Semester - Wise Course Curriculum for 2-year M.Tech. in "Renewable Energy" as per New PG Ordinance - 2019-2020 for Academic Year 2020-21 Onwards

Semester I				Semester II			
Cat.	**Course**	**L-T-P**	**Cr.**	**Cat.**	**Course/ Thesis**	**L-T-P**	**Cr.**
DC	Introduction to Energy Systems	3-0-0	9	DE	Departmental Elective-3	3-0-0	9
DC	Materials for Energy Systems	3-0-0	9	DE	Departmental Elective-4	3-0-0	9
DC	Instrumentation and Control of Energy Systems	3-0-3	12	DE	Departmental Elective-5	3-0-0	9
DE	Departmental Elective-1	3-0-0	9	DE	Departmental Elective-6	3-0-0	9
DE	Departmental Elective-2	3-0-0	9	DE	Departmental Elective-7	3-0-0	9
DP	Renewable Energy Laboratory	0-0-3	3	DT	Thesis (One Unit)		11
HU/L	Humanities / Language	2-0-0	6	**Electives - 3**	Photovoltaic Power Plants		
Electives - 1	Energy, Environment and Sustainability				Solar Thermal Systems		
	Mathematical Techniques			**Electives - 4**	Wind Energy Systems		
	Alternative Fuels for Transportation				Geothermal Energy Systems		
Electives - 2	Electrical Conversion, Control and Grid Integration			**Electives - 5**	Biomass Energy Systems		
	Energy Storage				Small Hydro Energy Systems		
	Thermodynamics			**Electives - 6**	Energy Systems Modelling and Analusis		
					Urban Solid Waste Technology and Management		
					Tidal and Wave Energy		
				Electives - 7	Economics and Finacing of Renewable Energy		
					Hydrogen Energy Systems		
					Reliability and Life Testing / Analysis		
	Total credits in the semester		57 (50-60)		Total credits in the semester		56 (50-60)

Semester III				Semester IV			
Cat.	**Course**	**L-T-P**	**Cr.**	**Cat.**	**Course/ Thesis**	**L-T-P**	**Cr.**
DT	Thesis (Five Unit)		55	DT	Thesis (Five Unit)		55
	Total credits in the semester		55 (50-60)		Total credits in the semester		55 (50-60)
3 Credits of practical component is attached with core course and 3 Credits of Practical Laboratory added seperately as as per requirements of the Course							

Subject	Thermodynamics		
Course description	M.Tech in Renewable Energy / Semester – 01 / Mandatory		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	An introduction to classical thermodynamics and transport with engineering applications.	02
02	Basic postulates and laws of thermodynamics	03
03	Work and heat, enthalpy, entropy and availability and irreversibility	05
04	Steady and Unsteady first and second law analyses	05
05	Equations of state, compressibility functions, and Law of Corresponding States.	04
06	Thermodynamic potentials, chemical and phase equilibrium, phase transitions	05
07	Thermodynamic properties of solids, liquids, and gases.	04
08	Combustion and thermochemistry	06
09	Analysis of advanced power cycles and HVAC applications	08
	TOTAL	42

Text / References

Thermodynamics: An Engineering Approach - Cengel, Y. A. and Boles, M. A. (McGraw-Hill, 2014)

Fundamentals of Engineering Thermodynamics - Moran, J. M., Shapiro, H. N., Boettner, D. D. and Bailey M. B. (Wiley, 2014)

Fundamentals of Classical Thermodynamics - Van Wylen, Sonntag, and Borgnakke, (Wiley, 1994)

Advanced Engineering Thermodynamics - Adrian Bejan (John Wiley & Sons, 2016)

Energy Systems: A New Approach to Engineering Thermodynamics - (CRC Press, 2012)

Subject	Mathematical techniques		
Course description	M.Tech in Renewable Energy / Semester – 01 / Mandatory		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Determinants, Matrix and vector algebra	03
02	Solution of Linear Systems	03
03	The Algebraic Eigenvalue Problem	03
04	Topics in Linear Algebra and Calculus	06
05	Transforms and Fourier series	05
06	Introduction to Optimization	05
07	Topics in Numerical Analysis	08
08	Ordinary Differential Equations	03
09	Partial Differential Equations	03
10	Probability and statistics	03
	TOTAL	42

Text / References

Mathematical Techniques: An Introduction for the Engineering, Physical, and Mathematical Sciences - Dominic Jordan and Peter Smith (Oxford University Press, 2008)

Mathematical Methods for Engineers and Scientists 1 - Tang, Kwong-Tin (Springer, 2007)

Mathematical Methods for Engineers and Scientists 2 - Tang, Kwong-Tin (Springer, 2007)

Mathematical Methods for Engineers and Scientists 3 - Tang, Kwong-Tin (Springer, 2007)

Mathematical Techniques for Engineers and Scientists - Larry C. Andrews, Ronald L. Phillips (SPIE Press, 2003)

Advanced Engineering Mathematics - Erwin Kreyszig (John Wiley & Sons, 2010)

Subject	Introduction to Energy Systems		
Course description	M.Tech in Renewable Energy / Semester – 01 / Mandatory		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Overview of energy systems, power vs energy	02
02	Sources of Energy : Conventional and Renewable	03
03	Fuel and combustion	03
04	Basics of electrical engineering	03
05	Power generation, transmission and distribution systems	03
06	Thermal energy, thermodynamic cycles and power stations	03
07	Internal combustion engines (engines and turbines)	03
08	Nuclear energy and reactors	03
09	Hydro power systems	02
10	Solar energy systems	03
11	Wind energy systems	03
12	Biomass energy systems	03
13	Ocean thermal, tide and wave energy systems	02
14	Small, mini and micro hydro systems	02
15	Geothermal energy systems	02
16	Carbon footprint of energy conversion systems	02
	TOTAL	42

Text / References

Powerplant Technology - M. M. El Wakil (McGraw Hill Education, 2017)

Applied Combustion - Eugene L. Keating (CRC Press, 2007)

Renewable Energy Systems: Advanced Conversion Technologies and Applications - Fang Lin Luo, Ye Hong (CRC Press, 2017)

Understanding Renewable Energy Systems - Volker Quaschning (Routledge, 2016)

Wind Energy Explained – J.F.Manwell, J.G. McGowan and A.L. Rogers (John Wiley & Sons Ltd.)

Solar Energy Engineering: Processes and Systems - Soteris A. Kalogirou (Academic Press, 2009)

Biomass Gasification Principles and Technology, Energy technology review No. 67, - T.B. Read (Noyes Data Corp. , 1981)

Understanding Clean Energy and Fuels from Biomass - H. S. Mukunda Wiley (2011)

Ocean Energy - Laura K. Murray (ABDO Publishing, 2016)

Comprehensive Energy Systems (Elsevier, 2018)

Subject	Materials for Energy Systems		
Course description	M.Tech in Renewable Energy / Semester – 01 / Mandatory		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Fossil and Nuclear energy systems : Materials and coatings for super-critical turbine operation, corrosion resistant alloys for turbine blades, High temperature structural materials, proliferation resistant ceramics and coating technology, long life nuclear waste containment materials, Oxide dispersion strengthened alloys.	08
02	Solar energy systems: High efficiency and low cost solar cells, thin film technology based cells, low cost materials, novel nano surfaces to reduce reflection and expand capture spectrum band, end of life material recycle, concentrating solar power, materials with high solar absorbance and low thermal emittance, Electrochemical/catalytic and Dye sensititised solar cells	08
03	Wind energy systems : Smart blade materials for automatic pitch adjustment, materials for improving gearing efficiency	08
04	Battery technology : Lithium-ion battery - Tin and silicon based alloys as alternatives to carbon anodes, Aqueous electrolytes, room temperature ionic liquids and solid electrolytes, materials for massive electrical energy storage	08
05	Biofuels: Corrossion resistant materials for biofuel processing, Advance catalysts for thermochemical conversion	05
06	Superconducting power distribution cables, High temperature superconducting materials	05
	TOTAL	42

Text / References

Nuclear Materials Science - Karl R. Whittle (Iop Publishing Limited, 2016)

Nuclear Corrosion Science and Engineering - Damien Feron (Elsevier, 2012)

Thin Film Solar Cells: Fabrication, Characterization and Applications - Jef Poortmans, Vladimir Arkhipov (John Wiley & Sons, 2006)

Advanced Materials Science and Engineering of Carbon - Michio Inagaki, Feiyu Kang, Masahiro Toyoda, Hidetaka Konno (Butterworth-Heinemann, 2013)

Wind Turbine Technology: Principles and Design - Muyiwa Adaramola (CRC Press, 2014)

Development of Form-Adaptive Airfoil Profiles for Wind Turbine Application - Irfan Ahmed (kassel university press GmbH, 2017)

Materials for Advanced Batteries - D. Murphy (Springer Science & Business Media, 2013)

Lithium Ion Rechargeable Batteries: Materials, Technology, and New Applications - Kazunori Ozawa (John Wiley & Sons, 2012)

Lithium-Ion Batteries: Advanced Materials and Technologies - Xianxia Yuan, Hansan Liu, Jiujun Zhang (CRC Press, 2016)

Nanomaterials in Advanced Batteries and Supercapacitors - Kenneth I. Ozoemena, Shaowei Chen (Springer, 2016)

Materials For Biofuels - Ragauskas Arthur J (World Scientific, 2014)

Fundamentals of Materials for Energy and Environmental Sustainability - David S. Ginley, David Cahen (Cambridge University Press, 2011)

Composite Superconductors - K. Osamura (CRC Press, 1993)

High-Temperature Superconductors - X G Qiu (Elsevier, 2011)

Subject	Instrumentation and control of energy systems		
Course description	M.Tech in Renewable Energy / Semester – 01 / Mandatory		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction to process control	02
02	Electrical components, Analog and Digital electronics	05
03	Micromechanical devises and smart sensors	03
04	Pressure, level and flow sensing	03
05	Heat and temperature sensing	03
06	Position, force and light sensing	03
07	Humidity and other sensors	02
08	Regulators, valves and motors	02
09	Programmable logic controller, signal conditioning and transmission	03
10	Process control	03
11	Thermal power plant : Boiler and turbine instrumentation and control	03
12	Thermal power plant : Effluent and emission monitoring and control	02
13	Hydroelectric power generation, regulation & monitoring of voltage & frequency of output power.	03
14	Nuclear power control station	03
15	Diesel generator control	02
	TOTAL	42

Text / References

Fundamentals of Industrial Instrumentation and Process Control - William C. Dunn (Mcgraw Higher Ed, 2009)

Fundamentals of Instrumentation and Measurement - Dominique Placko (John Wiley & Sons, 2013)

Power Plant Instrumentation and Control Handbook: A Guide to Thermal Power Plants - Swapan Basu, Ajay Debnath (Academic Press, 2014)

Nuclear Reactor Kinetics and Plant Control - Yoshiaki Oka, Katsuo Suzuki (Springer Science & Business Media, 2013)

Subject	Energy, environment and sustainability		
Course description	M.Tech in Renewable Energy / Semester – 02 / Core		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Energy	02
02	Energy and human activities	03
03	Energy sources	04
04	Energy and development	04
05	Energy facts	04
06	Energy and environment	04
07	Technical solutions	06
08	Policies to reduce environmental degradation	06
09	World energy trends	04
10	Energy and life style	05
	TOTAL	42

Text / References

Energy, Environment and Development - José Goldemberg, Oswaldo Lucon (Earthscan, 2010 - Nature)

Climate Change and Global Energy Security: Technology and Policy Options - Marilyn A. Brown, Benjamin K. Sovacool (MIT Press, 2011)

Exergy: Energy, Environment and Sustainable Development - Ibrahim Dincer, Marc A. Rosen (Newnes, 2012)

Subject	Energy storage		
Course description	M.Tech in Renewable Energy / Semester – 02 / Core		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	General concepts of energy storage	02
02	Thermal energy storage	04
03	Reversible chemical reactions	03
04	Energy storage in organic fluids	04
05	Mechanical energy storage	03
06	Electromagnetic energy storage	03
07	Hydrogen storage	03
08	Electrochemical energy storage	03
09	Non rechargeable batteries	03
10	Lead acid batteries	03
11	Energy storage for medium to large applications	04
12	Storage of energy for vehicle propulsion	04
13	Economics of energy storage	03
	TOTAL	42

Text / References

Energy Storage: Fundamentals, Materials and Applications - Robert Huggins (Springer, 2015)

Energy Storage for Power Systems - A.G. Ter-Gazarian (Institution of Engineering and Technology, 2011)

Energy Storage - Crawley Gerard M (World Scientific, 2017)

Thermal Energy Storage: Systems and Applications - Ibrahim Dincer (John Wiley & Sons, 2011)

Lithium Batteries: Science and Technology - Christian Julien, Alain Mauger, Ashok Vijh, Karim Zaghib (Springer, 2015)

Subject	Electrical conversion, control and grid integration		
Course description	M.Tech in Renewable Energy / Semester – 02 / Core		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction	02
02	Integration of distributed energy resources in distribution power systems	03
03	Operational aspects of distribution systems with massive DER penetrations	04
04	Prediction of photovoltaic power generation output and network operation	03
05	Prediction of wind power generation output and network operation	03
06	Energy management systems for DERs	04
07	Protection of DERs	03
08	Lightning protections of renewable energy generation systems	02
09	Distributed energy resources and power electronics	04
10	AC/DC microgrids	04
11	Stability problems of distributed generators	04
12	Virtual synchronous generators and their applications in microgrids	04
13	Application of DERs in electricity market	02
	TOTAL	42

Text / References

Integration of Distributed Energy Resources in Power Systems : Implementation, Operation and Control - Toshihisa Funabashi (Academic Press, 2016)

Large Scale Grid Integration of Renewable Energy Sources - Antonio Moreno-Munoz (Institution of Engineering and Technology, 2017)

Subject	Photovoltaic power plants		
Course description	M.Tech in Renewable Energy / Semester – 02 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction to photovoltaics	02
02	Basic functional principles of photovoltaics	04
03	Crystalline silicon technologies	03
04	Chalcogenide thin film solar cells	03
05	Thin film silicon-based PV technologies	04
06	Organic photovoltaics	03
07	Characterization and measurements methods	04
08	III-V and PV concentrator technologies	04
09	PV modules and manufacturing	03
10	PV systems and applications	04
11	PV converters and batteries	04
12	PV deployment in distribution grids	04
	TOTAL	42

Text / References

Photovoltaic Solar Energy: From Fundamentals to Applications - Angèle Reinders, Pierre Verlinden, Alexandre Freundlich (John Wiley & Sons, 2017)

Handbook of Photovoltaic Science and Engineering - Antonio Luque, Steven Hegedus (John Wiley & Sons, 2011)

High-Efficiency Solar Cells: Physics, Materials, and Devices - Xiaodong Wang, Zhiming M. Wang (Springer Science & Business Media, 2013)

Solar Power Generation - Paul Breeze (Academic Press, 2016)

Advances in Solar Photovoltaic Power Plants - Md. Rabiul Islam, Faz Rahman, Wei Xu (Springer, 2016)

Solar Photovoltaic Projects in the Mainstream Power Market - Philip Wolfe (Routledge, 2013)

Subject	Wind energy systems		
Course description	M.Tech in Renewable Energy / Semester – 02 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Wind Energy Today	02
02	Wind: Origin and Local Effects	04
03	Physics of Wind Energy	04
04	Components of a Wind Energy Converter	05
05	Design Considerations	06
06	Operation and Control of Wind Energy Converters	06
07	Economics and Policy Issues	05
08	Life Cycle Assessment of a Wind Farm	06
09	Outlook	04
	TOTAL	42

Text / References

Introduction to Wind Energy Systems: Basics, Technology and Operation - Hermann-Josef Wagner, Jyotirmay Mathur (Springer, 2017)

Wind Power Basics: A Green Energy Guide - Dan Chiras (New Society Publishers, 2010)

Wind Power in Power Systems - Thomas Ackermann (John Wiley & Sons, 2012)

Wind Energy Systems: Optimising Design and Construction for Safe and Reliable Operation - John Dalsgaard Sørensen, Jens N Sørensen (Elsevier, 2010)

Advances in Wind Energy Conversion Technology - Mathew Sathyajith, Geeta Susan Philip (Springer Science & Business Media, 2011)

Wind Energy Conversion Systems: Technology and Trends - S.M. Muyeen (Springer Science & Business Media, 2012)

Wind Energy Generation: Modelling and Control - Olimpo Anaya-Lara, Nick Jenkins, Janaka B. Ekanayake, Phill Cartwright, Michael Hughes (John Wiley & Sons, 2011)

Subject	Small hydro energy systems		
Course description	M.Tech in Renewable Energy / Semester – 02 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction : Key features of small hydro schemes	02
02	Scheme identification : Site survey, hydrology and geology, cost estimates and environmental assessment	03
03	Preliminary analysis : Hydrology, Geology, Penstocks and intakes, Turbine selection, Powerhouse arrangement	06
04	Detailed design of intake works, canals and penstocks	06
05	Turbine selection	06
06	Generators and electrical systems	04
07	Auxiliary plant	04
08	Specifications and contracts	03
09	Powerhouse layout and design	04
10	Construction, commissioning and operation	04
	TOTAL	42

Text / References

Small Hydroelectric Engineering Practice - Bryan Leyland (CRC Press, 2014)

Planning and Installing Micro-Hydro Systems: A Guide for Designers, Installers and Engineers - Chris Elliott (Routledge, 2014)

Designing and Building Mini and Micro Hydropower Schemes: A Practical Guide - Luis Rodríguez, Teodoro Sanchez (Practical Action Pub., 2011)

Hydropower - Paul Breeze (Academic Press, 2018)

Introduction to Hydro Energy Systems: Basics, Technology and Operation - Hermann-Josef Wagner, Jyotirmay Mathur (Springer Science & Business Media, 2011)

Subject	Biomass energy systems		
Course description	M.Tech in Renewable Energy / Semester – 02 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	Topic	Hours
01	Properties of Biomass Fuels	03
02	Sustainability Considerations for Electricity Generation from Biomass	02
03	Combustion of Biomass	04
04	Gasification of Biomass	04
05	Pyrolysis of Biomass	04
06	Hydrothermal Processing of Biomass	04
07	Anaerobic Digestion	04
08	Esterification	04
09	Fermentation of Biomass	04
10	Fischer-Tropsch Synthesis from BioSyngas	05
11	Bio-Oil Applications and Processing	04
	TOTAL	42

Text / References

Biomass Processing Technologies - Vladimir Strezov, Tim J. Evans (CRC Press, 2014)

Technologies for Converting Biomass to Useful Energy: Combustion, Gasification, Pyrolysis, Torrefaction and Fermentation - Erik Dahlquist (CRC Press, 2013)

Biomass for Energy in the Developing Countries: Current Role, Potential, Problems, Prospects - D. O. Hall, G. W. Barnard, P. A. Moss (Elsevier, 2013)

Biofuels and Bioenergy: Processes and Technologies - Sunggyu Lee, Y.T. Shah (CRC Press, 2012)

Bioenergy Research: Advances and Applications - Vijai G. Gupta, Maria Tuohy, Christian P Kubicek, Jack Saddler, Feng Xu (Newnes, 2013)

An Introduction to Bioenergy - Nigel G Halford (World Scientific Publishing Company, 2015)

Bioenergy: Principles and Applications - Yebo Li, Samir Kumar Khanal (John Wiley & Sons, 2016)

Biorefineries: Targeting Energy, High Value Products and Waste Valorisation - Miriam Rabaçal, Ana F. Ferreira, Carla A. M. Silva, Mário Costa (Springer, 2017)

Subject	Geothermal energy systems		
Course description	M.Tech in Renewable Energy / Semester – 02 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Geothermal energy as a natural resource and potential	03
02	Geology of geothermal regions	04
03	Transport processes in geothermal reservoirs	06
04	Exploration strategies and techniques	04
05	Geothermal well digging	03
06	Reservoir engineering	04
07	Single, double and triple flash steam power plants	06
08	Dry steam power plants	03
09	Binary cycle power plants	03
10	Advanced geothermal energy conversion systems	06
	TOTAL	42

Text / References

Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact - Ronald DiPippo (Butterworth-Heinemann, 2015)

Flow and Heat Transfer in Geothermal Systems: Basic Equations for Describing and Modeling Geothermal Phenomena and Technologies - Aniko Toth, Elemer Bobok (Elsevier, 2016)

Geothermal Energy: Clean Power from the Earth's Heat - John Harvey Sass, Wendell A. Duffield (US Department of interior and US Department of Survey Circular 1249, 2003)

Geothermal Reservoir Engineering - Malcolm Alister Grant, Paul F Bixley (Academic Press, 2011)

Geothermal Engineering: Fundamentals and Applications - Arnold Watson (Springer Science & Business Media, 2013)

Subject	Tidal and wave energy systems		
Course description	M.Tech in Renewable Energy / Semester – 02 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction	02
02	The Marine Resource	02
03	Wave Energy Technology	06
04	Tidal Energy Technology	06
05	Device Design	05
06	Power Systems	03
07	Physical Modelling	04
08	Numerical Modelling	05
09	Environmental Effects	03
10	Consenting and Legal Aspects	02
11	The Economics of Wave and Tidal Energy	04
	TOTAL	42

Text / References

Wave and Tidal Energy - Deborah GreavesGregorio Iglesias (Wiley, 2018)

Ocean Energy: Tide and Tidal Power - R. H. Charlier, Charles W. Finkl (Springer Science & Business Media, 2009)

Offshore Renewable Energy: Accelerating the Deployment of Offshore Wind, Tidal, and Wave Technologies (Routledge, 2013)

Electricity from Wave and Tide: An Introduction to Marine Energy - Paul A. Lynn (John Wiley & Sons, 2013)

Ocean Energy: Governance Challenges for Wave and Tidal Stream Technologies - Glen Wright, Sandy Kerr, Kate Johnson (Routledge, 14-Dec-2017)

Marine Renewable Energy: Resource Characterization and Physical Effects - Zhaoqing Yang, Andrea Copping (Springer, 2017)

Ocean Wave Energy: Current Status and Future Prespectives - Joao Cruz (Springer Science & Business Media, 2007)

Tidal Power: Harnessing Energy from Water Currents - Victor M. Lyatkher (John Wiley & Sons, 2014)

Subject	Solar thermal systems		
Course description	M.Tech in Renewable Energy / Semester – 02 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	Topic	Hours
01	Solar Radiation and heat transfer	03
02	Radiation Characteristics of Opaque Materials	02
03	Radiation Transmission through Glazing: Absorbed Radiation	02
04	Flat-Plate and Concentrating Collectors	04
05	Energy Storage	03
06	Solar Process Loads and economics	06
07	Solar Water Heating: Active and Passive	04
08	Building Heating: Active, Passive and Hybrid Methods	04
09	Solar Cooling	02
10	Solar Industrial Process Heat and Thermal Power Systems	04
11	Solar Ponds: Evaporative Processes	04
12	Design of Active Systems, Passive and Hybrid Systems	04
	TOTAL	42

Text / References

Solar Engineering of Thermal Processes, 4th Edition - John A. Duffie, William A. Beckman (Wiley, 2013)

Solar Thermal Systems: Successful Planning and Construction - Dr Felix A. Peuser, Karl-Heinz Remmers, Martin Schnauss (Routledge, 2013)

Solar Energy Engineering: Processes and Systems - Soteris A. Kalogirou (Academic Press, 2013)

Solar Energy: The State of the Art - Jeffrey M. Gordon (Routledge, 2013)

Solar Energy: Principles of Thermal Collection and Storage - Sukhatme (Tata McGraw-Hill Education, 2008)

Harnessing Solar Heat - Brian Norton (Springer Science & Business Media, 2013)

Subject	Energy systems modelling and analysis		
Course description	M.Tech in Renewable Energy / Semester – 03 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	Topic	Hours
01	Modelling overview-levels of analysis, Steps in model development, examples of models.	02
02	Quantitative Techniques: Interpolation-polynomial, Lagrangian.	02
03	Curve-fitting, regression analysis, solution of transcendental equations.	03
04	Systems Simulation-information flow diagram, solution of set of nonlinear algebraic equations, successive substitution, Newton Raphson.	03
05	Examples of energy systems simulation Optimisation: Objectives/constraints, problem formulation.	02
06	Unconstrained problems- Necessary & Sufficiency conditions.	03
07	Constrained Optimisation- Lagrange multipliers, constrained variations, Kuhn-Tucker conditions.	03
08	Linear Programming - Simplex tableau, pivoting, sensitivity analysis.	02
09	Dynamic Programming.	03
10	Search Techniques- Univariate / Multivariate.	03
11	Case studies of optimisation in Energy systems problems.	02
12	Dealing with uncertainty- probabilistic techniques.	03
13	Trade-offs between capital & energy using Pinch Analysis.	02
14	Energy- Economy Models: Scenario Generation, Input Output Model.	03
15	Numerical solution of Differential equations- Overview, Convergence, Accuracy.	03
16	Transient analysis- application example.	03
	TOTAL	42

Text / References

F. Carl Knopf, Modeling, Analysis and Optimization of Process and Energy Systems, Wiley, 2011

W. F. Stoecker Design of Thermal Systems, Mcgraw Hill, 1981

S.S.Rao Optimisation theory and applications, Wiley Eastern, 1990

S.S. Sastry Introductory methods of numerical analysis,Prentice Hall, 1988

P. Meier Energy Systems Analysis for Developing Countries, Springer Verlag, 1984

R.de Neufville, Applied Systems Analysis, Mcgraw Hill, International Edition, 1990

Beveridge and Schechter,Optimisation Theory and Practice,Mcgraw Hill, 1970

Subject	Reliability and life testing / analysis		
Course description	M.Tech in Renewable Energy / Semester – 03 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	Topic	Hours
01	Concepts and Mathematical Models for Reliability	04
02	Reliability and Life Cycle	06
03	Reliability Testing and Estimation	06
04	Databases of failure rates of electronics/mechanical components	04
05	System Reliability and Redundancy	06
06	System Safety Analysis	06
07	Maintainability and Availability	05
08	Reliability Management	05
	TOTAL	42

Text / References

Introduction to Reliability Engineering - E. E. Lewis (John Wiley & Sons, 1996)

Practical Reliability Engineering - Patrick O'Connor, Andre Kleyner (Wiley-Blackwell, 2012)

Handbook of Reliability Engineering and Management 2/E - W. Grant Ireson, Clyde F. Coombs, Richard Y. Moss (McGraw-Hill Education, 1996)

Reliability Theory and Practice - Igor Bazovsky (Dover Publications Inc, 2004)

Subject	Economics and financing of energy systems		
Course description	M.Tech in Renewable Energy / Semester – 03 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction and scope	02
02	Economic operation in power systems	03
03	Power generation costs	05
04	Financial mathematics	04
05	Inflation, interest and cost of capital	04
06	Investment appraisal methods	05
07	Financial and economic analysis of projects	05
08	Introduction on cost allocation to cogeneration projects	05
09	Overview of energy markets and prices	04
10	Case studies	05
	TOTAL	42

Text / References

Power and Energy Systems Engineering Economics: Best Practice Manual - Panos Konstantin, Margarete Konstantin (Springer, 2018)

Power System Economic and Market Operations - Jin Zhong (CRC Press, 2018)

Electricity Markets: Theories and Applications - Jeremy Lin, Fernando H. Magnago (John Wiley & Sons, 2017)

Power Systems and Restructuring - Nouredine Hadjsaïd, Jean-Claude Sabonnadière (John Wiley & Sons, 2013)

Subject	Urban solid waste technology and management		
Course description	M.Tech in Renewable Energy / Semester – 03 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction to Waste Management, Engineering and Economics	02
02	Waste Characterization: Approaches and Methods	03
03	LCA of Waste Management systems	04
04	Waste Prevention and Minimization	04
05	Material recycling	04
06	Waste Collection	02
07	Mechanical Treatment	05
08	Thermal treatment : Incineration, Pyrolysis and Gasification	05
09	Biological treatment : Composting, Anaerobic Digestion, Mechanical Biological and Emerging Biological Technologies	05
10	Landfilling: Concepts, Challenges and Environmental Issues	04
11	Special and Hazardous Waste	04
	TOTAL	42

Text / References

Solid Waste Technology & Management - Thomas H. Christensen (Wiley, 2010)

Municipal Solid Waste Management in Developing Countries - Sunil Kumar (CRC Press, 2016)

Improving Municipal Solid Waste Management in India: A Sourcebook for Policymakers and Practitioners - P U Asnani, Chris Zurbrugg (World Bank Publications, 2007)

Sustainable Solid Waste Management - Jonathan W. C. Wong, Rao Y. Surampalli, Ammaiyappan Selvam, Tian C. Zhang, Rajeshwar D. Tyagi (American Society of Civil Engineers, 2016)

Municipal Solid Waste Management: Strategies and Technologies for Sustainable Solutions - Christian Ludwig, Stefanie Hellweg, Samuel Stucki (Springer Science & Business Media, 2012)

Solid Waste Engineering: A Global Perspective - William A. Worrell, P. Aarne Vesilind, Christian Ludwig (Cengage Learning, 2016)

Subject	Alternative fuels for transportation		
Course description	M.Tech in Renewable Energy / Semester – 03 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Introduction	02
02	Transport biofuels: Thermo-physical properties, production and cost	03
03	Vegetable Oils and biodiesel	03
04	Ethanol and Methanol	03
05	Dimethyl Ether	03
06	LPG and CNG	03
07	Hydrogen and Hythane	03
08	Syngas	03
09	Neat biofuels and blends	03
10	Effect of alternative fuels on engine performance	05
11	Engine modifications required for fuelling with alternative fuels	05
12	Prospectus of biofuels in aviation	02
13	Life cycle assessment of biojet fuels	04
	TOTAL	42

Text / References

Biofuels for Road Transport: A Seed to Wheel Perspective - Lucas Reijnders, Mark Huijbregts (Springer Science & Business Media, 2008)

Biofuels for Aviation: Feedstocks, Technology and Implementation - Christopher Chuck (Academic Press, 2016)

Transportation Biofuels: Novel Pathways for the Production of Ethanol, Biogas and Biodiesel - Alwin Hoogendoorn, Han van Kasteren (Royal Society of Chemistry, 2011)

Prospects of Alternative Transportation Fuels - Akhilendra P Singh, Rashmi Avinash Agarwal, Avinash Kumar Agarwal, Atul Dhar, Mritunjay Kumar Shukla (Springer, 2017)

Alternative Fuels and Advanced Technology Vehicles: Incentives and Considerations - Thomas Huber, Jack Spera (Nova Science, 2012)

Alternative Fuels for Transportation - Arumugam S. Ramadhas (CRC PressINC, 2010)

Transitions to Alternative Vehicles and Fuels - National Research Council, Division on Engineering and Physical Sciences, Board on Energy and Environmental Systems, Committee on Transitions to Alternative Vehicles and Fuels (National Academies Press, 2013)

Green Diesel Engines: Biodiesel Usage in Diesel Engines - Breda Kegl, Marko Kegl, Stanislav Pehan (Springer Science & Business Media, 2013)

Alternative Fuels and Advanced Vehicle Technologies for Improved Environmental Performance: Towards Zero Carbon Transportation - Richard Folkson (Elsevier, 2014)

Subject	Hydrogen energy		
Course description	M.Tech in Renewable Energy / Semester – 03 / Elective		
Total credits	9	**Teaching hours**	42

SrNo	**Topic**	**Hours**
01	Hydrogen energy : History and current status	04
02	Hydrogen production through steam reforming	04
03	Hydrogen production through alkaline water, PEM membrane water and steam electrolysis	06
04	Hydrogen production through photocatalytic water splitting	03
05	Hydrogen storage materials : Interstitial and Non-Interstitial hydrides and High surface area adsorbants	05
06	Liquid hydrogen carriers	02
07	Compressed hydrogen : properties and storage tanks	03
08	Polymer Electrolyte, Solid Oxide and Alkaline Electrolyte fuel cells	06
09	Hydrogen combustion systems	03
10	Hydrogen safety fundametals	03
11	Effect of hydrogen on mechanical properties of metals	03
	TOTAL	42

Text / References

Hydrogen Energy Engineering: A Japanese Perspective - Kazunari Sasaki, Hai-Wen Li, Akari Hayashi, Junichiro Yamabe, Teppei Ogura, Stephen M. Lyth (Springer, 2016)

Hydrogen Technology: Mobile and Portable Applications - Aline Léon (Springer Science & Business Media, 2008)

Hydrogen Storage Materials: The Characterisation of Their Storage Properties - Darren P. Broom (Springer Science & Business Media, 2011)

Hydrogen Storage Technology: Materials and Applications - Lennie Klebanoff (CRC Press, 2012)

Hydrogen Energy: Background, Significance and Future - Albert O. Backus (Nova Publishers, 2006)

Subject	Project – Phase 01		
Course description	M.Tech in Renewable Energy / Semester – 03 / Mandatory		
Total credits	9	**Teaching hours**	