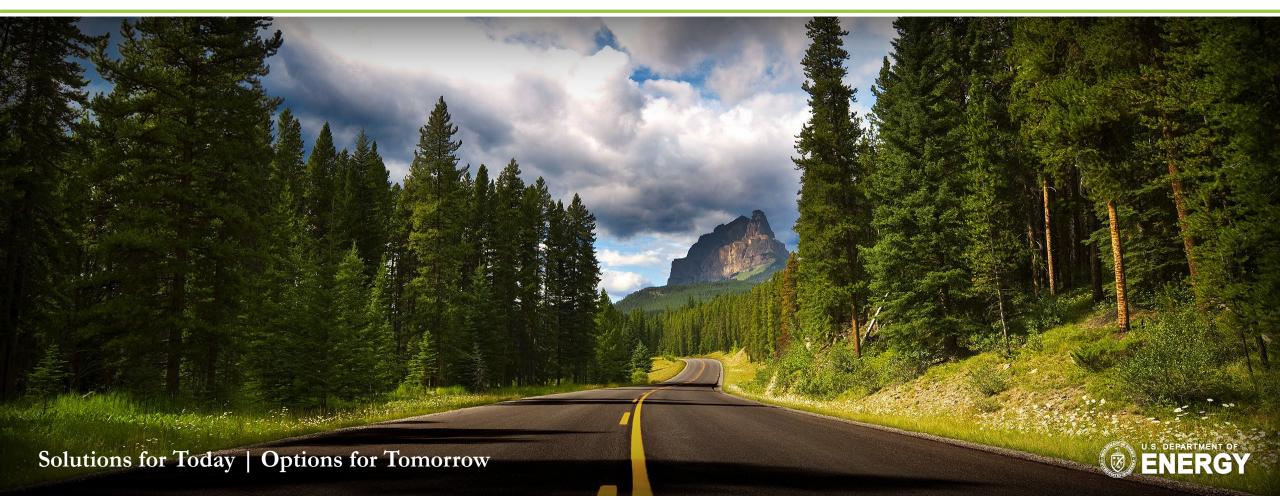
Systems Perspective



Expanding Focus to Critical Minerals

Morgan Summers & Clint Noack





• REE Overview

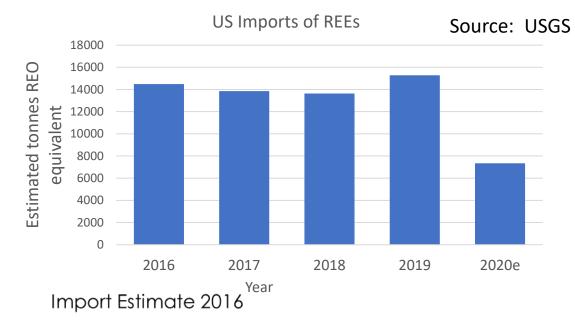
- Changing markets
- Life Cycle Analysis (LCA)
- Focus on Critical Materials
 - Growth potential
- Future Work

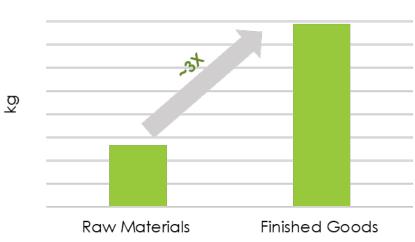




Imported Product	Parts with REES
1. Light Emitting Diodes (Modules/ Lamps)	Modules/Lamps
2. Ceramic Capacitors	Capacitors
3. Headphones	Permanent Magnets
4. Linear Fluorescent Lamps	Modules/Lamps
5. Mobile Phones	Vibration Motor, Speakers, Screen (Permanent Magnets/Phosphors)
6. Laptops	HDD, Speakers, LED display (Permanent Magnets/ Phosphors)
7. Speakers	Permanent Magnets
8. PVC Stabilizers	PVC stabilizer
9. Desktop Monitors (Non Cathode Ray)	LED Backlight (Large Screen)
10. AC and Refrigerator Compressors	Magnetic Pumps
11. Finished Refrigerators	Magnetic Pumps

Source: Adamas Intelligence



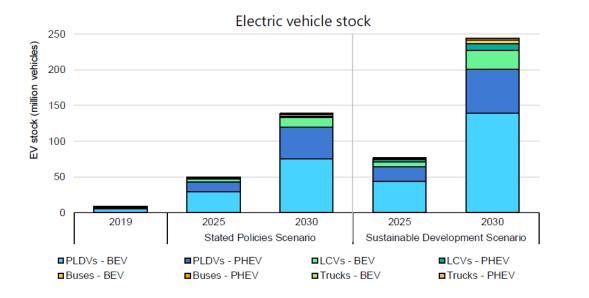


COVID caused imports of REE raw materials to decrease while imports of finished goods containing REEs remained strong



Projected Global EV

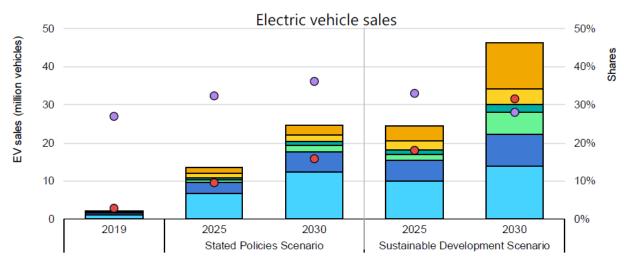




Stock and Sales by Scenario 2019, 2025, and 2030

In 2018, 93% of all passenger EVs sold used permanent magnet traction motors.

– Adamas Intelligence



China Europe EUS Japan India Others OEV sales share (right axis) OPHEV share in EVs (right axis)





- Key tool to demonstrate the potential benefits of developing a domestic REE/CM supply chain
- Literature review on publicly available REE unit processes focusing on emissions related to the current REE industry including mining technics used, extraction processes, waste streams, along with downstream processes where available.

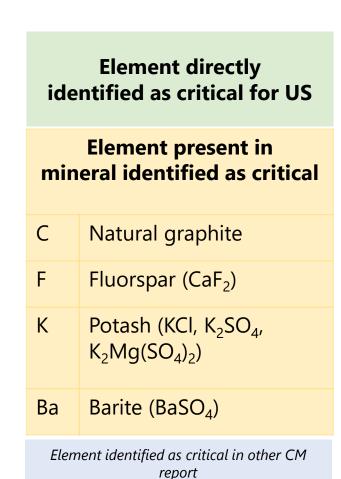


What's critical when everything is "critical"?

Only 23 naturally occurring elements not deemed critical by at least one country

IA																	18 VIIIA
1 Hydrogen	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	2 Helium 4.002602
3 Lithium 6.94	4 Be Beryllium 9.0121831											5 Boron 10.81	6 C Carbon	7 N Nitrogen 14.007	8 Oxygen 15.999	9 Fluorine 18.998403363	10 Neon 20.1797
11 Na Sodium 22.96976928	12 Mg Magnesium 24.305	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 Aluminium 26.9815385	14 Si Silicon 28.085	15 Phosphorus 30.973761998	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Argon 39.948
¹⁹ K	°Ca	Sc	²² Ti	²³ V	²⁴ Cr	²⁵ Mn	Fe	²⁷ Co	²⁸ Ni	°°Cu	[®] Zn	Ga	Ge	³³ As	³Se	³⁵ Br	^{³⁵} Kr
Potassium 39.0983	Calcium 40.078	Scandium 44.955908	Titanium 47.867	Vanadium 50.9415	Chromium 51.9961	Manganese 54.938044	Iron 55.845	Cobalt 58.933794	Nickel 58.6934	Copper 63.546	Zinc 65.38	Gallium 69.723	Germanium 72.630	Arsenic 74.921595	Selenium 78.971	Bromine 79.904	Krypton 83.798
³⁷ Rb	[®] Sr	³⁹ Y	^{**} Zr	^₄ Nb	Mo	Tc	[≇] Ru	[®] Rh	^{**} Pd	⁴⁷ Ag	^{⁴®} Cd	^⁴ In	Ŝn	Sb	⁵² Te	53	⁵⁴Xe
Rubidium 85.4678	Strontium 87.62	Yttrium 88.90584	Zirconium 91.224	Niobium 92.90637	Molybdenum 95.95	Technetium (98)	Ruthenium 101.07	Rhodium 102.90550	Palladium 106.42	Silver 107.8682	Cadmium 112.414	Indium 114.818	Tin 118.710	Antimony 121,760	Tellurium 127.60	lodine 126.90447	Xenon 131.293
⁵⁵ Cs	Ba	57 - 71 Lanthanoids	⁷² Hf	Та	⁷⁴ W	Re	⁷⁶ Os	" Ir	Pt	⁷⁹ Au	[⊪] Hg	^{®1} TI	Pb	Bi	^{₿4} Po	^{₅₅} At	[®] Rn
Caesium 132.90545196	Barium 137.327		Hafnium 178.49	Tantalum 180.94788	Tungsten 183.84	Rhenium 186.207	Osmium 190.23	Iridium 192.217	Platinum 195.084	Gold 196.966569	Mercury 200.592	Thallium 204.38	Lead 207.2	Bismuth 208.98040	Polonium (209)	Astatine (210)	Radon (222)
⁸⁷ Fr	Ra	89 - 103 Actinoids	[™] Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	¹¹⁴ FI	Мс	Lv	"Ts	Ög
Francium (223)	Radium (226)		Rutherfordium (267)	Dubnium (268)	Seaborgium (209)	Bohrium (270)	Hassium (269)	Meitnerium (278)	Darmstadtium (281)	Roentgenium (282)	Copernicium (285)	Nihonium (286)	Flerovium (289)	Moscovium (289)	Livermorium (293)	Tennessine (294)	Oganesson (294)

57 La Lanthanum 138.90547	58 Cerium 140.116	59 Praseodymium 140.90766	60 Nd Neodymium 144,242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Europium 151.964	64 Gd Gadolinium 15725	65 Tb Terbium 158.92535	66 Dysprosium 102,500	67 Ho Holmium 164.93033	68 Erbium 167,259	69 Tm Thulium 168.93422	70 Yb Ytterbium 173.045	71 Lu Lutetium 174.9668
Ac			⁹² U			Åm		⁹⁷ Bk	°°Cf	^{°°} Es	Fm	Md	Νο	Lr
Actinium (227)	Thorium 232.0377	Protactinium 231.03588	Uranium 238.02891	Neptunium (237)	Plutonium (244)	Americium (243)	Curium (247)	Berkelium (247)	Californium (251)	Einsteinium (252)	Fermium (257)	Mendelevium (258)	Nobelium (259)	Lawrencium (266)



Synthetic elements

ATIONAL

U.S. DEPARTMENT OF

Find where growth is happening

How will the energy sector respond to market forces with tech?



TECH TRENDS + ENERGY FUTURES

BIG, GROWING DOMESTIC MARKETS THAT WILL MATTER IN THE FUTURE

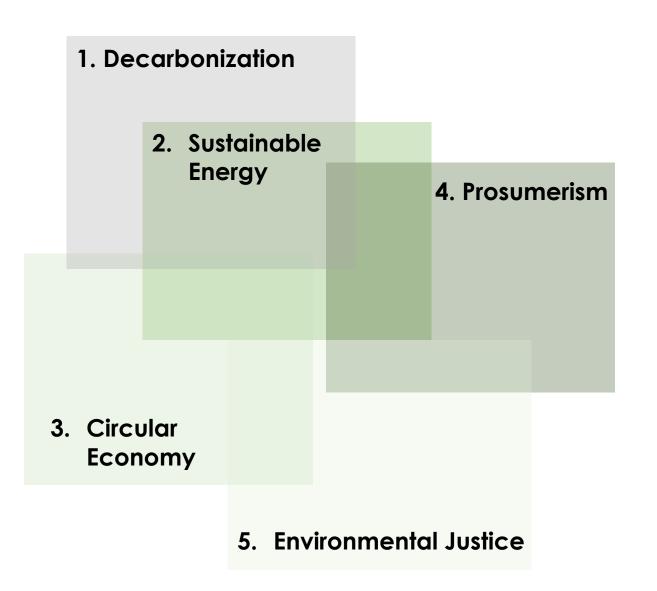
DEFINED HERE AS:

Economically important sectors of the energy industry that rely on critical minerals.

WHICH IS UNCERTAIN: Synthesis of various outlooks paints a picture of diverse outcomes where we look for common ground.



Global, unifying trends driving technology



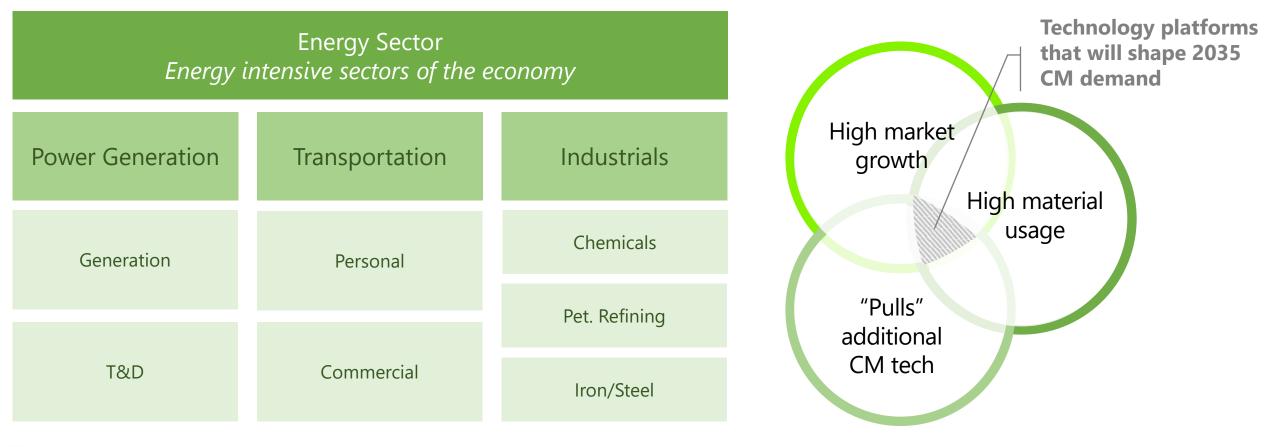


Evaluate multi-sector impacts

Review of incumbent and emerging technology concepts in the power generation, transportation, and industrials subsectors shows the climate-driven energy transition will continue to drive demand for CM

SCOPE OF ANALYSIS - TECHNOLOGY CONSUMERS

ASSESSMENT METHODOLGY







Market Analysis

- Continue developing an understanding of CM markets and the drivers that predict future growth
- Development of domestic resource recovery potential from conventional and unconventional sources

LCA

- Identifying the process gaps for specific feedstocks
- Assess the LCA impacts of utilizing waste coal-based feedstocks (refuse, fly ash, and AMD)



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Thank you

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