

Introduction to Energy Sources

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Key concepts, categories, advantages & challenges – organized for quick reference.

1. What Is Energy?

Term	Definition
Energy	The ability to do work or produce heat. Measured in joules (J) or kilowatt-hours (kWh).
Power	Rate at which energy is used or generated. $1\text{ kW} = 1\text{ kJ/s}$.
Renewable vs. Non-renewable	<i>Renewable</i> : replenished on a human timescale (e.g., sunlight). <i>Non-renewable</i> : finite reserves that deplete over time (e.g., coal).

2. Major Energy Source Categories

Category	Typical Sources	Primary Conversion Process	Typical Uses
Fossil Fuels	Coal, crude oil, natural gas	Combustion → heat → steam turbine → electricity or direct heat	Power plants, transportation, industry
Nuclear	Uranium-235, Plutonium-239	Nuclear fission → heat → steam turbine → electricity • Photovoltaic (PV) cells → electricity	Base-load electricity
Renewables – Solar	Sunlight (photons)	• Solar thermal → heat → steam turbine • Photovoltaic (PV) cells → electricity	Rooftop/utility PV, water heating, CSP plants
Renewables – Wind	Wind kinetic energy	Wind turbines → mechanical rotation → generator → electricity	Utility-scale farms, distributed turbines
Renewables – Hydro	Flowing water (rivers, dams)	Water turbine → generator → electricity	Large dams, run-of-river plants
Renewables – Biomass	Wood, agricultural waste, algae	Combustion or anaerobic digestion → heat or biogas → electricity/heat	Rural heating, biofuels

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Category	Typical Sources	Primary Conversion Process	Typical Uses
Renewables – Geothermal	Earth's internal heat	Steam or hot water wells ? turbine ? electricity or direct heating	District heating, geothermal power plants
Emerging – Ocean	Tides, waves, thermal gradients	Tidal turbines, wave converters, OTEC (Ocean Thermal Energy Conversion)	Niche coastal installations

3. Comparative Overview

Parameter	Fossil Fuels	Nuclear	Solar PV	Wind	Hydro	Biomass	Geothermal
Carbon Emissions	High (combustion)	Low (operational)	Near? zero	Near?zero	Near?zero	Moderate (combustion)	Near?zero
Availability	Widely distributed (but depleting)	Limited to uranium deposits	Global, day?time only	Global, wind? dependent	Site? specific (water resources)	Depends on feedstock logistics	Site? specific (tectonic activity)
Capacity Factor (average % of max output)	40?80?%	80?90?%	15?25?%	25?45?%	30?60?%	60?80?%	70?90?%
Typical LCOE (USD/MWh, 2023)	40?120	90?130	30?60	35?70	40?80	70?120	50?100
Key Advantages	Established infrastructure, high energy density	Stable base ?load, low operating emissions	Scalable, modular, silent	Fast ramp ?up, low operating cost			