RENEWABLE AND ALTERNATIVE ENERGY SOURCES – 9 CFU LM

Coccia (72 hours)

Introduction to energy sources. Energy in the global context. Influence of economic and demographic growth on global energy needs (OECD countries, non-OECD countries). Energy prices (oil price, natural gas price, CO_2 price). Demand and supply of primary energy (coal, oil, natural gas, uranium, renewables). Community energy policies. Fuels. Physical classification (solids, liquids, and gases) and classification based on origin (natural or synthetic).

Geothermal Energy. General aspects. Components of a geothermal system: source, storage reservoir, heat transfer fluid. Classification of geothermal sources by low, medium, and high enthalpy. Geothermal sources: hydrothermal, geo-pressurized, and petrothermal. Steam-dominant and water-dominant systems. Uses of geothermal waters based on temperature. High-enthalpy geothermal plants for electricity generation: backpressure system, condensing system, binary plants. Geothermal probes. Environmental impact of geothermal systems. Geothermal energy in Italy: number of plants and electricity production. Geothermal for district heating worldwide.

Solar Energy. Emission spectrum. Direct and diffuse solar radiation. Calculation of solar radiation. Measurement of solar radiation. Technologies for direct conversion of solar energy into heat. Low, medium, and high-temperature solar thermal systems. Types and designs of different collectors (materials, operation, cost, working temperatures of heat transfer fluids, efficiencies, and use cases). Thermal balance of flat-plate collectors. Instantaneous efficiency. Measured efficiency. Parabolic-cylindrical collectors. Instantaneous efficiency. Other types of collectors (parabolic and parabolic-cylindrical collectors). Heat transfer fluids (water, steam, mineral oils, synthetic oils, liquid metals, molten salts). Components of a solar thermal system circuit (pumps, safety valves, expansion tanks, air release valves, thermal energy storage tanks). Open or closed circuits with natural or forced circulation. Solar tower systems. Systems with solar concentrators. Thermal energy storage technologies: solar ponds. Trombe walls. Photovoltaic Solar Energy: Electrical conduction in metals. Current density. Charge density. Overview of band theory. Crystal structure and conduction in semiconductors. Pure or intrinsic semiconductors. Extrinsic or doped semiconductors. Diffusion current. p-n junctions. Photovoltaic effect. Photoelectric effect. Photovoltaic cell. Theoretical maximum efficiency of a photovoltaic cell. Current-voltage characteristic curve. Photovoltaic cell characteristic curve as a function of temperature and solar radiation. Types of photovoltaic cells. Monocrystalline silicon cells. Czochralski method for cell production. Anti-reflective coating (ARC) treatments. Polycrystalline silicon cells. Amorphous silicon cells. Thin-film cells. CdTe (Cadmium Telluride) cells. Multi-junction cells. Photovoltaic

module. Interconnection of modules. Photovoltaic strings. PV field diagram (inverters, transformers, and delivery points). Shading and bypass diodes. Calculation of photovoltaic panel efficiency. Basic sizing of a photovoltaic system. Concentrated photovoltaic (CPV) systems (solar receiver, solar concentrator, concentration factors, acceptance angles). Diffractive and reflective optical concentrators, tracking systems. Disposal and recycling of a PV system at end of life.

Wind energy. Kinetic energy of the wind. Betz limit. Relationship between wind speed and power: power curve. Capacity factor. Energy production. Wind speed and direction statistics for a site. Vorticity factor. Horizontal and vertical axis wind turbines (specific characteristics). Rotor diameters. Components of a wind turbine. Wind map of Italy and wind resources in Europe. Estimation of wind speed at height (Hellmann's formula). Anemometers for wind speed measurement. Wind duration curve. Estimation of the maximum power extractable from a wind turbine based on characteristic curves. Wind atlas. Wind farm diagram. Offshore wind. Environmental impact of a wind farm (noise, electromagnetic interference, visual impact, effects on flora and fauna, indirect emissions). Economic aspects: installation, operation, and maintenance costs. Aerodynamics of the wind blade and the resulting effect of air flow on an airfoil. Wind farms. Wake effects and Jensen model. Flickering.

Biomass energy. Classification, composition, and types of biomasses. Characterization of residual lignocellulosic biomass. Energy conversion. Conventional and innovative pretreatments. Valorization of by-products from energy conversion. Thermochemical conversion: technologies and examples. Biochemical conversion: technologies and examples. Focus on the innovative production of biohydrogen from biomass. Definition of waste. Commodity characteristics and energy content of Municipal Solid Waste (MSW). Disposal systems: separate collection, landfills, composting, waste-to-energy, and incineration. Thermochemical destruction technologies: grate furnaces, rotary drum furnaces, fluidized bed furnaces, gasification, pyrolysis, plasma technologies, electric fusion furnaces. Pollutant reduction. Treatment and waste production in Italy and Europe. Mechanical Biological Treatment (MBT). Refuse-derived fuel (RDF). Brief overview of environmental aspects related to the management of biomass and waste-to-energy conversion plants. Methodology for quantifying odor impact using dynamic olfactometry according to UNI EN 13725:2022.

Hydrogen and Fuel Cells. Generalities and physical properties of hydrogen. Current uses, production chain, and production methods: electrolysis, steam reforming, gasification, biological processes, alternative methods (photoelectrolysis, sonophotolysis). Hydrogen storage: in liquid phase, with metal hydrides and carbon nanostructures, with ammonia, in solid phase through clathrate hydrates. Storage and transport costs. Electrochemical energy conversion systems. Operating principle of a hydrogen-fed fuel cell. Anodic and

cathodic reactions. Thermodynamics of fuel cells. Polarization curve. Fuel cell efficiencies: thermodynamic, voltage, and current. Effect of pressure and temperature on cell performance. Main types of fuel cells. Low-temperature cells: AFC, PEFC, PAFC, DMFE. High-temperature cells: MCFC, SOFC.

Nuclear Energy. Radioactivity. Nuclear fuels. Dosimetry: absorbed dose, equivalent dose. Fission reaction and control systems. Nuclear reactors. BWR (Boiling Water Reactor), PWR (Pressurized Water Reactor), PHWR (Pressurized Heavy Water Reactor), LWGR (Light Water Graphite Reactor), GCR (Gas Cooled Reactor) plants. Fast breeder reactors (FBR). Nuclear power plants worldwide. Nuclear energy in Italy. Economic aspects. Fusion reaction. Radioactive waste. Classification and management of radioactive waste. New technologies SMR/AMR (Small Modular Reactor/Advanced Modular Reactor). Global nuclear electrical capacity. Nuclear costs.