Indian Institute of Technology Kanpur

COURSES OF STUDY

2023

Indian Institute of Technology Kanpur
KANPUR-208016

SUSTAINABLE ENERGY ENGINEERING

Course Template for M.Tech./BT-MT (dual degree)

Courses	Semester →	1	2	Summer Term	3	4
		SEE-601* [9]	**SEE-604* [9]**	0-2 Research Credits (SEE699)/Courses	SEE699 [36]	SEE699 [36]
		SEE-602* [9]	**SEE-605** [9]**			
		SEE-603* [9]	**SEE-612* [9]**			
		SEE-609*^ [9]	**SEE690/691**[0]**		**SEE690/691**[0]**	
		1-3 DE [9-27]	1-3 DE [9-27]			
		0-2 OE[$] [0-18]	0-2 OE[$] [0-18]			
	Credits →	36	36	[0-18][#]	36	36
					Min. Total Credits (PG)	**144**

1. Total number of courses: 8
2. *Student must take a total of (2) two core basket courses combined from Semester I and II.
3. **Compulsory course.
4. A student should take at the least 3DE's.
5. [$,^]Refer to the open elective course basket for more details.
6. [#]Optional summer research credits

Note: SEE 616 [9] was designated as a core course ONLY for students' of 2022 batch. However, those who have already taken SEE 603 are exempted from SEE 616 as core/compulsory. This course is now designated as an elective for students' of 2023 batch and onwards.

Course Template for M.S. (R)

Courses	Semester →	1	2	Summer Term	3	4
		SEE-601* [9]	**SEE-604* [9]**		SEE899 [36]	SEE899 [36]
		SEE-602* [9]	**SEE-605** [9]**	0-2 Research units (SEE899)[#]		
		SEE-603* [9]	**SEE-612* [9]**			
		SEE-609*,& [9]	**SEE690/691** [0]**		**SEE690/691**[0]**	
		0-2 DE [0-18]	0-2 DE [0-18]			
		0-1 OE[$] [0-9]	0-1 OE[$] [0-9]			
		0-2 Research units (SEE899)	0-2 Research units (SEE899)			
	Credits →	36	36	[0-18][#]	36	36
					Min. Total Credits (PG)	**144**

1. Total number of courses: 6 for students from 2023 batch and onwards.
2. **Student must take a total of (2) two core basket courses combined from Semester I and II.
3. **Compulsory course.
4. [$,&]Refer to the open elective course basket for more details.
5. [#]Summer research credits (recommended).
6. A student should take at the least 2 DE's.

Course Template PhD

A) For students with M.Tech. background

	Semester →	1	2	Summer Term	3	4
Courses		**SEE-601* [9]**	**SEE-604* [9]**		SEE799 [36]	SEE799 [36]
		SEE-602* [9]	**SEE-605** [9]**	0-2 Research Units (SEE799)#		
		SEE-603* [9]	**SEE-612* [9]**			
		SEE-609*,& [9]	**SEE690/691** [0]**			
		SEE888 [3]**	2-3 DE [18-27]		**SEE690/691** [0]**	
		2-3 DE [18-27]	0-1 OE$ [0-9]			
		0-1 OE$ [0-9]	0-2 Research units (SEE799)			
	Credits →	36+3	36	[18]#	36	36
					Min. Total Credits (PG)	**144+3**

1) Total number of courses: 6 for students from 2023 batch and onwards.
2) *A student must take two courses from the core basket.
3) **Compulsory course. The 3 credits from SEE 888 on the top of minimum course requirements.
4) &,$Refer to the open elective course basket for more details.
5) #Summer research credits (recommended).
6) A student should take at the least 2 DE's.

Note: SEE 616 [9] was designated as a core course ONLY for students' of 2022 batch. However, those who have already taken SEE 603 are exempted from SEE 616 as core/compulsory. This course is now designated as an elective for students' of 2023 batch and onwards.

B) For students with B.Tech./M.Sc. background

	Semester →	1	2	Summer Term	3	4
Courses		**SEE-601* [9]**	**SEE-604* [9]**		SEE799 [18]	SEE799 [36]
		SEE-602* [9]	**SEE-605** [9]**	0-2 Research Units (SEE799)#		
		SEE-603* [9]	**SEE-609*,& [9]**		**SEE690/691** [0]**	
		SEE-612* [9]	**SEE690/690** [0]**		0-2 DE [0-18]	
		SEE888 [3]**	0-3 DE [0-27]		0-2 OE [0-18]	
		2-3 DE [18-27]	0-2 OE$ [0-18]			
		0-1 OE$ [0-9]	0-2 Research units (SEE799)			
	Credits →	36+3	36	[18]#	36	36
					Min. Total Credits (PG)	**144 + 3**

1) Total number of courses: 10 for students from 2023 batch and onwards.
2) * Core basket course, a student must take **three** such courses.
3) **Compulsory course. The 3 credits from SEE 888 on the top of minimum course requirements.
4) &,$Refer to the open elective course basket for more details.
5) # Summer research credits (recommended)
6) A student should take at the least 4 DE's.

Note: SEE 616 [9] was designated as a core course ONLY for students' of 2022 batch. However, those who have already taken SEE 603 are exempted from SEE 616 as core/compulsory. This course is now designated as an elective for students' of 2023 batch and onwards.

Note: SEE888 is compulsory for all the Ph.D. scholars, but not mandatory for comprehensive examination.

Department of SEE			
Course ID	**Course Title**	**Credits L-T-P-C**	**Content**
SEE-211	ENERGY CLIMATE CHANGE AND SUSTAINABILITY	3-0-0-9	The objective of this course is to make students understand the importance of energy in the context of human development and its consequences. The course will cover the evolution and types of energy technologies, the role of materials, mining, and manufacturing. It will also teach the issues created by the increasing energy demand coupled with increasing population and changing lifestyles, environmental issues caused by growing energy demand and global warming, carbon cycle, emissions, and sequestration and finally, the possible way forward for a sustainable future. **Course References:** **1.** Sustainable Energy – Choosing Among Options. J.W. Tester, E.M. Drake, M.W. Golay, M.J. Driscoll, and W.A. Peters. MIT Press (2005) **2.** Energy and the Environment, James A. Fay & Dan S. Golomb **3.** Energy and Civilization: A History, Vaclav Smil, The MIT Press (2017) **4.** Atmospheric Science, Wallace, and Hobbs **5.** Earth's Climate Past and Future, William F Ruddiman **6.** Understanding Climate Change Feedback, National Research Council **7.** Climate change and technological options, Konrad and Hurtmud **8.** Human impacts on weather and climate, William R. Cotton
SEE-601	THERMO-FLUID ENGINEERING	3-0-0-9	Fluid Mechanics: Basic concepts, fluid Statics, conservation of mass and momentum and energy in an inertial and non-inertial frame of reference, Dimensional Analysis, inviscid and viscous fluid flow: external and internal, boundary layer theory; Heat Transfer: Basic concepts of conduction, convection, and radiation; one-dimensional steady state and unsteady state conduction; Network circuit analysis; Convective heat transfer; Forced and free convection over flat plate and in pipes; Boiling and condensation; Radiation heat transfer, radiation properties, and shape factors; heat exchange between real surfaces; radiation network for an absorbing and transmitting medium; Basics of solar radiation; Applications: Heat exchanger design. **Course References:** **1.** Introduction to Fluid Mechanics -Fox, McDonald, Pritchard **2.** Fluid Mechanics - F. M. White **3.** Fundamentals of Heat and Mass Transfer -Bergman, Lavine, **4.** Incropera, Dewitt **5.** Heat Transfer – Cengel

SEE-602	PHYSICS OF ENERGY MATERIALS	3-0-0-9	Semiconductors: Elements of basic quantum mechanics, reciprocal lattice, band theory, direct and indirect bandgap semiconductors, intrinsic and extrinsic semiconductors and their properties, optical absorption, generation, and recombination in semiconductors. Ionic transport: ionic and electronic conductivity, Nernst equation, transport in ionic media. Thermal Properties: Phonons, Heat capacity, Thermal conductivity. Phase transitions: Phase transitions, phase change materials-fundamentals & applications. Applications: Solar photovoltaics, LEDs, Solar thermal materials, thermoelectrics, batteries. **Course References:** **1.** Introduction to Solid State Physics by C. Kittel **2.** Electronic Properties of Materials by R.E. Hummel **3.** Solid State Physics by A.J. Dekker **4.** Semiconductor Device Fundamentals by R. F. Pierret
SEE-603	BASIC ELECTRICAL ENGINEERING	3-0-0-9	Introduction, Single-Phase Circuits, Power Calculation; Analysis of 3-Phase Circuits, Mutually Coupled Circuits, Transformers: Magnetic Circuits, Equivalent Circuit and Performance Direct-Current Machines: Construction: Equivalent Circuit, Torque-Speed Characteristics, Applications Induction Machines: Construction, Equivalent Circuit, Torque-speed characteristics, Speed Control, Starting, Applications Synchronous Machines: Construction, Equivalent Circuit, Generator & Motor Operation, Power Angle Characteristics, Hunting, Pull-Out Principles of Industrial Power Distribution **Course Reference**: **1.** Fundamentals of Electric Circuits, Alexander, and Sadiku. **2.** Introductory Circuit Analysis, R. L. Boylestad, **3.** Electric machinery fundamentals, Stephen J Chapman, **4.** Electric Machinery, A. E. Fitzgerald, Charles Kingsley Jr., **5.** Stephen D. Umans, **6.** Engineering Circuit Analysis, Hayt, Kemmerly and Durbin, **7.** Principles and applications of electrical engineering, Giorgio **8.** Rizzoni
SEE-604	THERMODYNAMICS OF ENERGY SYSTEMS	3-0-0-9	Open and closed systems, first and second laws, concept of characteristic potential and entropy, control volume analysis, properties of pure substance, chemical potential, phase equilibrium, binary solutions, chemical reaction, Air standard cycles, Rankine cycle, reheat and regenerative Rankine cycles, Vapour compression refrigeration cycle, Heat pump, vapour absorption cycle (qualitative analysis only), properties of moist air, Psychrometric chart, air- conditioning processes, Solar intensity on a tilted plane, flat plate collector, concentration limit, parabolic trough and parabolic dish collector, central receiver tower, thermal storage system, Basics of electrochemistry, equilibrium electrochemistry, kinetics, fundamental; of a battery, fundamentals of a fuel cell **Course References**:

			1. Thermodynamics - an engineering approach, Cengel and Boles, 2. 7th Edition, Mcgraw Hill Education 3. Chemical Engineering Thermodynamics, Smith, Van Ness, and 4. Abbott, 7r.h edition, Mcgraw Hill 5. Solar Energy - Principles of Thermal Collection and Storage, SP 6. Sukhatme, JK Nayak, third edition, 2008, McGraw Hill 7. Electrochemical Systems, Newman and Aiyea, Wiley Inter Science 8. Fuel Cell Systems Explained, Larminie, Dicks, Second Edition, Wiley
SEE-605	AN INTRODUCTION TO SUSTAINABLE ENERGY TECHNOLOGIES	2-0-3-9	Introduction to energy sustainability; Introduction to Sustainable Energy Systems including thermal (Rankine/Brayton cycle) conversion, photovoltaic technologies and their testing, solar thermal engineering including conversion and storage, fuel cells, wind energy systems, batteries, supercapacitors, hydrogen as fuel, its generation and storage, tidal energy. **Course References**: 1. Energy storage, Robert A. Huggins, Springer Science & Business Media, 2010 2. The Physics of Solar Cells, Jenny A. Nelson, World Scientific 3. Publishing Company 4. Fuel Cell Fundamentals, R. O'Hayre, S-W. Cha, W. Colella, F. B. 5. Prinz, John Wiley and Sons, USA, 2005 6. Advanced Batteries: Materials Science Aspects, Robert Huggins, 7. Springer; 2009. 8. Power System Analysis, John J. Grainger and William D. 9. Stevenson, Jr., Tata McGraw- Hill, 2003.
SEE-606	ELECTROCHEMICAL ENERGY SYSTEMS	3-0-0-9	Thermodynamics of electrochemical systems; equilibrium and non-equilibrium phenomena in electrochemical systems; chemical vs electrochemical kinetics; energy devices in electrochemistry: batteries, Supercapacitors, fuel cells, solid oxide fuel cells. **Course References:** 1. Energy storage, Robert A. Huggins, Springer Science & Business Media, 2010., 2. Energy storage: A new approach, Ralph Zito, Wiley, 2010., 3. Electrochemical Engineering Principles, Prentice Hall Publications, 1990., 4. Electrochemical Systems, J. Newman and N. P. Balsara, Wiley Publications, 4th Edition, 2021., 5. Advanced Batteries: Materials Science Aspects, Robert Huggins, Springer; 2009., 6. Electrochemical Supercapacitors: Scientific Fundamentals and Technological, B. E. Conway, Springer; 1999.,

			7. Supercapacitors: Materials, Systems, and Applications, Max Lu, Francois Beguin, Elzbieta Frackowiak, Wiley, 2013. **8.** Fuel Cell Fundamentals, R. O'Hayre, S-W. Cha, W. Colella, F. B. Prinz, John Wiley and Sons, USA, 2005, **9.** Fuel Cells: From Fundamental to Applications, S. Srinivas, Springer, USA, 2006., Principles of Fuel Cells, X. Li, CRC Press, USA, 2005., **10.** Fuel Cells: Principles and Applications, B. Viswanathan and M. A. Scibioh, Universities Press, India, 2006., **11.** Electrochemical methods, 2nd Ed., A.J. Bard and L.R. Faulkner, **12.** John Wiley & Sons, Inc., 2001, 13. The CRC Handbook of Solid-State Electrochemistry, Edited by P.J. Gellings and H.J.M. Bouwmeest
SEE-607	HYDROGEN ENERGY: PRODUCTION, STORAGE AND UTILIZATION	3-0-0-9	Overview of a hydrogen-based economy and hydrogen energy. Important components of the utilization of hydrogen energy: production, storage, transportation, and conversion to thermal or electrical energy. Methods of hydrogen production: Reforming of Carbonaceous Sources, Pyrolysis of Biomass and reformation of bio- oil and gaseous products, Gasification of Renewable Biomass and its Reformation, Electrolysis of Water, Thermochemical splitting of water, Photo-catalytic and photo-electrochemical routes for hydrogen production and Biological Hydrogen Production. Methods of hydrogen storage and associated apparatus. Characterization of hydrogen storage materials. Applications based on hydrogen as a working fluid: Vehicular Applications, Purification, Thermal Energy Storage, backup power, Compressor, Heating and Cooling system, and Reversible gettering. Conversion of hydrogen into thermal and electrical energy. Fuel cell for hydrogen. **Course References**: **1.** Hydrogen Energy: Challenges and Solutions for a Cleaner Future, Bahman Zohuri, Pergamon Press, Springer, 2019. **2.** Handbook of Hydrogen Energy, Eds.: S.A. Sherif, D.YI. Goswami, E.K. Stefanakos, A. Steinfield, CRC Press, 2014. **3.** Compendium of Hydrogen Energy: Hydrogen Production and Purification, edited by Velu Subramani, Angelo Basile, T. Nejat Veziroglu, Elsevier, 2015.
SEE-608	INTRODUCTION TO BIOENERGY AND BIOFUELS	3-0-0-9	This course contents include renewable feedstocks, biomass to low-carbon energy systems including biopower, bioheat, and biofuels, including conversion technologies, end products, and their applications. The course encompasses thermochemical energy processes (gasification, pyrolysis, reforming), mechanical and chemical processes (oil extraction and trans-esterification), and biochemical processes (fermentation and anaerobic digestion). Characterization of biofuels. Concepts of sustainability, systems thinking, Life Cycle Analysis (LCA), environmental issues, prevailing energy policies, the economics of energy markets, and incorporation of these concepts into bioenergy systems.

			Course Reference: **1.** Biofuels and Bioenergy, John Love, John A. Bryant, ISBN: 978-1-118-35056-0, Wiley- Blackwell (2017) **2.** Biomass for renewable energy, fuels, and chemicals. D.L. Klass, Academic Press. **3.** Biohydrogen, Ashok Pandey, S. Venkata Mohan, Jo-Shu Chang, Patrick C. Hallenbeck, Christian Larroche, ISBN 978-0-444-64203-5, second edition, Elsevier (2019) **4.** Robert C. Brown, Biorenewablc Resources: Engineering New Products from Agriculture. Wiley-Blackwell Publishing (Second Edition) **5.** Ycbo Li and Samir Kumar Khanal, Bioenergy: Principles and Applications. Willey Blackwell, ISBN: 10-987-65-4321 (2016) **6.** Sunggyu Lee and Y.T. Shah, Biofuels and Bioenergy Processes and Technologies. CRC Press (2013) **7.** Sergio C. Capareda, Introduction to Biomass Energy Conversions, CRC Press, ISBN: 978-1-4665-1333-4 (2013).
SEE-609	MATHEMATICAL AND COMPUTATIONAL TOOLS FOR ENGINEERING	3-0-0-9	At the end of the course, the student should be able to: Solve simple mathematical problems (system of equations, PDEs/ODEs, curve fittings, data analysis) using programming languages like MATLAB/Python. Analyze complex engineering systems (coupled multiphysics mathematical systems) using software tools like COMSOL/ANSYS. Formulate mathematical methods/models for energy engineering problems. Write codes in Python/MATLAB and solve research problems in commercial tools. Perform data analytics on experimental/analytical/numerical data (statistics, processing, curve-fitting, correlation) and perform interpretations (interpolations/extrapolations) **Course References:** **1.** S. C. Chapra and R. P. Canale, Numericnethods for engineers, 7th ed, (McGraw-Hill Education, 2015) **2.** Mahendra K Verma. Practical Numerical Computing Using Python: Scientific & Engineering Applications. (Independently Published, 2021). **3.** K.E. Atkinson, An Introduction to Numerical Analysis, (Wiley, 1978). **4.** William H. Press, Saul A. Teukolaky, William T. Vetterling, Brian P. Flannery. Numerical recipes: the art of scientific computing, (Cambridge University Press, 2007) **5.** Krevazig, Advanced Engineering Mathematics, (Wiley, 2006) **6.** RV. Hogg, A. T. Craig, Introduction to mathematical statistics, (Macmillan, 1970) **7.** N. R. Draper, H. Smith, Applied regression analysis, (Wiley, 1966)
SEE-610	INTRODUCTION TO MATERIALS	3-0-0-9	**Module 1:** Basic Theory. Introduction to molecular modelling; Summary of classical mechanics: conservation laws,

	MODELING AND SIMULATIONS		Hamiltonian and Lagrangian formulation; Failures of classical mechanics, Basic concepts in quantum mechanics: physical observables and operators, expectation values, Schrödinger's equation, Heisenberg's uncertainty principle; The many-holly Hamiltonian, Born-Oppenheimer approximation, variational principle, the concept of the potential energy surface. Ensembles arid statistical averaging. Simple numerical problems to illustrate some of these concepts. (8 lectures + 2 computing sessions) **Module 2:** Quantum Chemical Calculations. Hartree-Fock (HF), Post Hartree-Fock approaches and DFT; Basis-sets and Pseudo-potential. Applications and hands-on experience with commercial software like Gaussian, VASP or CP2K. (8 lectures + 2 computing sessions) **Module 3:** Molecular Dynamics and Monte Carlo Simulations. Introduction to Molecular Mechanics; Force-fields; Basics of Molecular Dynamics Simulation; Minimum image convention, Ewald summation, Thermostats and Barostats; Introduction to Monte Carlo Methods. Applications and hands-on experience with commercial software like Lammps or Gromacs. (8 lectures + 2 computing sessions) **Module 4:** Meso-scale and Rare-Event Simulation methods. Coarse-grained Modeling Methods; Rare-event simulation techniques like meta dynamics and umbrella sampling. Applications and hands-on experience with commercial software. (8 lectures + 2 computing sessions) **Course References:** **1.** Jensen, Frank. Introduction to computational chemistry. John Wiley & sons, 2017. **2.** Cramer, Christopher J. Essentials of computational chemistry: theories and models. John Wiley & Sons, 2013. **3.** Frenkel, Daan, and Berend Smit. Understanding molecular simulation: from algorithms to applications. Vol. 1. Elsevier, 2001. **4.** Allen, Michael P., and Dominic J. Tildesley. Computer simulation of liquids. Oxford University Press, 2017.
SEE-611	ENERGY SYSTEMS: MODELLING AND ANALYSIS	3-0-0-9	Introduction to integrated energy systems (6) Solar PV systems with transmission grid; Solar Thermal Systems for Power Generation (including ORC), heating and cooling applications; wind turbine for power generation and irrigation. Relevant fundamental principles (6) Thermal and Wind-based systems: Class conservation, energy conservation, momentum conservation, equilibrium thermodynamics, mechanics. PV-systems: I-V characteristics anal maximum power point Application of fundamental principles to develop solve sternly/unsteady state models for performance, and design calculations for operations/processes in energy systems (24) Solar Thermal: Heat exchanger (e.g. boiler, feed-water heater, condenser), thermal energy storage, hydro turbine; gas turbine; combined cycles Solar PV: System model, battery (inverter) storage, transmission, and distribution

			Wind: wind turbine, generator, and system integration. Dynamic analysis and design of integrated renewable energy processes Case study on applications: Power generation (including fuel cell), Process heating, cooling, Hz generation including hybrid systems (4) **Course Reference**: **1.** Smith arid Van Ness, Chemical Engineering Thermodynamics **2.** Marlin, Process Control: Designing Processes and Control Systems for Dynamic Performance **3.** Handbook of Photovoltaics Science and Technology, Antonio Luque Steven Hegedus **4.** Handbook of Hydrogen Energy, Eds.: S.A. Sherif, D.Y1. Goswami, E.K. Stefanakos, A. Steinfield, CRC Press, 2014. **5.** Wind Energy Explained: Theory, Design and Applications - J. F. Manwell, J. G. McGowan, A. L. Rogers, Wiley
SEE-613	SOLAR PHOTOVOLTAICS	3-0-0-9	Introduction to solar cells: Solar spectrum, concept of airmass, history of solar cells, economics, status, emerging technologies, and recent development. Basics of semiconductors: band theory, direct and indirect bandgap semiconductors, intrinsic and extrinsic semiconductors, and their properties. Optoelectronic processes in solar cells: Optical absorption, generation and recombination in semiconductors, charge transport, charge extraction, contacts, continuity equation P-N junction: Band diagram, Operation of p-n junction in forward and reverse bias, depletion width, drift-diffusion currents, I-V characteristics of P-h' junction in Darts and Light. Device characterization of solar cells: Open circuit voltage, short circuit current, fill factor, efficiency, quantum efficiency, Equivalent circuit of the solar cell, series anal shunt resistance, diffusion length, effect of recombination processes. A brief overview of different types of solar cells: First-generation technologies: Primarily Si-based, Second-generation technologies (low cost) thin films (a-Si, CdTe, CIGS), Third generation (high efficiency and low cost) Organic solar cells, multi-junction, Perovskite solar cells, Comparative Performance, PV Processing with emphasis on migration from solar cells to modules to systems, present status and future outlook. **Course Reference**: **1.** Safa O. Kasap, Optoelectronics & Photonics: Principles & Practices: International Edition, Pearson Education Limited **2.** Robert F. Pierret, Semiconductor Device Fundamentals, Pearson **3.** Jenny A. Nelson, The Physics of Solar Cells, World ScientificPublishing Company **4.** Ben G. Streetinan, Solid State Electronic Devices, Prentice Hall India **5.** Charles Kittel, Introduction to Solid State Physics, Wiley

SEE-614	WIND ENERGY	3-0-0-9	Review of basic concepts of fluid mechanics, Introduction to wind energy, Fundamentals of wind power- How wind is generated, overview of wind meteorology, Estimation of wind energy potential, History of wind energy harnessing methods, Wincl turbine technology, Fundamentals of Horizontal axis wind turbine and its design, Vertical axis wind turbine, other wind harnessing. **Course Reference**: **1.** Wind Turbine Technology — David A Spera, ASME Press **2.** Wind Energy Engineering — T M Letcher, Academic Press Wind Energy Explained: Theory, Design and Applications - J. F. Manwell, J. G. McGowan, A. L. Rogers, Wiley **3.** Fluid Mechanics — F. M. White, Mcgraw-Hi11 Wind Tunnel Designs and Their Diverse Engineering Applications, N A Ahmed (Ed.) InTech **4.** Small-Scale Wind Power — John Abraham ñ Brian Plourde, Momentum Press
SEE-615	SOLAR THERMAL ENGINEERING	3-0-0-9	Solar radiation, the reckoning of time, extraterrestrial radiation, relevant angles, factors influencing intensity, estimation of intensity on a tilted phone, prediction of availability, solar thermal collectors, flat plate collectors, compound parabolic concentrator, parabolic trough and parabolic dish, Fresnel lens based concentrators, central receiver tower, thermal analysis of collectors, the effect of sum tracking, performance tests for collectors, thermal route to solar power, active and passive heating systems, absorption cooling devices, solar dryers, solar desalination systems, solar pond, sensible and latent thermal energy storage systems, economic analysis of solar thermal systems, sustainable habitat **Course Reference**: **1.** Solar Energy — Principles of Thermal Collection and Storage, SP Sukhatme, JK Nayak, third edition, 2008, McGraw Hill **2.** Solar Engineering of Thermal Processes, Duffie and Beckman, fourth edition, 2013, Wiley Publication **3.** Solar Energy Engineering — Processes and Systems, SA Kalogirou, first edition, 2009, Academic Press **4.** Solar Energy — Garg and Prakash, McGraw-Hill Education, 1st revised edition, 2019
SEE-616	ESSENTIAL ELECTRICAL ENGINEERING FOR RENEWABLES INTEGRATION	3-0-0-9	Introduction to power system structure and power electronics, smart grills, etc. (1 Lecture), Basic circuit principles - three-phase circuits, power calculations (2 Lectures), Three phase transformers and per unit analysis (2 Lectures), Synchronous generators - models, reactances, capability curves (3 Lectures), Transmission line parameter calculation (4 Lectures), Transmission line model (4 Lectures), Power flow analysis (4 Lectures), Power electronic circuit components, features, interconnection rules (1 Lecture), Easic Plc-dc converter structures, steady-state voltage gain in ideal ad non-ideal conditions (3 lectures), CCD\'I and D Chat operation of basic dc-dc power converters [5 lectures), DC-DC converter applications in renewable systems (1 lecture), Inverters, structure, common

			PWM schemes, ripple-filters, steady-state analysis (5 lectures), Inverter applications for interfacing renewable systems, bi-directional power flow (3 lectures), Resonant Converters (2 lectures) **Course Reference**: **1.** Power System Analysis, John J. Grainger and William D. Stevenson, Jr., Tata McGraw-Hill, 2003. **2.** Power System Analysis, Hadi Saadat, Tata McGraw-Hill, 2002. **3.** Power System Analysis and Design, J. Duncan Glover, hi. Sorma and Thomas J. Overbye, Thomson, 2008 **4.** Power Electronics, Ned Mohan & Tore M. Undeland & William P. Robbins, Wiley **5.** Power Electronics, M. H. Rashid, Pearson
SEE-617	INTRODUCTION TO SUSTAINABLE ENERGY POLICY	2-0-0-6	The course begins with providing an overall context about the relationship between energy and society. Next, it focuses on theoretical approaches to understanding the policy processes. Following this, it traces the historical development of the energy policy in India. The major emphasis of the course will be on the more contemporary development of energy policy in India within the context of global climate change governance and the increasing prominence of sustainable energies within it. The course ends with foregrounding the policy challenges of governing a just sustainability transition towards renewables. **Course References:** **1.** Dubash, Navroz K. 2019. India in a Warming World: Integrating Climate Change and Development. Oxford University Press., **2.** Dubash, Navroz K., Radhika Khosla, Narasimha D. Rao, and Ankit Bhardwaj. 2018. “India’s Energy and Emissions Future: An Interpretive Analysis of Model Scenarios.” Environmental Research Letters 13(7):074018. doi: 10.1088/1748-9326/aacc74., **3.** Goldthau, A. (Ed.). (2016). The handbook of global energy policy. John Wiley & Sons., **4.** Jasanoff, Sheila. 2018. “Just Transitions: A Humble Approach to Global Energy Futures.” Energy Research & Social Science35:11–14. doi: 10.1016/j.erss.2017.11.025., **5.** Mitra, S. (2019). TEnergizing India: Fuelling a Billion Lives. Rupa Publications., **6.** Singh, A. (2006). Power sector reform in India: current issues and prospects. Energy policy, 34(16), 2480-2490. **7.** Singh, A. (2008). The economics of the Iran-Pakistan-India Natural Gas pipeline. Economic and Political Weekly, 57-65., **8.** Singh, A. (2009). A market for renewable energy credits in the Indian power sector. Renewable and Sustainable Energy Reviews, 13(3), 643-652., **9.** Singh, A. (2009). Climate co-benefit policies for the Indian power sector: domestic drivers and North—South cooperation. Climate Policy, 9(5), 529-543.,

			10. Swarnakar, Pradip. 2019. “Climate Change, Civil Society, and Social Movement in India.” Pp. 253–72 in India in a Warming World. Oxford University Press., **11.** Urpelainen, Johannes, and Setu Pelz. 2020. Covid-19 and a Just Transition in India’s Coal Mining Sector. John Hopkins., **12.** Vihma, Antto. 2011. “India and the Global Climate Governance: Between Principles and Pragmatism.” **13.** The Journal of Environment & Development 20(1):69–94. doi: 10.1177/1070496510394325., Wu, F. (2018). Energy and climate policies in China and India: A two-level comparative study.Cambridge University Press., **14.** Yenneti, Komali, and Rosie Day. 2015. “Procedural (in)Justice in the Implementation of Solar Energy: The Case of Charanaka Solar Park, Gujarat, India.” Energy Policy 86:664–73. doi: 10.1016/j.enpol.2015.08.019.
SEE-618A	ENERGY EFFICIENT BUILDING DESIGN	3-0-0-9	Energy use in buildings: Building sector’s energy usage and associated greenhouse gas emissions. Air-conditioning systems and psychrometry of air-conditioning processes: Common air-conditioning systems, moist air processes and their combinations used for air-conditioning. Thermal comfort, indoor air quality, and indoor infection transmission: Physiological considerations in comfort, environmental comfort indices, comfort conditions, indoor air quality concerns, common air pollutants and their control, airborne infection transmission causes and mitigation techniques. Heating load: Steady-state building heat transfer, indoor and outdoor design conditions, heating load calculation. Solar radiation: Earth’s motion about the sun, time, solar angles, solar irradiation, heat gain through the fenestration. Cooling load: Heat gain, cooling load, heat extraction rate, indoor and outdoor design conditions, cooling load calculation. Energy calculations and building simulation: Degree Day method, weather files, software tools for energy simulation. Implications of climate change on building energy use: Emission trends and drivers, representative concentration pathways, future weather files, climate resilience. Energy-efficient and sustainable building practices: Green buildings, passive solar architecture, sustainable construction practices, case studies. **Course References:** **1.** Heating Ventilating and Air Conditioning – Analysis and Design by McQuiston, Parker, and Spitler **2.** ASHRAE Handbook—Fundamentals **3.** Buildings. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. **4.** Green Building – Guidebook for Sustainable Architecture by Bauer, Mösle and Schwarz **5.** Refrigeration and Air-conditioning by C P Arora

SEE-619	FINITE VOLUME METHODS FOR ENGINEERS	3-0-0-9	Introduction, Governing equations and general scalar transport equation, Mathematical classification of PDEs, Mesh terminology and types, Discretization methods; Solution of discretization equations, Accuracy, consistency, stability and convergence, 2D steady and unsteady problems, BC; Errors and stability analysis; Diffusion in orthogonal and non-orthogonal meshes, Gradient calculation and discussion, Direct Vs Iterative solvers; Data-structures, TDMA, Jacobi and gauss-seidel methods; General iterative solvers; Multigrid methods, 2D convection-diffusion problems: steady, unsteady, BC; Convection-diffusion in non-orthogonal meshes, Accuracy of discretization schemes Higher order schemes and Discussion, Discretization of governing equations; BC and solution methods; Staggered and collocated formulations, Pressure-velocity coupling: SIMPLE, SIMPLER, Pressure-velocity checker-boarding Solution algorithms, Turbulence modelling; Boundary conditions and applications
SEE-620	HEAT-DRIVEN COOLING SYSTEMS	3-0-0-9	Absorption refrigeration cycle, thermodynamic properties and processes with mixtures, water/lithium bromide system, ammonia/water system. Principle of adsorption cooling, adsorption phenomena, adsorption refrigeration systems. Operating principle of desiccant evaporative cooling. Solid and liquid desiccant technology. Working principle of ejectors. Ejectors as components of refrigeration systems. **Course References:** **1.** Absorption Chillers and Heat Pumps, K. E. Herold, R. Radermacher, S. A. Klein, 2nd Edition, CRC Press, 2016. **2.** Adsorption Refrigeration Technology, R. Wang, L. Wang, J. Wu, Wiley, 2014. **3.** Desiccant Assisted Cooling, C. E. L. Nobrega, N. C. L. Brum, Springer, 2014. **4.** Ejectors for Efficient Refrigeration, G. Grazzini, A. Milazzo, F. Mazzelli, Springer, 2018.
SEE-621	BIOMASS CONVERSION AND BIOREFINERIES	3-0-0-9	The overarching goal of this course is to focus on renewable feedstocks for the chemical industry. The transition from petroleum-based chemicals to a biomass-based production system will be the central theme with a special focus on carbohydrate-based bio-feedstocks. Contents include an introduction to biomass structure and classification, classical methods of carbohydrate chemical conversions and the evolution of such technologies during the rise (and fall) of oil as an inexpensive commodity. Biorefineries, biochemical and chemical conversions leading to bioethanol, biobutanol and other downstream products. Chemicals from ethanol and ethylene. Valorization of sucrose, oxidation, esterification, sucrose-derived urethanes, polymerizable sucrose derivatives, and conversion to isomaltulose. Valorization of glucose, preparation of sorbitol, citric acid, lactic acid, acetic acid, and alkylpolyglucosides (APG's). PLA preparation (methods, industrial production). Sugar-derived polyamides and polyesters. LCA and TEA analysis. **Course References:** **1.** Valorization of Biomass to Value-Added Commodities:

			Current **2.** Trends, Challenges, and Future Prospects (Green Energy and Technology), Michael O. Daramola, Augustine O. Ayeni, Springer **3.** Biomass for renewable energy, fuels, and chemicals. D.L. Klass, Academic Press. **4.** Robert C. Brown, Biorenewable Resources: Engineering New Products from Agriculture. Wiley-Blackwell Publishing (Second Edition) **5.** Industrial Microbiology by Prescott & Dunn **6.** Shang-Tian Yang (Ed.), Bioprocessing for Value Added Products from Renewable Resources, Elsevier, 2007
SEE-622A	SUSTAINABLE ENERGY – ENABLING NET ZERO EMISSIONS	3-0-0-9	**1. Motivation& Introduction** Overview in Global and Indian context: Evolution of humankind and the increase in Energy Demand, Rampant use of fossil fuels post-industrial revolution and Greenhouse gas emissions, Efforts on both the demand side and supply side – expected scenarios and Expected GHG trajectory linked to energy use. **2. Climate Change:** Understanding Climate Change: Science, Impacts and Mitigation Options, Historical evolution of global temperatures and greenhouse gas concentrations, Different GHG and their global warming potential, regional distribution of CO2 and other GHG emissions: total and per capita, Sectoral contributions to GHG emissions, Natural sinks of GHG and Negative Emissions, impacts of global temperature increase, Mitigation options and their economics **3. Energy Demand :** Importance of demand-side interventions to address climate change: Global and in India, Energy consumption trends: by region and by sector, Need for energy efficiency, Projections of energy demand under BAU and energy efficiency scenarios, 3.1 Industrial : Role of industrial emissions, Major energy-consuming industrial sectors (Steel, cement etc.), Emissions and fuel consumption, Energy efficiency interventions and BEE efforts, Demand projections, the role of technology and policies, 3.2 Transport : Expected growth in the sector, Fossil fuel reliance and geo-political implications, GHG emissions and other pollutants, Mitigation plans for controlling emissions, Role of technologies and standards **,** 3.3 Buildings & Rural Demand : Why focus on the built environment, Projected expansion in the built environment and appliance penetration: Urban and Rural, Rural demand projections and inefficiencies in energy use, The need for energy efficiency, Initiatives and Schemes by Government and Utilities: Opportunities and Barriers, **4. Supply:** Major sources of energy generation., LCOE calculations, Carbon emissions from various sources, Expected scenarios – global and India, Role of growing renewables, Challenges 4.1 Solar: Solar as an energy source: various technologies and Relative Costs, Embedded carbon, Development over the year, Global Projections and India's potential, Expected challenges and barriers 4.2 Wind: Wind energy as an energy source: the potential and relative cost,

			Embedded carbon, Development over the years, Expected challenges and barriers 4.3 Others: Other major sources of renewable energy and their current status and expected movement:, Hydro, Nuclear, Geothermal, Biofuel, Hydrogen, Role of storage **5. Alternate Mitigation Strategies** The need for CCUS (carbon capture utilisation and storage), The scale needed to achieve climate targets, Technology and storage options, Implementation examples, Bottlenecks to scale deployment **6. Net Zero and Global Climate Discussions** What do we mean by Net Zero? Definition as per some standards, Relation of Net zero and COP commitments, Global Climate Negotiations, Social challenges **Course Reference**: **1.** Andrews, John, Nicholas Alfred Jelley, and Nick Jelley. Energy science: principles, technologies, and impacts. Oxford University Press, 2022. **2.** Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change **3.** Dubash, Navroz K. An India in a Warming World: Integrating Climate Change and Development. Oxford University Press, 2019 **4.** Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies. United Nations Environment Programme, 2022. India Energy Outlook 2021, IEA, 2021. **5.** Net Zero by 2050, IEA, 2021. **6.** Tester, Jefferson W., Elisabeth M. Drake, Michael J. Driscoll, Michael W. Golay, and William A. Peters. Sustainable Energy: Choosing Among Options. 2nd edition. MIT Press, 2012 **7.** World Energy Outlook 2022, IEA, 2022. **8.** More reference material will be prescribed during the course in various forms.
SEE-623	FUEL CELL ELECTRICAL ENERGY SYSTEMS	3-0-0-9	This course will equip students with the basics of fuel cells, models and controllers, fuel cell power system architectures, power converter design, and control for a wide variety of fuel cell applications. **1. Course Outline**: Basics of fuel cells: Introduction, operation, types of fuel cells, and modelling. **2.** Electrical characteristics of fuel cells: Electrical characteristics and efficiency in steady operation, dynamic operations with and without battery/ultracapacitor. **3.** Modeling and controllers for fuel cells: Linear and non-linear models, dynamic model, linear and non-linear controller design. **4.** Fuel cell power system architectures: Modular stack architecture, two-stage architectures, three-stage architectures, high-voltage variable DC bus architecture,

			low-voltage variable DC bus architecture, fixed low-voltage variable DC bus architecture, **5.** Power converters for fuel cell applications: DC to DC, DC to AC, interleaved converters, current-fed converters, and resonant DC-DC converters. **6.** Transportation applications: configurations of automotive fuel cell systems, power demand and efficiency, hybrid fuel cell vehicles, passenger car drive configuration, heavy-duty vehicle drive configuration, and challenges in automotive fuel cell power systems. **7.** Aerospace power applications: System performance requirements, operation, and various converter topologies. **8.** Fuel cell locomotives: System description, converter topologies, and energy management. **9.** Stationary power applications: Operation and converter topologies for smaller and larger power plants **10.** State-of-the-art fuel cell electrical energy systems: Case studies, and technical challenges for mass deployment. **Course Reference:** **1.** Bei Gou, Woonki Na, and Bill Diong: Dynamic Modeling and Control with Power Electronics Applications, CRC Press, Second Edition, 2020. **2.** M Venkatesh Naik and Paulson Samuel - "Non-Isolated Power Converters for Fuel Cell Power Sources", Lambert Academic Publishing, 2021. **3.** Frano Barbir - "PEM fuel cells – theory and practice", Academic Press. 2nd edition, 2013. **4.** Robert W. Erickson and Dragan Maksimovic - "Fundamentals of Power Electronics", Springer, Third Edition 2020. **5.** Iqbal Husain – "Electric and Hybrid Vehicles", Design Fundamentals, CRC Press, 3rd editions, 2021. **6.** M. Ehsani, Y. Gao, S. Gay, and A. Emadi – "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", CRC Press, 2005.
SEE-624A	DESIGN STRATEGIES FOR NET-ZERO ENERGY BUILDINGS	3-0-0-9	This course will equip students with the knowledge and tools to design net-zero energy buildings. The students will learn basic building design principles, passive heating and cooling techniques, renewable energy integration, lighting principles, and retrofit techniques. **Course outline:** **1.** Basic principles and overview of net-zero buildings: Introduction, vernacular architecture, measuring energy use in the built environment (site versus source energy), energy source considerations, energy and carbon, energy use metrics, energy and climate, energy targets and baseline. **2.** Thermal comfort and indoor air quality considerations: Physiological considerations in comfort, environmental comfort indices, comfort conditions, adaptive comfort, indoor air quality considerations.

			3. Fundamentals design considerations: Climate and site assessment, building mass and geometry, building type and zone. **4.** Solar geometry: Sun's motion around the earth, solar angles and time, sun-path diagrams, sunbeams, and solar heat gains. **5.** Shading: Exterior shading devices, design of overhangs and fins, egg crate shading devices, glazing as a shading element, interior shading devices, solar heat gain coefficient, roof and wall reflectivity. **6.** Passive cooling: Ventilation cooling, radiant cooling, evaporative cooling, earth cooling, and desiccant-based cooling. **7.** Building envelope: Envelope heat transfer, thermal planning, and envelope design considerations. **8.** Passive solar heating: Design considerations, direct gain systems, Trombe walls, and sunspaces. **9.** Renewable energy integration: Basic renewable energy systems and design guidelines for integrating photovoltaic systems in buildings. **10.** Lighting: Basic concepts and design strategies. **11.** Energy efficiency retrofits for existing buildings and case studies: Techniques for improving the energy efficiency of existing buildings and case studies of net-zero buildings. **Course References:** **1.** Heating, Cooling, Lighting: Sustainable Design Strategies towards Net Zero Architecture by Norbert Lechner. **2.** Net Zero Energy Design by Thomas Hootman. **3.** Heating Ventilating and Air Conditioning – Analysis and Design by McQuiston, Parker, and Spitler. **4.** ASHRAE Handbook—Fundamentals.
SEE-625	STRUCTURAL, MICROSTRUCTURAL AND SPECTROSCOPIC CHARACTERIZATION OF MATERIALS	3-0-0-9	One of the important aspects of understanding materials and their properties and establishing correlations with processing is the determination of their structure and composition at different length scales. The main objective of this course is to make the students learn different structural and compositional characterization methods, including fundamental principles, how to analyze the data and how to avoid making common mistakes that can lead to erroneous interpretations. **Course References:** **1.** Marc de Graef and Michael E. Henry, Structure of Materials, Cambridge University Press **2.** David Brandon and Wayne D. Kaplan, Microstructural Characterization of Materials, Wiley **3.** B.D. Cullity, Elements of X-ray Diffraction, Prentice Hall **4.** Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, **5.** Wiley-VCH
SEE-626M	ECOLOGICAL PRINCIPLES AND BIODIVERSITY FOR SUSTAINABILITY	3-0-0-5	Minimisation of adverse impacts on ecology and biodiversity is sine qua non for the long-term sustainability of projects and the welfare of human society. Concomitantly, numerous projects

have been utilising ecological processes and biodiversity services as cost-effective, efficient, and carbon-negative substitutes for anthropogenic constructions in the fields of water purification, waste treatment, and amelioration of local climatic conditions. To these ends, a knowledge and understanding of ecological processes and biodiversity is pivotal for the students of sustainability. This course intends to provide this knowledge and understanding using case studies from field situations to build up on conceptual frameworks.

Expected Learning Outcomes

1. Conceptual and working knowledge of Ecology and ecological processes.
2. Conceptual and working knowledge of Biodiversity, its advantages, and threats to biodiversity.
3. Exemplar understanding of utilisation of ecological processes and biodiversity for sustainable works.

Course outline:

1. Introduction to Ecology, Biodiversity, and Sustainability
2. Biodiversity – Organisation of the living world
3. Biodiversity – Economic valuation
4. Ecological interactions
5. Introduction to Behavioural Ecology
6. Ecological Energetics – Introduction, food chains, food webs, and trophic levels
7. Ecological Energetics – Biogeographical cycles
8. Population Ecology – Growth and regulation of populations
9. Community changes and ecological succession
10. Biogeography and geographical distributions
11. Biogeography – Push and pull factors.
12. Human Ecology – Introduction and impacts in Anthropocene.
13. Human population growth and requirements
14. Threats to biodiversity and ecology
15. Case studies – Impacts of oil spills
16. Case study – Impact of plastics on Ecology and Biodiversity
17. Climate change and its impacts on Ecology and Biodiversity
18. Conservation of biodiversity – In situ conservation
19. Conservation of biodiversity – Ex situ conservation
20. Employing Ecology and Biodiversity for sustainable development

Course Reference:

1. Krebs, C. J. The experimental analysis of distribution and abundance. New York: Harper and Row.,
2. Odum, E. P., & Barrett, G. W. Fundamentals of Ecology. Philadelphia: Saunders.,
3. Awadhiya, A., Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis,

			Selected articles/papers as referred to in the lectures.
SEE-627	ELECTRIC VEHICLES	3-0-0-9	Electric vehicles (EVs) are gradually replacing conventional vehicles due to climate concerns, shortage of oil resources, and energy security. EVs enable the usage of energy from renewable energy sources such as hydro, solar, and wind. At present, there are more than 15 million EVs on the road and several car manufacturers are introducing new models. Based on this need, this course presents several features of EVs for beginners to understand. **Course outline:** 1. Introduction: History, Benefits, Types of EV Comparison between ICE vehicles and EV Details of Commercial EVs, 2. Basics of EV: Motor drives Energy sources Charging Vehicle to Grid Subsystems, 3. Vehicle dynamics: Dynamic, Equations Modeling, MATLAB Simulations, 4. Power Electronics: DC-DC converters, DC-AC inverters, Speed Control, Loss analysis 5. EV Charging: AC Charging DC Charging, Battery Swapping, Wireless Charging, On-road Charging **Course Reference**: **1.** Iqbal Husain, ELECTRIC and HYBRID VEHICLES, Design Fundamentals, CRC Press, 2003., M. Ehsani, Y. Gao, S. Gay and A. Emadi, Modern Electric, **2.** Hybrid Electric, and Fuel Cell Vehicles, CRC Press, 2005 **3.** “Power Converters for Electric Vehicles”, L. Ashok Kumar and S. Albert Alexander, CRC Press, 2020., **4.** "Fundamentals of Power Electronics", Robert W. Erickson and Dragan Maksimovic, Springer, Third Edition 2020. **5.** “Electric Vehicles: Modern Technologies and Trends”, N. Patel, A. K. Bhoi, S. Padmanaban, Springer, 2020. **6.** "Modern Electric Vehicle Technology”, C.C. Chan, K.T. Chau, Oxford University Press, 2001.
SEE-628	Policy Processes and Analytical Methods: Application to Climate Policies	3-0-0-9	Students will learn quantitative methods used in arriving at the right data points needed for informed policy making. It will also help students understand policy frameworks used as the basis of policy formation. Students will be trained in creating linkages between these tools and frameworks and their use in creating various policy options in the context of achieving global climate objectives. Throughout the course, concepts are illustrated with examples from energy and climate policy. **Course Reference:** **1.** Alessandro Rubino, Alessandro Sapio, and Massimo La Scala, Handbook of Energy Economics and Policy: Fundamentals and Applications for Engineers and Energy Planners, 2014. **2.** Ang, Alfredo H-S., and Wilson H. Tang. Probability Concepts in Engineering: Emphasis on Applications to

			Civil and Environmental Engineering. 2nd ed. New York, NY: John Wiley & Sons, 2006. **3.** Drake, Alvin W. Fundamentals of applied probability theory. Mcgraw-Hill College, 1967. **4.** Frank Fischer, Gerald J. Miller, and Mara S. Sidney, Handbook of Public Policy Analysis: Theory, Politics, and Methods, 2007. **5.** Michael Howlett and Ishani Mukherjee, Handbook of Policy Formulation, 2017. **6.** Neufville, Richard de. Applied Systems Analysis: Engineering Planning and Technology Management. McGraw-Hill, Inc; New York, New York, USA, 1990. **7.** Pindyck, Robert S. The social cost of carbon revisited, Journal of Environmental Economics and Management, Volume 94, 2019. **8.** Webster, Mort. Communicating Climate Change Uncertainty to Policy-Makers and the Public. Climatic Change 6, 2003
SEE-629M	Ecology, Equity and the Economy		Natural capital forms the foundation for economic activities. The real wealth of nations lies in the mineral and biological capital, social and human capital. The economic wealth is driven by how efficiently the nation is able to convert this into financial capital. In the process of creating a 'medium of exchange' there is an inevitable decline in the stock of non-renewable resources and pollution of renewable resources. As the economy grows, the land use changes. Urban sprawls, infrastructure, mining, dams, are responsible for deforestation, loss of habitats and the degradation of natural ecosystems. Technological progress has pushed up economic growth. However, the distribution of income and wealth has hardly been equitable in society. The consequences of economic growth are showing up at a planetary level in climate change. The frequency and intensity of natural disasters has increased in the last decade and has imposed a burden on the economy. Can we afford to continue such a form of economic growth? In this course, participants will learn about sustainable development and why markets fail to address issues like resource depletion, pollution and income inequality. Participants will also understand why farmer poverty persists in India. The course will encourage discussions with briefcases. **Course References:** **1.** This Fissured Land - Madhav Gadgil & Ramchandra Guha; Oxford University Press; 2nd Edition **2.** Ecology, Equity and the Economy – Gurudas Nulkar; Ecological Society, 2nd Edition **3.** Principles of Sustainability – Simon Dresner; Routledge; 2nd Edition **4.** How the World Really Works - Valclav Smil; Penguin; 2022 **5.** Sapiens - Yuval Noah Harari; Random House; 3rd Edition **6.** The Third Curve – Mansoor Khan; Mansoor Production, 1st Edition

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<tr><td></td><td></td><td></td><td>7. Selected essays and articles</td></tr>
<tr><td>SEE-888</td><td>INTRODUCTION TO PROFESSION AND COMMUNICATION</td><td>1-0-0-3</td><td>Introduction to Profession - The need for sustainable energy engineering in the current context, key developments, research & development trends, career options
Professional Ethics - Workplace: perspective and best practices Collaboration: best practices
Mechanics of Publishing / Patenting & Bidding for Projects and Other Resources
• Various stages of paper publishing in the Journal
• Dealing with rejection, reviewer' comments
• Intellectual Property Rights: What can be patented?
• Mechanics of project submission & approval
• Developing laboratory and attracting students
• Industrial teamwork, international collaboration
Technical Writing
• Basic principles of scientific/technical/report writing
• Developing a pattern of organization
• Common types of arguments
• Scientific Journal papers writing
• Editing for emphasis
Oral Presentation
• Presentation skills for conferences
• Slide preparation and representation of data Mitigation plans for controlling emissions.
Plagiarism
• What is it?
• Author's responsibilities and rights
• Plagiarism checking and avoidance aids
Course Reference:
1. T.N. Huckin and L.A. Olsen, Technical Writing and Professional Communication for nonnative speakers of English, second (international edition, McGraw Hill (1991)
2. Michael Alley, The craft of Scientific Writing, Springer Pub, 3rd Edition, (1996).</td></tr>
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