MAIN INDUSTRIAL DEPENDENCE	RARE EARTH ELEMENT	CURRENT DEPENDENCE RISK	GRAPHENE OPPORTUNITY	MARKET IMPACT	READINESS
Optical Glass, Catalys Ts, NiMH Batteries	Lanthanum (La)	Price volatile	Graphene-enhanced catalysts and electrodes reduce La loading	Lower catalyst cost, improved efficiency, reduced import reliance	Deployable in composites
Catalysts, Glass Polishing, UV absorbers	Cerium (Ce)	Vulnerable in polishing and UV filters	Graphene oxide replaces Ce as UV absorber and catalyst support	Cuts Ce demand in large-volume sectors; costs & ESG win	Deployable (depends on OEM integration)
NdFeB Magnets (minor), Alloys	Praseodymium (Pr)	Needed for high performance magnetic alloys	Graphene-based carbon magnets (R&D) offer REE-free path	Long-term strategic independence from Pr/Nd Supply	Mid-term R&D
High Performance Magnets (EVs, turbines)	Neodymium (Nd)	Huge geopolitical risk	Graphene-carbon magnets can reduce Nd content	Future EV motors less vulnerable to China-controlled REE chain	Mid-term R&D
Nuclear Batteries (Radioactive)	Promethium (Pm)	N/A	No replacement potential	N/A	Low
SmCo Magnets, Neutron Absorbers	Samarium (Sm)	Defense Critical	Graphene magnetic composites may reduce Sm usage	Potential defense/ aerospace reliance	Early R&D
Red Phosphor In LEDs, TV Screens	Europium (Eu)	Limited global supply	Graphene quantum dots produce tunable red emission	REE-free LED phosphors; major ESG & procurement advantage	High Potential
MRI Contrast Agents, Magnets	Gadolinium (Gd)	High regulatory risk (MRI toxicity concerns)	Graphene-based MRI contrast systems reduce Gd dependence	Major medical safety & regulatory advantage	Preclinical/ Emerging
Green Phosphor In LEDs, Screens	Terbium (Tb)	High scarcity	Graphene quantum dots can emit green-light alternatives	Future REE-free displays and lighting	High Potential
High Temp Stability In NdFeB Magnets	Dysprosium (Dy)	Extreme supply risk	Graphene-based composites may reduce Dy loading	Long-term EV motor cost stabilization	R&D
Strong Magnets, Nuclear Control Rods	Holmium (Ho)	N/A	Limited replacement potential	N/A	Low
Optical Amplifiers, Fiber Optics	Erbium (Er)	N/A	Graphene as saturable absorber reduces Er demand	Lower-cost optical systems; 2D material advantage	Emerging
Lasers, X ray sources	Thulium (Tm)	N/A	Not replaceable	N/A	Low
Fiber Lasers, Optical Materials	Ytterbium (Yb)	N/A	Graphene reduces Yb doping requirements	Cheaper lasers; newer 2D photonic devices	Pilot-Level
PET Scanners, Scintillators	Lutetium (Lu)	N/A	Low substitution potential	N/A	Low
Aluminum Alloys, SOFC Fuel cells	Scandium (Sc)	N/A	Graphene-reinforced aluminum reduces Sc usage	Lighter, cheaper aerospace components; large total addressable market	Deployable (composites)
YAG Lasers, Phosphors, Ceramics	Yttrium (Y)	N/A	Graphene strengthens optical ceramics	Cost reduction in advanced optics	Pilot-Level