Different approaches to more rapid innovation adoption cycles

Attribute	Brief Description- (shortened here for ease of reference)	Past Examples	Example that can benefit from this rapid innovation cycle adoption
Small enough unit size to be massed produced	Small units are prototyped and tested quickly before factories are built	PV Li-ion batteries	Heat Pumps Fuel Cells
Modularity	Modularity confers many of the same benefits as small unit size but can also apply to larger units that cannot be massed produced but can be standardised and added sequentially to a facility. Stepwise additional	PV Aluminium smelting	Electrolytic hydrogen routes for chemical production Small modular nuclear reactors Standardised building retrofits
Offers services valued by consumers	Technologies need to be first taken up in niche markets where a small number of consumers are willing to pay a premium for specific benefits, such as low carbon for learning, building network effects and future application	Passenger cars Smart thermostats LED's Micro-mobility	Autonomous, connected, electric and shared vehicles Connected appliances Building-integrated PV Decentralised energy trading
Spillovers (strong synergies with technology advances elsewhere)	Shared between researches and engineers form different sectors, reducing the need for dedicated energy R&D as they become simultaneously beneficial	Combined-cycle gas turbines (from jet turbines) PV (from semiconductors) Li-ion for EV's (from Li-ion for consumer products Offshore wind and geothermal (from oil and gas)	CCUS (from oil and gas exploration, chemical catalysis and gas separation) Batteries, fuel cells and electrolysers (from each other and other electrochemical technologies) Biofuels (from agriculture Smart connected energy
Can be used as a drop-in replacement or bolt-on device	A new technology can be adopted more quickly if it requires no changes to associated equipment or infrastructure as it is fully compatible with the dominant existing means of the energy service provision	Certain biofuels, e.g. Hydrotreated vegetable oil Biomethane Catalytic converter Desulphurisation	Hydrogen-based synthetic fuels Electric vehicles using existing road and electricity infrastructure Bio jet fuels

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Replaces hardware or labour with digital solutions	Many recent energy sector innovations have replaced manual or analogue equipment or infrastructure with digital ones, adding more commercial value.	Seismic geological exploration Power Grid management	Autonomous, connected, electric and shared vehicles Passive demand response Digital twin O & M 3D printing
Minimal dependence on improvements in other technologies in the energy value chain	For instance, the success of CO2 capture depends on simultaneous developments in R&D as each coupled element in the value chain can slow the pace of innovation	Biomass power generation Nuclear LED's Coal gasification	Renewables plus storage options Enhanced smelting reduction-based steel
Minimal need for adaptation to local conditions	Some technologies, such as batteries, may need to be adapted to local climatic conditions when they are deployed in a new region of temperature extremes, swings or weather conditions or variance in fuel supply electricity supply or water quality.	Internal combustion engines Turbines	Novel battery chemistries Electrolysers Fuel Cells

 The examples illustrated are ones chosen by IEA to help relate the attribute to the example of technology, innovation, or process change