

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**NAME OF DEPARTMENT:** Department of Hydro and Renewable Energy**Subject Code:** HRO-101**Course Title:** Small Hydro Power Development**L-T-P:** 3-0-0**Credits:** 03**Subject Area:** OEC**Course Outlines:**

Necessity and importance of harnessing small hydro power; Small hydro power scenario and type of schemes; Site selection and investigations, Environmental aspects, Flow duration, water power studies; Diversion structures & power channels, Desilting arrangements, forebay tank and balancing reservoir, Penstock and power-house building; Types of turbines and their selection, Gates and valves, Governing system (mechanical & electrical); Types of generators– synchronous and induction, Protection & controls, Power evacuation system; Cost estimation, financial, and policy aspects.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRO-102

Course Title: Energy Conservation and Management

L-T-P: 3-0-0

Credits: 03

Subject Area: OEC

Course Outlines:

Definition of energy conservation, energy management, Energy conservation opportunities, general principles, Types, procedures, and instruments for energy auditing in an industry, Assessments of technical merits of energy conservation methods and techniques in specific applications, energy saving methods, energy strategy, and industrial energy applications, Energy conservation in steam boilers, engines; principles, types, and applications of different heat recovery systems, Energy conservation in electrical motors, transformers, and conductors, Energy conservation in illumination in building shells, Material conservation and recycling, waste to energy.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**NAME OF DEPARTMENT:** Department of Hydro and Renewable Energy**Subject Code:** HRE-102 **Course Title:** Introduction to Renewable Energy Resources Technology**L-T-P:** 3-0-0**Credits:** 03**Subject Area:** ESC

Course Outlines: Introduction to energy sources, reserves and estimates, global energy scenario, renewable energy and its environment implications, global warming and climate change; Solar energy and its availability, types of solar radiation, solar angles, solar thermal and solar photovoltaic based power generation; Wind energy and its availability, types of wind mills/turbines and their characteristics, elementary design principles, Betz limit; Biomass and its sources, Thermo-chemical processes - biomass gasification and pyrolysis, Biochemical processes – anaerobic digestion and fermentation, Biodiesel and Bioethanol, Biorefinery concept; Hydropower Technology: Planning and investigation, civil works, electromechanical equipment; New energy technology, ocean and tidal energy, geothermal energy, hydrogen energy.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**NAME OF DEPARTMENT/ CENTRE/SCHOOL:** Department of Hydro and Renewable Energy**Subject Code:** HRC-101**Course Title:** Computer Programming**L-T-P:** 3-0-2**Credits:** 04**Subject Area:** PCC

Course Outlines: Introduction to computer systems: CPU organization, memory and input-output devices; Number systems, Fixed and Floating point numbers; Errors and Approximations; Basic Concepts of Programming Language: Algorithm; Input/output, constants, variables, expressions and operators; Conditions and selection statements; Looping and control structures; File handling; data structures; pointers; Modular Programming: Functions, parameters, scope and lifetime of variables, passing by value, passing by reference, passing arguments by constant reference; Design of functions and their interfaces, recursive functions; Function overloading and default arguments; Library functions; Object Oriented Programming: Classes and Objects; Constructors and Destructors; Operator Overloading and Type Conversions; Inheritance: extending classes; Virtual Functions; Polymorphism; Manipulating Strings.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/ CENTRE/SCHOOL: Department of Hydro and Renewable Energy

Subject Code: HRC-102

Course Title: Energy Resources, Economics and Environment

L-T-P: 3-0-0

Credits: 3

Subject Area: PCC

Course Outlines: Global Trends in Energy Use, Disaggregation by supply, end use, Energy and Environment, The Kaya Identity, formulation of energy Sankey diagrams; Resources & Reserves Growth Rates in Consumption, Primary energy analysis, net energy analysis examples; Fundamental concepts of economics, decision-making process, investment appraisal methods; Project cost and benefits, economic and financial models, cost of saved energy. Economics and the Environment, Business and the Environment; Environmental effects, recent successes in abatement of acid rains, lead emissions, and ozone depletion, uniqueness of climate change problem; The Kyoto protocol, the Paris agreement, the Kigali agreement, myths and realities related to global climate change, nuclear waste, thermal pollution. Environmental impacts of fossil fuels, nuclear energy, hydro energy, solar energy, wind energy and biomass energy. Water-energy nexus; Sustainability: Definition and Challenges, sustainability assessment. Future energy scenarios

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/ CENTRE/SCHOOL: Department of Hydro and Renewable Energy

Subject Code: HRC-104

Course Title: Renewable Energy Resources Development and Technology

L-T-P: 3-0-0

Credits: 03

Subject Area: PCC

Course Outlines: Need for Renewable energy and its environmental implications; Solar Energy Technologies: Types of solar radiation and their assessment, solar constant, solar geometry, solar thermal and solar photovoltaic-based power generation; Wind Energy Technology: Availability of wind resources, types of windmills/turbines and their characteristics, elementary design principles, Betz limit; Biomass Energy Technologies: Sources, quantitative estimation and characterization, Thermo-chemical processes, Biochemical processes, Biodiesel and Bioethanol, Biorefinery concept, Waste to energy; Hydropower Technology: Planning and investigation, civil works, electromechanical equipment, case studies; Ocean and tidal energy, geothermal energy, hydrogen energy.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/ CENTRE/SCHOOL: Department of Hydro and Renewable Energy

Subject Code: HRE-101

Course Title: Energy Resources, Economics and Sustainability

L-T-P: 3-0-0

Credits: 03

Subject Area: ESC

Course Outlines: World energy scenario, primary energy demand and supply, trends in energy use patterns, energy and development linkage, formulation of energy Sankey diagrams; Energy chain, primary energy analysis, net energy analysis examples; Energy economics - simple payback period, time value of money, internal rate of return, net present value, life cycle costing, levelized cost of energy; Financial analysis of renewable energy projects, government incentives, and disincentives; Environmental impacts of energy use - air pollution, solid and water pollution, energy-water nexus; Introduction to Life cycle assessment (LCA) and its relation with environmental decision support, Case studies.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**NAME OF DEPARTMENT:** Department of Hydro and Renewable Energy**Subject Code:** HRC-302**Course Title:** Energy Systems Modelling and Simulation**L-T-P:** 3-1-2/2**Credits:** 4**Subject Area:** PCC

Course Outlines: Introduction: Energy system modelling: definition and history, energy chain, primary energy analysis. Modelling overview: levels of analysis, steps in model development, integrated assessment modelling. Quantitative Techniques: Interpolation - polynomial, lagrangian. Curve-fitting, regression analysis. Systems Simulation: information flow diagram, solution of a set of algebraic equations, successive substitution, Newton Raphson, Examples of energy systems simulation. Optimisation: Objectives/constraints, problem formulation, unconstrained problems-necessary & sufficiency conditions. constrained optimisation lagrange multipliers. Linear and dynamic programming: simplex tableau, sensitivity analysis. dynamic programming. Numerical solution of differential equations- overview, convergence, accuracy. Case studies in energy systems problems.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRC-304

Course Title: Energy Storage Systems

L-T-P: 3-0-0

Credits: 3

Subject Area: PCC

Course Outlines: Introduction and need for energy storage systems (ESS); National and global status of ESS; Overview of energy storage technologies: thermal, mechanical, chemical, electrochemical, electrical, comparison and applications of ESS; Mechanical Energy Storage: Types and working principle; Pumped hydro storage, national and international status, fixed and variable technology; innovative PSP technologies; Chemical Energy Storage: Types and working principle; Battery energy storage technologies, hydrogen energy storage, national and international status; innovative chemical energy storage technologies; Thermal Energy Storage: Types and working principle; sensible vs. latent heat thermal energy storage; national and international status; innovative thermal energy storage technologies; ESS for e-Mobility and Stationary Applications: Charging infrastructure, grid to vehicle (G2V), vehicle to grid (V2G), grid-scale energy storage technologies, sizing energy storage technologies; Policies and regulations; Financial aspects; Policies in India and globally; key issues in indigenization of energy storage technologies and mitigation measures.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-403

Course Title: Electric Vehicle Technology

L-T-P: 3-1-2/2

Credits: 4 **Subject Area:** PEC

Course Outlines: Need for transportation electrification, global scenario, history of modern electrified transportation systems, introduction to basic theoretical concepts forces acting on vehicles, and electric drive rating; Vehicle architectures, powertrain components, electric traction motor sizing and performance, practical electric vehicle design considerations, standard drive cycles; Power electronic switches, DC/DC converters, DC/AC converters, modulation schemes and traction motor control; Batteries, cell balancing circuits, and battery pack management; Hybrid energy storage systems and alternative vehicle architectures; Battery charging infrastructure, charging requirements, types of charging, AC/DC converters; Types of battery chargers, on-board chargers, off-board chargers, wireless charging electric vehicle charging and renewable based electric charging; Standards, policies and regulations.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-405

Course Title: Energy System Dynamics

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outlines: Purpose and concepts of system dynamics; Complex systems; Purpose and overview of the modeling process; Fundamental modes of dynamic behavior; Interactions of the fundamental modes; Other modes of behaviour; Causal diagram notations; Guidelines for causal loop diagrams (CLDs); Conceptualization with CLDs; Policy analysis with CLDs; Explaining policy resistance; Identifying stocks and flows; Mapping stocks and flows; Relationship between stocks and flows; First-order systems; Positive feedback and exponential growth; Negative feedback and exponential decay; Multiple loop systems; Nonlinear first-order systems; Modeling S-shaped growth; Delays; Structure and behavior of material delays vs. information delays; Validation and model testing; Principles for modeling decision making; Formulating rate equations; Table functions; Eliciting model relationships interactively; Case studies on the application of system dynamics in energy systems.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-409

Course Title: Hydropower Planning and Management

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outlines: Development and purpose of water resources, electricity act, constitutional provisions, water policy, hydropower policy, electricity regulation; Types of hydro projects, components including civil works and E&M equipment, site configurations, hydropower planning on existing structures and new sites; Environmental impact assessment, cumulative impact assessment, environmental flows; Financing of projects, cost estimation, financial and economic analysis, techno-economic evaluation, tariff computation; Methods for stream gauging, rainfall, runoff and its estimation, peak flood estimation, demonstration of discharge measuring instruments; Hydrological analysis, flow duration studies, assessment of power potential and determination of installed capacity; Site selection, surveys and investigations; Types of project reports and their relevance, methods of project implementation, project planning, schedules, operation and maintenance, management of hydropower plants.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-414

Course Title: Solar PV concepts, technology and application

L-T-P: 3-1-2/2

Credits: 4

Subject Area: PEC

Course Outlines: Introduction to photovoltaic technology; Scenario and status of solar photovoltaic technology in India and the World; Solar energy mission, policies and financing. Solar radiation – basic concepts, assessment and variability; Photovoltaic metrology. Fundamentals of semiconductors; Structure and working of solar cells; Characteristics and electrical models of solar cells. Overview of solar cell technologies and related concepts. Photovoltaic system technology: grid-connected systems/ stand-alone systems/ hybrid systems. Components of solar PV system; Characteristics and operation of solar modules and solar PV systems. Design of grid-connected PV plants and stand-alone PV plants; Operation and maintenance of Solar PV systems.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-416

Course Title: Wind Energy Technology

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outlines: Wind energy, Causes of wind flow; Wind energy scenario in India, properties of wind, wind velocity, estimation of power in wind; Types of wind turbines, characteristics, construction of wind mills; Aerodynamic considerations of wind mill design, wind stream profile, rotor blade profile and cross section, Betz limit; Drive system-gears, electrical machines for wind energy systems, synchronous and asynchronous generators and power electronics. Integration of wind energy systems to electrical networks, regulating and control systems for wind mills; Tip Speed Ratio, Coefficient of Power, Cut in Speed, Cut out speed; Wind energy potential estimation and site selection; wind farms, cost estimation of the energy from wind energy conversion system.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-417

Course Title: Hydrogen Energy and Fuel Cells

L-T-P: 3-1-2/2

Credits: 4

Subject Area: PEC

Course Outlines: The market for hydrogen: Process industries, oil refineries, petrochemicals, ammonia industry, methanol industry, iron and steel industry. Conventional methods of hydrogen production: hydrogen from coal, natural gas, hydrocarbon process industry, chlor-alkali industry. Hydrogen from renewable sources: Water splitting, gasification, pyrolysis, electrolysis, photo-electrochemical, Biological- anaerobic digestion, Dark fermentation and photo fermentation, Hydrogen storage, and distribution: general storage methods, compressed storage-composite cylinders, metal hydride storage, chemical hydride storage and cryogenic storage, distribution techniques, mass shipping of hydrogen. Hydrogen utilization-fuel cells: types, advantages and drawbacks, applications and integration with other renewable energy sources. Thermodynamics of fuel cells: Reversible cell potential, Energy conversion Efficiency. Electrochemistry of fuel cells: Electrode potential and cell polarization, Activation kinetics, voltage loss due to charge transport, Mass transport. Scale-up issues: fuel cells-contact resistance management, flow field design. Case Studies.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-418

Course Title: Policy, Regulations and Financing for Energy

L-T-P: 3-0-0

Credits: 3

Subject Area: PEC

Course Outlines: Introduction and scope of energy economics, impact of energy and energy use. Energy demand and supply: Determinants, variability and uncertainty of renewable energy sources; elasticity of energy demand and supply; consumer and producer demand; complementarity/substitution issues; forecasting energy demand: approaches, tools and techniques. Energy regulation and acts: Theories, regulatory mechanism and governance, energy policy, policy interplays and trade-offs. Electricity tariff, Availability Based Tariff (ABT), tariff models: open access, licensing, trading; case studies. Power markets: Economic basics, vertically integrated utilities vs re-structured power markets, demand side aspects, power purchase agreements and market risks. Organization of wholesale power markets, long term, day ahead, real-time market, power market trading; Role of stakeholders. Financing of energy projects; Challenges in integration of renewable resources: Role of flexibility and storage; Policy and regulatory framework for renewable energy development: RPO, FiT, RECs; Renewable energy forecasting, scheduling, dispatch and deviation settlement regulations.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-419

Course Title: Biomass production and utilization

L-T-P: 3-1-2/2

Credits: 4

Subject Area: PEC

Course Outlines: Biomass as an energy source: forest and agro residues, aquatic biomass, animal waste, municipal solid waste, biomass production through energy plantation, agroforestry, short rotation intensive culture, biomass harvesting, handling, and pre-conversion processes; Biomass properties: particle and bulk density, particle size distribution, ash content and volatile matter in biomass, heating value, biomass characterization procedures, proximate and ultimate analysis, ash deformation and fusion characteristics, calorific value; Thermo-chemical conversion processes: briquetting/size reduction, biomass combustion, co-generation, pyrolysis, gasification, torrefaction. Chemical conversion processes: vegetable oils, bio-diesel, transesterification, refining, fuel properties. Biochemical conversion processes: biogas production, biogas plants, bioethanol production, advanced fermentation technologies; Sustainability aspects: Integrated biorefinery, simulations using ASPEN Plus, techno-economic analysis, life cycle assessment.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-502

Course Title: Energy-Food-Water Nexus

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outlines: Energy, food, Water (E-F-W) and Sustainable Development Goals (SDGs); Global and Indian energy, water, and food scenario; Transdisciplinary approach towards nexus; Interdependencies and interrelationships between the three resources. Energy: market, sources and applications; Energy policies; Energy-Water interactions; Energy-Food interactions; Role of Renewables; Challenges and opportunities. Water: sources and applications; water footprint; Water-Food interactions; Water security and policies; Challenges and opportunities. Food dependence on water and energy: Industrialization of the agri-food system; Case studies in food production and processing industry. Methods and models; Multi-criteria decision making and Sustainability analysis methods; Complexity and Uncertainty; Resource management; E-F-W nexus at local and regional levels; Sustainable practices for water and energy consumption; role of technology in the nexus; Impact of nexus on economy, environment, policies, and community engagement. Interdisciplinary case studies: Formulation and analysis.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Hydro and Renewable Energy

Subject Code: HRL-503

Course Title: Environmental Planning and Management

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outlines: Basic ecological principles, pyramids, Nutrient cycles, Environmental components, policies and legislations, Environmental economics, valuation and natural resource planning; Life Cycle Assessment, Environmental Impact Assessment (EIA), Methods of EIA, Environmental Clearance, EIA Case studies. Environmental planning: Planning and its types, PDCA, Strategic Planning, Organizational Culture and Environmental policy, Stakeholder requirements. Environmental management: Approaches, Environmental Management System Frameworks and Components; ISO 14001 model Implementation, Operation, and Review, Corporate Social Responsibility, Case study. Design for the environment: Strategies, Green Design Framework, Environmental risk assessment and management, Circular economy, Environment compatible growth. Analytical and Graphical Tools: Cause-Effect or Ishikawa diagram; Analytic Hierarchy Process; Pareto curves.