will be conducted for a three-hour duration

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Note for Paper Setting

There will be 7 questions covering all the units. The first six questions (1, 2, 3, 4, 5 & 6) of 6 marks each will consist of one question from each unit, with internal choice provided, meaning there will be two questions from each unit. The 7th question will consist of 10 short answer type questions using Roman numerals (i, ii, iii,... x) each with 2 marks. There will be at least one question from each unit, and students will be required to attempt any seven questions out of ten.

Units	Syllabus
Unit 1	1. Introduction to philosophy: definition, nature and scope, concept, branches 2. Ethics: definition, moral philosophy, nature of moral judgments and reactions
Unit 2	1. Ethics with respect to science and research 2. Intellectual honesty and research integrity 3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP) 4. Redundant publications: duplicate and overlapping publications, salami slicing 5. Selective reporting and misrepresentation of data
Unit 3	1. Publication ethics: definition, introduction, and importance 2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc. 3. Conflicts of interest 4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types 5. Violation of publication ethics, authorship and contributorship 6. Identification of publication misconduct, complaints and appeals 7. Predatory publishers and journals
Unit 4	1. Open-access publications and initiatives 2. SHERPA/ROMEO online resource to check publisher copyright & self-archiving policies 3. Software tool to identify predatory publications developed by SPPU 4. Journal finder/journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal, etc.
Unit 5	A. Group Discussions 1. Subject-specific ethical issues, FFP, authorship 2. Conflicts of interest 3. Complaints and appeals: examples and fraud from India and abroad B. Software tools Use of plagiarism software like Turnitin, Urkund, and other open-source software tools
Unit 6	A. Databases 1. Indexing databases 2. Citation databases: Web of Science, Scopus, etc.

	B. Research Metrics 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index, altmetrics

Course Outcomes (COs)

At the end of the course students will be able to:

***CO1**: Demonstrate conceptual understanding of philosophy of science, ethical reasoning, and research integrity, and relate these principles to responsible scientific practice.*

***CO2**: Evaluate various forms of research and publication misconduct, including FFP, redundant publishing, authorship issues, conflict of interest, and selective reporting.*

***CO3**: Apply ethical guidelines, open-access principles, journal evaluation tools, and plagiarism-detection software to ensure high-quality, ethical, and compliant research publication.*

Suggested Readings:

1. Beall, J. (2012). Predatory publishers are corrupting open access. Nature, Vol. 489(7415), 179. https://doi.org/10.1038/489 l 79a.
2. Bird, A. (2006). Philosophy of Science. Routledge.
3. Bretag, Tracey (2016). The Handbook of Academic Integrity. Springer.
4. Chaddah , P. (2018). Ethics in Competitive Research: Do not get scooped; do not get Plagiarized. ISBN:978- 9387480865.
5. Grudniewicz, Agnes, D. Moher, Kelly D. Cobey+32 authors (2019). Predatory journals: no definition, no defense. Nature, Vol. 576.
6. Indian National Science Academy (2019). Ethics in Science Education, Research and Governance (2019). ISBN:978-81-939482-l- 7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf
7. Israel, Mark, Iain Hay (2006). Research Ethics for Social Scientists. London.
8. Lang, James M. (2013). Cheating Lessons: Learning from Academic Dishonesty. Harvard University Press. • MacIntyre, Alasdair (1967). A Short History of Ethics. London.
9. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research. Third Edition. National Academies Press.
10. Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1-10. https://www.niehs.nih.gov/research/resources/bioethics/whatis /index.cfrn
11. Whitley Jr., Bernard E. & Patricia Keith-Spiegel (2001). Academic Dishonesty: An Educator's Guide. Psychology Press.

<table>
<tr><td colspan="2">Name of the Course</td><td colspan="2">Research Methodology</td></tr>
<tr><td colspan="2">Course Code: ESE-RM-PhD-101</td><td>Credits-5, MM-100</td><td>Duration-3 Hrs</td></tr>
<tr><td colspan="4">Course Description
This course has a total of 5 units focusing on the basics of research methodology, such as pure and applied research, exploring or formulative research, descriptive research, diagnostic research, scientific writing, writing of research paper, short communications, review articles, monographs, technical and survey reports, authored books, and edited books and dissertation concept of renewable energy, and applications of tools in energy research.</td></tr>
<tr><td colspan="4">Course Objectives
• To equip researchers with fundamental concepts of research design, problem formulation, hypothesis development, and literature review.
• To develop competence in experimental design, analytical tools, research instrumentation, scientific writing, and proposal development.</td></tr>
<tr><td colspan="4">Evaluation
Continuous assessment will be conducted through tutorials, assignments, quizzes, and group discussions. At the end of the course, a final written examination of 100 Marks will be conducted.
1. Students who have at least 75% attendance in classes will be considered eligible for the final written examination.
2. The exam will be conducted for a three-hour duration
Note: The students can opt for MOOCs/SWAYAM and other accredited online platforms, with prior approval of relevant bodies. The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).</td></tr>
<tr><td colspan="4">Note for Paper Setting
There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.</td></tr>
<tr><td>Units</td><td colspan="3">Syllabus</td></tr>
<tr><td>Unit 1</td><td colspan="3">Foundations of Research: Meaning, objectives of research; criteria of good research; basic steps of research; types of research. Problem Identification & Formulation: selection of research problem. Hypothesis: Qualities of a good Hypothesis, Null & Alternative Hypothesis, Hypothesis Testing, Logic & Importance Review of related literature: Meaning, necessity and sources.</td></tr>
<tr><td>Unit 2</td><td colspan="3">Research Process and Experiment Design: Concept and Importance in Research, features of a good research design. Exploratory Research Design concept, types and uses, Descriptive Research Designs concept, types and uses, Concept of Independent & Dependent variables. Research Report: Writing preliminaries, main body of research, references and bibliography.</td></tr>
<tr><td>Unit 3</td><td colspan="3">Research and Development of Projects: Project formulation, National and international funding agencies for R & D projects, proposal submission. Analytical Tools and Techniques in Research: Working principles, types, basic operation and application of Microscopy, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Electrophoresis, Spectrophotometry, Chromatography and Mass spectrometry.</td></tr>
<tr><td>Unit 4</td><td colspan="3">Search engines: NCBI, PubMed, Google Scholar, Thomson Reuters, SCI etc, Reference Management Software like Zotero/Mendeley, Software for paper formatting like LaTeX/MS Office. Bioinformatics tools and applications.</td></tr>
<tr><td>Unit 5</td><td colspan="3">Writing Innovation: Introduction to Intellectual Property Rights (IPR), Basic forms of IPRs: — Patent, Copyright, Trademark, Designs, Process patent versus product patent, Art of writing a patent/innovation and claims, Preliminary patent. Intellectual Property, Patent Database Search and Patent.</td></tr>
<tr><td colspan="4">Course Outcomes (COs)
At the end of the course students will be able to:
CO1: Identify appropriate research designs, sampling methods, data collection approaches, and analytical techniques for scientific investigations.
CO2: Apply core principles of research methodology to design, conduct, document, and communicate high-quality research work.</td></tr>
</table>

Suggested Readings:

1. William Kemp, Organic Spectroscopy, ELBS London, 1987.
2. RM Silverstein, CG Bassler and TC Morril, Spectroscopic Identification of Organic Compounds, 4th Edition, John Wiley & Sons, New York, 1981.
3. Donald L Pavia, Gary M Lampman and George S Kriz, Introduction to Spectroscopy, 3 rd Edition, Saunders Golden Sunburst Series.
4. CN Banwell and Elaine M McCash, Fundamentals of Molecular Spectroscopy, 4th Edition.
5. Raymond Chang, Basic Principals of Spectroscopy, RE Krieger Publishing Co., Huntington, New York, 1978.
6. Paul D Leedy, Jeanne E Ormrod and Jeanne Ellis Ormrod, Practical Research: Planning and Design, Prentice Hall, 2004.
7. Robert V Smith, Graduate Research: A Guide for Students in the Sciences, University of Washington Press, 1998.
8. Anthony M Graziano and Michael L Rau, Research Methods: A Process of Inquiry, Prentice Hall, 2006.
9. Peter C Jurs, Computer Software Applications in Chemistry, 2nd Ed., John Wiley & Sons, New York, 1996.
10. Practical Skills in Chemistry, J. R. Dean, A. M. Jones, D. Holmes, R. Reed, J. Weyers and A Jones, Pearson Education Ltd. [Prentice Hall] (2002) 11. Research Methodology. Methods and Techniques: C. R. Kothari,

Name of the Course	Wind & Small Hydro Energy Systems	
Course Code: ESE-PhD-103(i)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course provides advanced knowledge of wind and small hydro energy conversion systems, covering their design, analysis, and operational principles. It equips PhD scholars with the skills to evaluate, model, and optimize these renewable energy technologies for research and practical applications.

Course Objectives

- To provide a rigorous understanding of wind energy fundamentals, atmospheric behavior, and wind resource assessment methods.
- To develop a strong foundation in aerodynamic theories and key design considerations governing wind turbine performance.
- To impart comprehensive knowledge of small hydropower systems, including components, classification, design criteria, and turbine technologies.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Wind Energy Basics: Potential of wind power in India, Atmospheric circulations, Classifications, Factors influencing wind, Wind shear, Turbulence, Wind resource assessment, Weibull distribution, Wind energy conversion systems, Classification, HAWT, VAWT, Components of wind turbine, Controlling of wind turbine, Wind turbine electric generator.
Unit 2	Aerodynamic Theories of Wind Turbine: Axial momentum theory, Power coefficient, Axial momentum theory considering wake rotation, Blade element theory, Combined blade element momentum theory.
Unit 3	Wind Turbine Design Considerations: Overview, Design procedure, Wind turbine topologies, Machine elements, Wind turbine loads, Wind turbine subsystems and components, Design evaluation, Power curve prediction.
Unit 4	Small Hydro Power Systems: Essential elements of hydroelectric power plant, Environmental issues related to large hydro projects, Potential of hydropower in India, Site selection for small hydro power, Classification of Small hydro power.
Unit 5	Hydraulic Component Design: Impact of jet, Classification of hydraulic turbines, Velocity triangles, Euler's equation of turbomachine, Similarity laws of hydraulic turbines, Design calculation of Francis, Kaplan and Pelton turbines, Performance characteristics of impulse and reaction turbines, Turbines for small hydro power, Types of Gates, Gate design, Governors.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Explain the operating principles, configurations, and resource characteristics of wind energy conversion systems.*

CO2: *Apply aerodynamic theories and design considerations to evaluate and analyze wind turbine performance.*

CO3: *Describe the structure, components, classification, and design elements of small hydro power plants.*

Suggested Readings:

1. Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2010). Wind Energy Explained: Theory, Design and Application (2nd ed.). John Wiley & Sons.
2. Laguna, M. (2004). Guide on How to Develop a Small Hydropower Plant. European Small Hydropower Association (ESHA).
3. Subramanya, K. (2013). Hydraulic Machines (3rd ed.). Tata McGraw-Hill Education.
4. Wagner, H.-J., & Mathur, J. (2011). Introduction to Hydro Energy Systems: Basics, Technology and Operation. Springer.

5. Harvey, A., Brown, A., & Hettiarachchi, P. (1993). Micro-Hydro Design Manual: A Guide to Small-Scale Waterpower Schemes. Intermediate Technology Development Group Publishing (ITDG).

Name of the Course	**Distributed Generation and Micro grids**	
Course Code: ESE-PhD-103(ii)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course explores the principles, technologies, and control strategies of Distributed Generation (DG) and modern microgrid systems. It emphasizes design, stability, integration challenges, and advanced research trends to enable resilient and sustainable energy networks.

Course Objectives

- To introduce the conceptual foundations, technologies, and operational characteristics of distributed generation systems.
- To examine technical, operational, and integration challenges associated with modern DG technologies.
- To develop analytical capability for optimal sizing, placement, and control of DG units and microgrid components in power systems.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Modern power system structure; Concept, need and evolution of Distributed Generation (DG), Centralized vs distributed power architecture, DG technologies – Solar PV, Wind, Micro-hydro, Biomass, Fuel Cells, Microturbines, CHP, DG penetration, sizing and resource assessment, Grid-connected and stand-alone operation, Interconnection standards and regulatory framework.
Unit 2	Power electronic interfaces for DG – DC-DC, AC-DC, DC-AC converters, Grid-forming vs grid-following inverters, MPPT and converter control, Synchronization, harmonics and power quality, Reactive power and voltage regulation, Protection issues, islanding and anti-islanding techniques, Distribution network impacts and reverse power flow.
Unit 3	A Microgrid concept and architecture – AC, DC and hybrid structures, Components – DG units, ESS, controllers, protection and communication, Energy Storage types and role in microgrids, Sizing and siting of DG/ESS, Operational modes – grid-connected, islanded and transition handling, Load characteristics and resource-load balancing.
Unit 4	Microgrid control strategies – hierarchical control (primary, secondary, tertiary), Centralized, decentralized and distributed control, Energy Management Systems – dispatch, forecasting, scheduling, Demand response and DSM, SCADA, DMS, MGCC and local controller operations
Unit 5	Microgrid economics – LCOE, CAPEX/OPEX, Life Cycle Costing, NPV/IRR, Tariff models and market participation, Business models for microgrids, Reliability and resilience evaluation, Policy and environmental aspects, Advanced topics – Smart Grid integration, Hybrid Microgrids, VPP.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Describe different distributed generation technologies and their applications in power distribution networks.*

CO2: *Design environmentally viable DG-based systems using appropriate renewable and non-conventional technologies.*

CO3: *Apply modern modeling, simulation, and analytical tools for evaluating DG and microgrid performance.*

CO4: *Develop practical engineering solutions for real-world DG and microgrid integration problems.*

Suggested Readings:

1. Twidell, J., & Weir, T. (2006). *Renewable Energy Resources* (2nd ed.). Cambridge University Press.
2. Sukhatme, S. P., & Nayak, J. K. (2017). *Solar Energy: Principles of Thermal Collection and Storage* (4th ed.). Tata McGraw-Hill Education, New Delhi.
3. Kreith, F., & Kreider, J. F. (1978). *Principles of Solar Engineering*. McGraw-Hill Book Company.
4. Soo, S. L. (1968). *Direct Energy Conversion*. Prentice-Hall.
5. Larminie, J., & Dicks, A. (2003). *Fuel Cell Systems Explained* (2nd ed.). John Wiley & Sons Ltd.
6. Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2009). *Wind Energy Explained: Theory, Design and Application* (2nd ed.). John Wiley & Sons Ltd.
7. Womack, E. J. (1986). *Power Generation: Engineering Aspects*. Chapman and Hall.
8. Rai, G. D. (2011). *Non-Conventional Energy Sources* (5th ed.). Khanna Publishers, New Delhi.
9. Lai, L. L., & Chan, T. F. (2007). *Distributed Generation: Induction and Permanent Magnet Generators*. IEEE Press & John Wiley & Sons Ltd., England.

Name of the Course	Economics & Planning of Energy System	
Course Code: ESE-PhD-103(iii)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course explores the economics, planning, and strategic development of contemporary energy systems, emphasizing energy policy, resource allocation, and long-term sustainability.

Course Objectives

- To evaluate the feasibility of Energy Technology projects.
- To explain techniques used in government Energy Policy formulation.
- To apply economic theory for analysing investment decisions in energy resources.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Energy sectors & scenario; Sector wise consumption of energy resources; Electricity; Fuel; Transportation; Energy Scenario of different sectors such as Coal, Oil, Natural Gas, RE, Hydro, Nuclear.
Unit 2	Global market outlook; Import and export position; Resources; Reserves; All India Energy Scenario; Energy Conservation Act 2001 and amendments; Energy Chain.
Unit 3	Energy Security Issues and Economics; Trade-Off between Energy Security and Climate Change; Energy Economics; Time Value of Money Concept; Simple Payback Period; IRR; NPV; Life Cycle Costing; LCA; LCOE; Cost of Saved Energy; Cost of Energy generated; Examples from energy generation and conservation.
Unit 4	Energy Regulations in Indian Power Sector; Structure of Indian Power Sector; Indian Electricity Grid Code; National Electricity Policy; Deviation Settlement mechanism; Retail Competition; Tariff Regulations; Annual Revenue Requirements; Tariff Structure; Role of State/Central Regulatory Commissions; involved costs; Energy purchase; Losses; Surcharges; O&M; Interests; Depreciation; Return on Equity.
Unit 5	Total Revenue Requirement; Tariff Policy; Understanding tariff order; Policies for Renewable Energy; Renewable Energy Policy; Incentives and subsidies; Foreign Investment; Role of MNES; IREDA; Bio Energy Policy; Solar Policy; Waste Management Practices and policies; Renewable purchase obligations; Feed in Tariffs; Renewable Energy Certificates; National policy on Hydropower; India EV Policy; Other schemes such as Saubhagya, UJALA, UDAY, RFMS, Smart Cities, etc.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Interpret energy acts and government policies.*

CO2: *Calculate payback period, cost of energy generated, and life cycle costing.*

CO3: *Determine energy tariffs defined by regulatory bodies.*

CO4: *Analyze policies and associated challenges.*

CO5: *Identify major government schemes in the energy sector.*

Suggested Readings:

1. Kleinpeter, M. (1995). *Energy Planning and Policy*. John Wiley & Sons.
2. Codoni, R., Park, H., & Ramani, K. V. (1985). *Integrated Energy Planning: A Manual* (Vols. I–III). Asian and Pacific Development Centre, Kuala Lumpur.
3. Parikh, J. (1997). *Energy Models for 2000 and Beyond*. Tata McGraw-Hill Publishing Company Limited.

4. Kumar, M. S. (1987). *Energy Pricing Policies in Developing Countries: Theory and Empirical Evidence*. International Labour Organization.
5. Munasinghe, M., & Meier, P. (1993). *Energy Policy Analysis and Modeling*. Cambridge University Press.
6. Desai, A. V. (1990). *Energy Planning*. Wiley Eastern Ltd.
7. Campbell, H., & Brown, R. (2003). *Benefit–Cost Analysis*. Cambridge University Press.
8. Park, C. S. (2002). *Contemporary Engineering Economics* (3rd ed.). Prentice Hall Inc.

Name of the Course	**Integrated Energy Systems**	
Course Code: ESE-PhD-103(iv)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course explores the design, integration, and optimization of multi-source energy systems for sustainable, high-efficiency power generation. It emphasizes advanced modelling, grid integration, and emerging technologies in renewable and hybrid energy frameworks.

Course Objectives

- To explain major renewable energy resources and their effects on the power system.
- To describe state-of-the-art and emerging technologies for efficient penetration and integration of renewable energy resources in power systems.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	**Syllabus**
Unit 1	Introduction to Energy Consumption Pattern - sector-wise analysis (agriculture, domestic, industrial, community); Historical and current demand growth trends; Future energy demand projections; Need for diversification of primary energy supply; Limitations of conventional energy systems; Substitution with alternative and renewable energy resources; Role of modern, efficient energy technologies and sustainability perspectives.
Unit 2	Renewable Resource Base - Potential, availability and site-specific characteristics of solar, wind, biomass/biogas, natural gas/CBG, forest/Agro-residue, tidal, geothermal, mini/micro-hydro and emerging renewables; Resource assessment techniques, mapping and seasonal variability; Conversion technologies, capacity factors, intermittency and grid suitability; Case examples of Indian/global deployment.
Unit 3	Hybrid & Integrated Energy Systems - Concepts of hybridization and multi-source power architecture; Selection, sizing and configuration of hybrid systems (PV-Wind-Biogas-Hydro etc.); Total energy approach, combined heat and power (CHP), co-generation; Waste heat recovery and utilization; Energy system modelling and optimization approaches; Software/analytical tools for hybrid system evaluation.
Unit 4	System Integration Aspects - Grid interfacing and system constraints; Voltage regulation, thermal loading, power flow & fault level impacts; Protection coordination and islanding behaviour; Stand-alone vs grid-connected configurations; Network voltage profile, stability and system efficiency considerations; Performance metrics; Case studies of stand-alone/hybrid microprojects and field installations.
Unit 5	Techno-Economic & Modelling Framework - Economic evaluation of hybrid systems (CAPEX, OPEX, LCOE, payback, IRR, sensitivity analysis); Mathematical modelling of integrated renewable systems; Optimization objectives (cost, reliability, emissions); Power electronic interfacing technologies - inverters, converters, MPPT, grid-compliance; Grid code requirements for hybrid integration; Role of storage and emerging smart-grid aligned deployment strategies.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Explain aspects of Integrated Energy Systems.*

CO2: *Describe the concept of integrated renewable energy systems.*
CO3: *Describe the concept of hybrid energy systems.*

Suggested Readings:

1. Bartram, L. (1993). *Renewable Energy Sources for Fuels and Electricity*. Island Press.
2. Ohta, T. (1994). *Energy Technology*. Pergamon Press.
3. Twidell, J., & Weir, T. (1986). *Renewable Energy Resources*. E & FN Spon.
4. Hunter, R., & Elliott, G. (1994). *Wind–Diesel Systems: A Guide to the Technology and Its Implementation*. Cambridge University Press.
5. Dincer, I., & Bicer, Y. (2019). *Integrated Energy Systems for Multigeneration*. Elsevier Science.

<table>
<tr><td>Name of the Course</td><td colspan="2">Renewable Energy Resources</td></tr>
<tr><td>Course Code: ESE-PhD-103(v)</td><td>Credits-5, MM-100</td><td>L-5, T-0, P-0</td></tr>
<tr><td colspan="3">Course Description
This course provides an advanced understanding of renewable energy resources, their scientific principles, and modern technological applications. It emphasizes sustainability, energy policy, and research-driven approaches for developing efficient, clean energy solutions.</td></tr>
<tr><td colspan="3">Course Objectives
• To familiarize students with global and national power scenarios, renewable energy technologies, and grid integration of renewable energy resources.
• To familiarize students with renewable energy sources such as solar, geothermal, wind, and fuel cells.
• To familiarize students with thermoelectric power generation.</td></tr>
<tr><td colspan="3">Course Evaluation & Paper Setting
There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).</td></tr>
</table>

Units	Syllabus
Unit 1	Energy demand and supply status (global & India), Classification of energy resources: renewable vs. non-renewable, Environmental impact of conventional energy systems, Sustainable development and energy security, Nuclear energy basics, Nuclear Fusion and Fission Reactions, Hydrogen production methods: electrolysis, thermochemical, biological, Hydrogen storage & transportation, Fuel cell working principle & types, Hydrogen economy & future trends.
Unit 2	Solar radiation and its measurement, Solar energy collectors and storage, Solar thermal electric conversion, Thermal electric conversion systems, Solar electric power generation, Solar photo-voltaic, Solar cell principle, Semiconductor junctions, Conversion efficiency and power output, Basic photovoltaic system for power generation, Energy storage: mechanical, thermal, electrochemical, chemical, Li-ion batteries, flow batteries, Pumped hydro storage, compressed air storage, Smart grids & renewable energy integration, Microgrids & hybrid renewable systems.
Unit 3	Wind characteristics and resource assessment, Wind energy conversion principles, Nature of wind, Power in the wind, Wind data and energy estimation, Types of wind turbines: HAWT, VAWT, Site selection considerations, Components of a wind energy conversion system, Classification of WEC systems, Offshore wind technology.
Unit 4	Biomass resources and availability, Biomass conversion technologies: Thermochemical (combustion, gasification, pyrolysis), Biochemical (anaerobic digestion, ethanol, biodiesel production), Biogas plants: types, design, applications, Biomass power plants and cogeneration.
Unit 5	Large, small, micro, pico hydro, Site selection, Components of hydroelectric plant, Run-of-river vs. reservoir systems, Tidal energy, Wave energy, Ocean thermal energy conversion (OTEC), Tidal barrage and tidal stream systems, Geothermal resources and types, Geothermal power plant types: dry steam, flash, binary cycle, Geothermal heat pump applications, Environmental aspects.

Course Outcomes (COs)
At the end of the course students will be able to:
CO1: *Analyse the energy scenario of the world and nation.*
CO2: *Evaluate different types of coal, including treatment, liquefaction, and gasification.*
CO3: *Compare liquid and gaseous fuels sourced from petroleum and their characterization.*
CO4: *Assess alternate energy sources, their scope, and limitations.*

CO5: Solve energy-related problems involving combustion and non-combustion systems.
Suggested Readings: 1. Bansal, N. K., Kleemann, M., & Heliss, M. (1990). *Renewable Energy Sources and Conversion Technology*. Tata McGraw-Hill. 2. Bent, S. (1982). *Renewable Energy*. Academic Press. 3. Boyle, G. (Ed.). (2012). *Renewable Energy: Power for a Sustainable Future* (3rd ed.). Oxford University Press.

Name of the Course	Solar Photovoltaic Systems	
Course Code: ESE-PhD-103(vi)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

A research-oriented course providing advanced knowledge of solar photovoltaic materials, device physics, system design, and performance analysis. It equips scholars with analytical and experimental skills for innovation in solar energy technologies.

Course Objectives

- To provide an understanding of solar photovoltaic systems, types of solar cells, and their applications.
- To explain the fundamentals and performance characteristics of solar cell technologies.
- To describe system components, configurations, and practical considerations for PV deployment.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Solar spectrum and radiation; measurement of direct, diffuse, and global radiation; tilted surface radiation; Solar cells fundamentals; PN junction behavior; IV and PV characteristics; maximum efficiency; overview of 1st, 2nd, and 3rd generation PV technologies.
Unit 2	Thin-film technologies (CdTe, CIGS, a-Si); perovskite solar cells; organic photovoltaics; multijunction and tandem cells; concentrator photovoltaics; heterojunction devices; quantum-dot and emerging materials; PV module fabrication, interconnection methods, bypass/blocking diodes; effects of shading, mismatch, and ageing; inverters and power electronics.
Unit 3	PV modules and arrays, mounting structures, electrical configuration, MPPT, inverters, charge controllers, battery storage, cabling, grounding, monitoring and data acquisition; grid-tied inverters, micro-inverters, power conditioning; DC/AC protection; thermal management and module reliability; system sizing; off-grid, hybrid, and grid-connected configurations; sources of losses and mitigation; performance analysis tools; introduction to DPR preparation.
Unit 4	Testing and certification of PV modules (IEC standards), reliability assessment, degradation; concentrator PV, reflector/lens systems.
Unit 5	High-temperature solar thermal systems; emerging applications such as floating PV, agro-PV, BIPV; financial and technical evaluation frameworks; performance in Indian climatic conditions.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Explain the fundamentals of solar spectrum, radiation, and photovoltaic operation.*

CO2: *Compare first, second, and third-generation solar cell technologies.*

CO3: *Evaluate PV module fabrication, interconnection, and power electronics.*

CO4: *Design PV systems for off-grid, hybrid, and grid-connected applications.*

CO5: *Assess PV performance, reliability, and certification requirements.*

Suggested Readings:

1. Solanki, C. S. (2015). *Solar Photovoltaics: Fundamentals, Technologies and Applications* (3rd ed.). PHI Learning.
2. Sukhatme, S. P., & Nayak, J. K. (2017). *Solar Energy: Principles of Thermal Collection and Storage* (4th ed.). McGraw-Hill Education.
3. Reinders, A., Verlinden, P., van Sark, W., & Freundlich, A. (2017). *Photovoltaic Solar Energy: From Fundamentals to Applications*. Wiley.
4. Duffie, J. A., & Beckman, W. A. (2013). *Solar Engineering of Thermal Processes* (4th ed.). Wiley.

5. Tao, M. (Ed.). (2014). *Terawatt Solar Photovoltaics: Roadblocks and Opportunities*. Springer.

Name of the Course	**Electric Vehicle Technology**	
Course Code: ESE-PhD-103(vii)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

A research-oriented exploration of electric vehicle architectures, powertrains, batteries, charging systems, and emerging technologies. The course integrates advanced modelling, design, and analysis approaches relevant to next-generation EV innovation.

Course Objectives

- To understand the operation of different types of electric vehicles.
- To examine design, control, and monitoring aspects of EV systems
- To gain knowledge of vehicle business models and policy frameworks.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Introduction to E/H Vehicles, Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving, Energy consumption concept of hybrid electric drive trains, Architecture of hybrid electric drive trains, Electric propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switched reluctance motor.
Unit 2	Introduction to Energy Storage, Requirements in Hybrid and Electric Vehicles: Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices, Sizing the drive system, Design of Hybrid electric vehicle and Plug-in Electric Vehicle, Energy management strategies, Automotive networking and communication, EV charging standards, V2G, G2V, V2B, V2H, Control Unit, Function of CU, Development Process, Software, Hardware, Data Management, GUI/HMI, Electric Vehicles charging station.
Unit 3	Type of Charging station, Selection and Sizing, Components of charging station, Single line diagram, Battery Management System (BMS)/Energy Management System (EMS), Battery charging and discharging calculation, Cell Selection and sizing, Battery lay outing design, Battery Pack Configuration, Construction, Battery selection criteria, Need of BMS, Rule based control and optimization-based control, Software-based high level, Supervisory control, Mode of power, Behavior of motor.
Unit 4	Advance Features, Business & Policy, E-mobility business, Electrification challenges, Connected mobility and autonomous mobility, Case study.
Unit 5	E-mobility Indian roadmap perspective, EVs in infrastructure system, Integration of EVs in smart grid, Social dimensions of EVs, Overview of national policies.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Describe electric vehicle functions and design.*

CO2: *Evaluate design-control aspects of EV systems.*

CO3: *Assess challenges related to electric vehicle business and policy.*

CO4: *Analyze and design EV integration.*

Suggested Readings:

1. Husain, I. (2010). *Electric and Hybrid Vehicles: Design Fundamentals* (2nd ed.). CRC Press, Boca Raton.
2. Larminie, J., & Lowry, J. (2012). *Electric Vehicle Technology Explained* (2nd ed.). John Wiley & Sons.

3. Muneer, T., & García, I. (2017). *The Automobile*. In *Electric Vehicles: Prospects and Challenges*. Elsevier.

Name of the Course	**Sustainable Buildings**	
Course Code: ESE-PhD-103(viii)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course explores advanced principles, technologies, and assessment methods for designing energy-efficient and environmentally responsible buildings. It equips scholars with research skills to develop innovative, sustainable solutions for the built environment.

Course Objectives

- To explain building energy behavior and factors influencing energy demand.
- To describe passive and active strategies for improving building energy performance.
- To examine modelling, standards, and evaluation frameworks for sustainable buildings.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	**Syllabus**
Unit 1	Building as an energy system; heat transfer in buildings; conduction, convection, radiation; thermal mass; air infiltration and ventilation; thermal comfort metrics (PMV, PPD); climate analysis; psychrometry; factors influencing building energy demand; walls, roofs, glazing systems; insulation materials; shading devices; passive design strategies; solar heat gain control; daylighting method; building orientation; envelope performance indices (U-value, SHGC); moisture control; green building concepts.
Unit 2	HVAC system types, load estimation, equipment efficiency, variable-air-volume systems, heat pumps, ventilation strategies, indoor air quality; cross ventilation, stack ventilation, wind towers, earth-air heat exchangers; shading devices; cool roofs; evaporative cooling; radiative cooling; courtyard effects; envelope design for cooling-dominant climates; airflow modelling.
Unit 3	Building energy modelling tools, simulation of envelope and HVAC performance, energy audits for buildings, benchmarking, ECBC, ASHRAE, ISO standards; retrofitting strategies, renewable integration in buildings, cost–benefit analysis, case studies of high-performance buildings.
Unit 4	Daylighting principles, fenestration design, daylight factor, glare control, energy-efficient lighting integration, simulation tools; lighting technologies (LED, CFL), daylight-linked controls, electrical systems in buildings, performance characteristics and efficiency measures.
Unit 5	Building envelope interactions, performance measurement, economic and environmental evaluation, case studies of passive buildings.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Analyze building energy behavior and thermal performance.*

CO2: *Evaluate HVAC systems, ventilation strategies, and passive cooling approaches.*

CO3: *Apply building energy modelling and auditing methods.*

CO4: *Assess daylighting, lighting systems, and building envelope performance.*

Suggested Readings:

1. ASHRAE. (2021). *ASHRAE Handbook – Fundamentals*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
2. Clarke, J. A. (2001). *Energy Simulation in Building Design* (2nd ed.). Routledge.
3. Kosny, J. (2015). *Thermal Insulation and Energy Efficiency in Buildings*. Elsevier.
4. Fanney, A. H., et al. (1980). *Handbook of Building Energy Analysis*. McGraw-Hill.
5. Anderson, B. (2019). *Energy Efficiency in Buildings: Theory and Practice*. Routledge.

Name of the Course	**Modeling and Optimization of Energy Systems**	
Course Code: ESE-PhD-103(ix)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course provides advanced theoretical and computational frameworks for modeling complex energy systems. It emphasizes optimization techniques to enhance efficiency, sustainability, and decision-making in modern energy infrastructures.

Course Objectives

- To explain the principles, types, and applications of modelling in energy systems.
- To develop understanding of model formulation, validation, and analysis.
- To apply optimization techniques for evaluating and improving energy systems.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Introduction to modeling: types and classification, uses, limitations, advantages of modeling; review of computational tools/techniques for solving non-linear equations, system of simultaneous equations.
Unit 2	Review of computational tools/techniques for differential equations, partial differential equations; curve fitting, multiple regression analysis and interpretation of results; steps of modeling, descriptions of system boundary, input, output, model coefficient and model parameters.
Unit 3	Examples of energy system modeling: static and dynamic modeling; modeling errors, accuracy and methods of model validation; econometric modeling: input output models considering energy budgeting.
Unit 4	Sensitivity analysis: importance of parametric analysis and tools for sensitivity analysis; optimization: problem formulation with practical examples from energy system.
Unit 5	Constrained optimization and unconstrained problems: necessary and sufficiency conditions; uses of linear programming technique for solution of problems related to energy systems/case studies.

Course Outcomes (COs)

At the end of the course students will be able to:

CO1: *Explain types, uses, and computational techniques of energy system modeling.*

CO2: *Develop models with defined boundaries, inputs, outputs, and validation methods.*

CO3: *Apply econometric and sensitivity analysis techniques to energy systems.*

CO4: *Formulate and solve optimization problems related to energy systems.*

Suggested Readings:

1. Rao S. S. (2004); Engineering Optimization: Theory and Practice, Third Edition, New Age International
2. Sundaram R. K. (1996); A First Course in Optimization Theory, Cambridge University Press
3. Kennedy P. (2008); A Guide to Econometrics, Sixth Edition, Wiley-Blackwell
4. Sarkar S. (2011); Optimization Theory, Laxmi Publications
5. Meier P. (1984); Energy Systems Analysis for Developing Countries, Springer Verlag
6. Ravindran A. Ragsdell K. M. and Reklaitis G. V. (2006); Engineering Optimization: methods and applications, Second Edition, Wiley
7. Neufville R. De. (1990); Applied Systems Analysis: Engineering Planning and Technology Management, McGraw Hill

Name of the Course	**Energy Storage Systems**	
Course Code: ESE-PhD-103(x)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course provides advanced knowledge of electrochemical, thermal, and hybrid energy storage systems with emphasis on design, modelling, and performance evaluation. It equips scholars with research-oriented skills for developing next-generation storage technologies for renewable energy integration.

Course Objectives:

- To explain the role, principles, and classifications of energy storage systems.
- To describe electrochemical, mechanical, and thermal storage technologies and their performance characteristics.
- To examine storage applications, standards, and evaluation frameworks in renewable and grid environments.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Role of storage in renewable energy systems; energy density, power density, efficiency, cycle life; classification of storage methods; historical development; performance indicators; basic principles governing storage and release of energy.
Unit 2	Batteries: lead-acid, lithium-ion, sodium-sulfur, flow batteries; working principles, construction, performance characteristics; fuel cells as storage elements; supercapacitors; charge/discharge dynamics; thermal management; degradation and safety issues.
Unit 3	Pumped hydro storage; compressed air storage (CAES); flywheel systems; gravity-based storage; sensible, latent, and thermochemical thermal storage; materials for storage; building-integrated storage systems; design considerations and performance evaluation.
Unit 4	Grid-scale storage applications; renewable–storage hybrid systems; microgrids; electric mobility; economics of storage systems.
Unit 5	Lifecycle analysis; safety codes and standards; emerging storage technologies; case studies of industrial and grid applications.

Course Outcomes (COs):

At the end of the course students will be able to:

CO1: *Explain the principles, metrics, and development of energy storage systems.*

CO2: *Evaluate electrochemical storage systems and associated performance characteristics.*

CO3: *Assess mechanical and thermal storage technologies and design considerations.*

CO4: *Analyse storage applications, economic factors, and safety standards.*

Suggested Readings:

1. H.A. Kiehne, Battery Technology Handbook, CRC Press.
2. G.M. Shaver & G.G. Karady, Grid-Scale Energy Storage: Technologies and Deployment Strategies, CRC Press.
3. R. Baxter, Energy Storage: A Nontechnical Guide, PennWell Books.
4. K.E. Kakosimos & G.P. Sakellaropoulos, Energy Storage: Fundamentals, Materials, and Applications, CRC Press.
5. P.T. Moseley & J. Garche (Eds.), Electrochemical Energy Storage, Elsevier.

Name of the Course	Biofuel and Bio Energy	
Course Code: ESE-PhD-103(xi)	**Credits-5, MM-100**	**L-5, T-0, P-0**

Course Description

This course provides an advanced understanding of the science, technology, and engineering principles behind modern biofuels and bioenergy systems. It explores biochemical and thermochemical conversion pathways, integrated biorefineries, and emerging sustainable energy innovations. Emphasis is placed on research-driven approaches for developing efficient, eco-friendly, and commercially viable bioenergy solutions for current and future energy challenges

Course Objectives:

- Develop Advanced Understanding of Bioenergy Systems to provide scholars with an in-depth understanding of biofuel and bioenergy.
- Build Research Competency in Emerging Biofuel Technologies to enable students to critically analyze, evaluate, and design advanced biofuel technologies
- Foster Innovation Toward Sustainable Energy Solutions to equip scholars with the ability to apply modern tools, modelling approaches, and interdisciplinary methods to global energy challenges.

Course Evaluation & Paper Setting

There will be 11 questions covering all the units. The first 10 questions of explanatory answers (1,2,3,........10) of 12 marks each and will consist of two questions from each unit (with internal choice provided). The students will be required to attempt one question from each unit. The 11th question will be compulsory and will consist of 10 short answer type questions (using Roman numerals i,ii,iii,........x) of 5 marks each, covering all the units.

The students will be required to attempt any eight questions out of these ten questions. Students with at least 75% attendance will be eligible for the final written examination.

Note: The passing marks for Ph.D. course work will be 55% aggregate with minimum 50% in each individual course (All three courses).

Units	Syllabus
Unit 1	Introduction to global energy demand and renewable energy landscape, Classification of biofuels: First, second, third, and fourth generation, Biomass resources and composition: Lignocellulosic biomass, agricultural residues, forestry wastes, municipal solid waste, algal biomass.
Unit 2	Microbial consortia and metabolic pathways for biofuel production, Pretreatment of lignocellulosic biomass, Fermentative production of bioethanol, biobutanol, and organic acids, Anaerobic digestion: Biogas, biomethane, Dark fermentation & photo-fermentation for biohydrogen, Algal biofuels: Cultivation, harvesting, lipid extraction
Unit 3	Pyrolysis: Principles, types, process parameters, bio-oil upgrading, Gasification: Syngas production, Fischer–Tropsch fuels, Torrefaction and hydrothermal carbonization, Transesterification and biodiesel production, Concept and design of integrated biorefineries, Bioenergy with carbon capture and storage (BECCS), Microbial fuel cells, electro-fermentation, power-to-X for CO_2 valorisation
Unit 4	Life Cycle Assessment (LCA) of biofuel systems, Techno-economic analysis (TEA) and cost modelling, Process simulation and modeling tools (Aspen Plus, SuperPro Designer basics), Environmental impacts and circular bioeconomy strategies, Supply chain logistics, feedstock variability, energy-water nexus, Bioenergy applications
Unit 5	Global and national bioenergy policies (India, EU, USA, Brazil), National Mission on Biofuels, SATAT, GOBARdhan, Waste-to-Energy schemes, Intellectual property rights (IPR) and regulatory frameworks, Socio-economic implications of biofuel deployment, Challenges in commercialization and scale-up, Carbon-negative biofuels, Bio-synthetic fuels, AI-driven optimization of bioenergy systems

Course Outcomes (COs):

At the end of the course students will be able to:

CO1: *Demonstrate advanced knowledge of biomass resources, biochemical/thermochemical conversion pathways, and the scientific principles governing biofuel and bioenergy production.*

CO2: *Critically analyze the performance, efficiency, and limitations of different biofuel technologies using experimental data, modelling tools, and current research literature.*

CO3: *Design and evaluate integrated biorefinery systems with emphasis on sustainability, process optimization, techno-*

economic feasibility, and environmental impact assessment.
CO4: *Apply interdisciplinary approaches including biotechnology, microbial engineering, catalysis, and process engineering to develop innovative solutions for advanced biofuel production.*
CO5: *Formulate research hypotheses, identify knowledge gaps, and propose high-impact research strategies that address national and global challenges in bioenergy and renewable fuel systems.*

Suggested Readings:

1. Biofuels and Bioenergy: Processes and Technologies by Sunggyu Lee and Y. T. Shah. Publisher Routledge, 2012
2. Bioenergy: Biomass to Biofuels by Anju Dahiya. Publisher: Elsevier Science & Technology Books, 2014, with a second edition in 2020
3. Handbook of Bioenergy (Energy Systems) by Sandra D. Eksioglu and Steffen Rebennack. Publisher: Springer
4. Bioenergy and Biofuel from Biowastes and Biomass edited by Samir Kumar Khanal. American Society of Civil Engineers (ASCE) 2010
5. Biomass for Renewable Energy, Fuels, and Chemicals by Donald L. Klass. Academic Press (part of Elsevier)
6. Biofuels: Analytical Insights and Perspectives by Ravi Kant Bhatia and Meenu Hans. Publisher CRC Press 2026