U.S. DEPARTMENT OF ENERGY

Critical Materials Strategy

Summary Briefing




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Technology and Rare Earth Metals (TREM)

March 22, 2011

Outline of Briefing

I. Background

II. Analysis

  A. Supply

  B. Demand

  C. Criticality

III. Program and Policy Directions

IV. Next Steps

Project Timeline

- *March 2010 - Project launched TREM10*

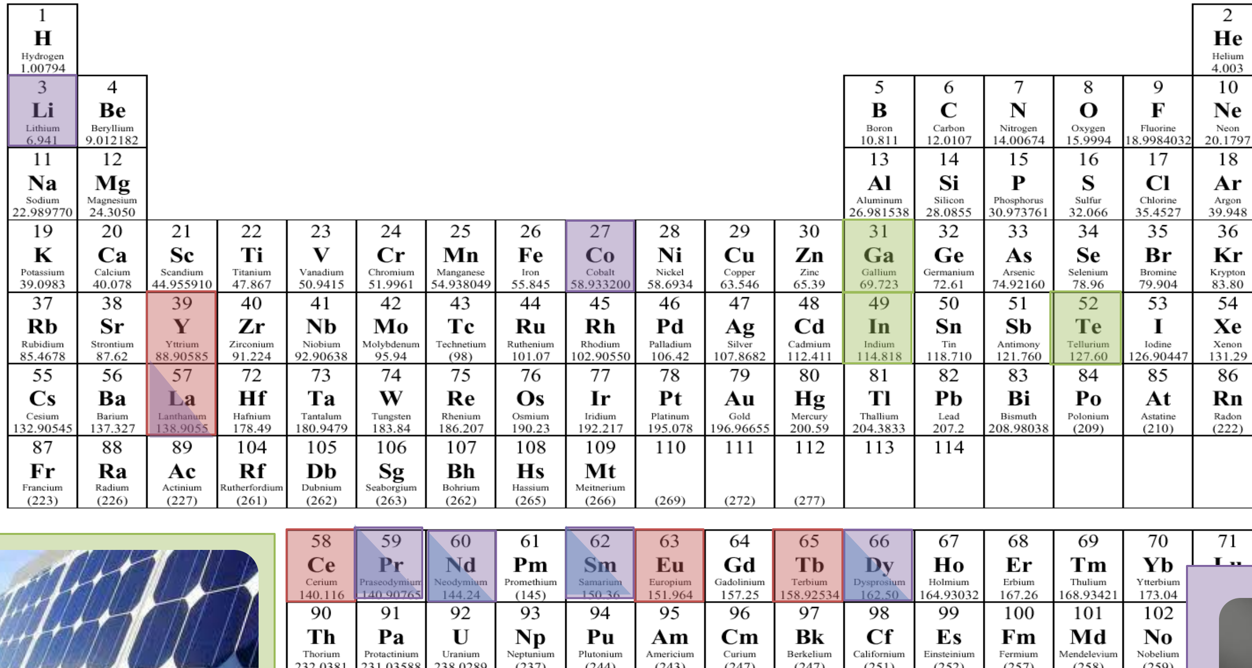
"I am today announcing that the Department of Energy will develop its first-ever strategic plan for addressing the role of rare earth and other strategic materials in clean energy technologies. "

"As a society, we have dealt with these types of issues before…We can and will do so again."

David Sandalow
Assistant Secretary for Policy and International Affairs
U.S. Department of Energy
March 17, 2010

- *June 2010 – Responses to public Request for Information*
- *Summer 2010 – Performed analysis, internal and inter-agency consultations, and drafted strategy*
- *December 2010 – Public release of the Critical Materials Strategy*
- *March 22, 2011 – TREM 11– 2nd public Request for Information*
- *Fall 2011 – Release update of Critical Materials Strategy*

Scope



Vehicles

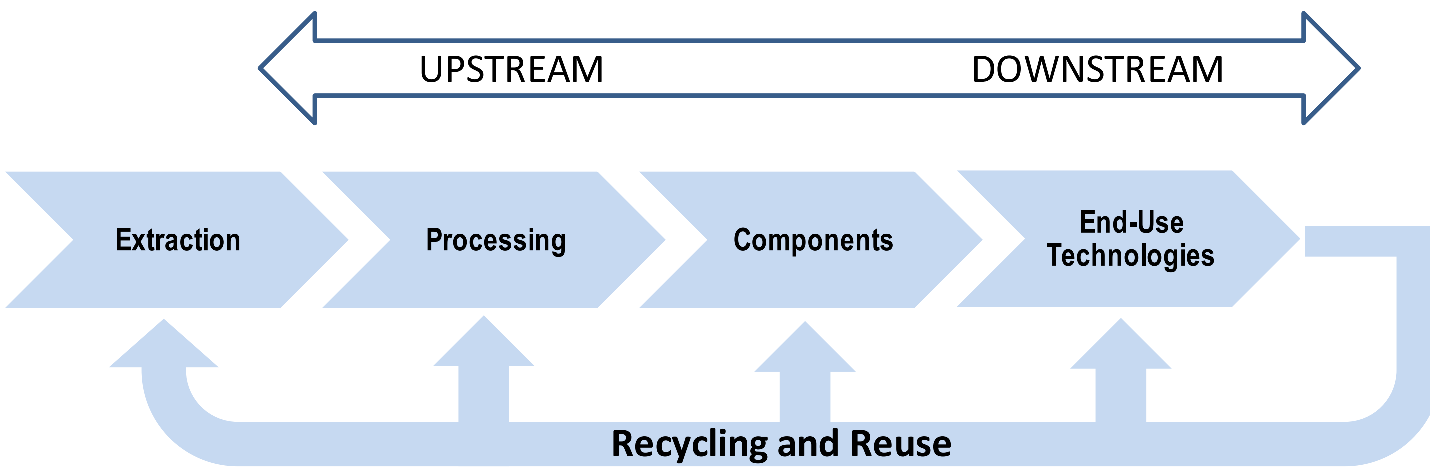
Lighting

Solar PV

Wind

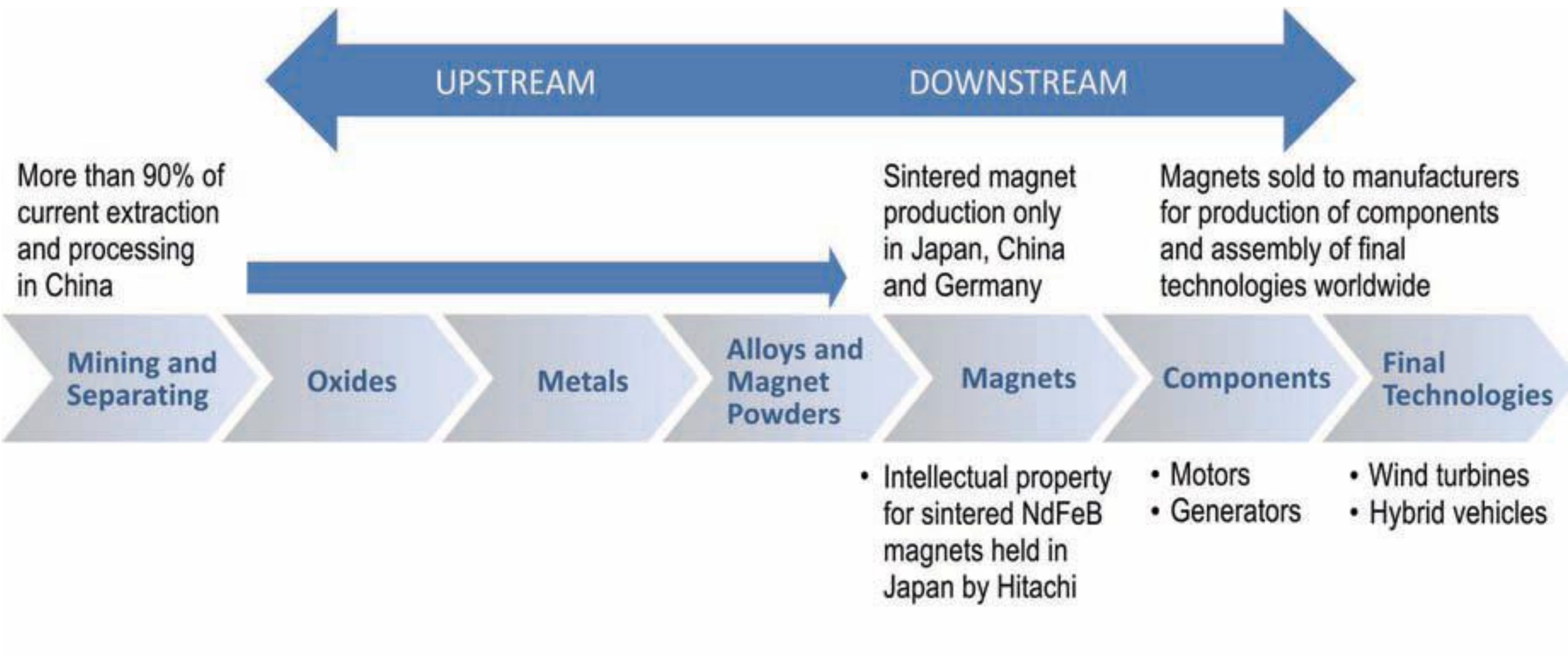
Strategic Pillars

- *Diversify global supply chains*
- *Develop substitutes*
- *Reduce, reuse and recycle*



The supply chain for materials use

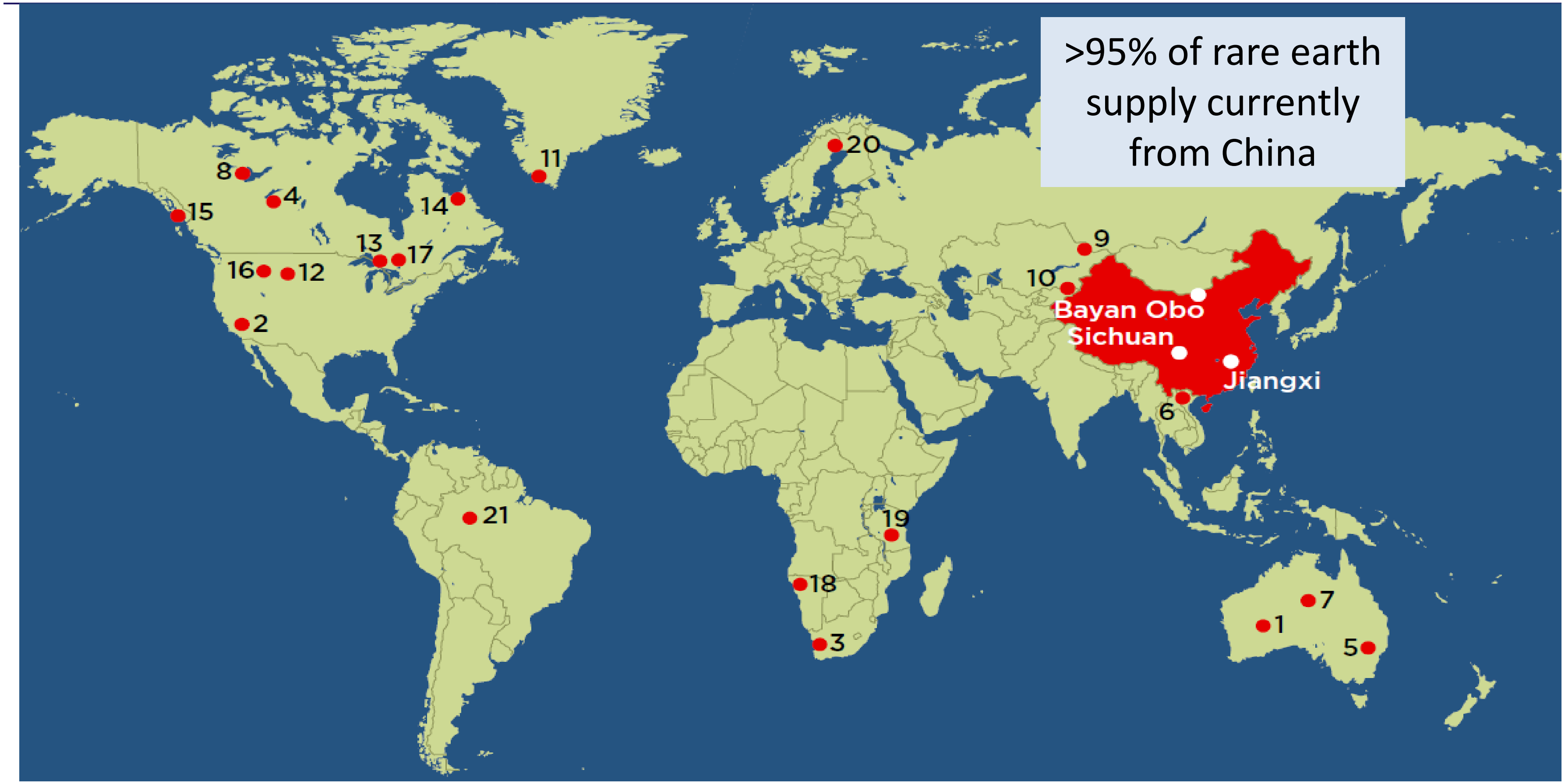
Supply Chain for Rare Earth Element Permanent Magnet Technologies



- Illustrates the supply chain for vehicle and wind turbine applications using Neodymium-Iron-Boron (NdFeB) permanent magnets

II. Analysis

Supply



(1) Lynas Corp., (2) Molycorp Minerals, (3) (4) Great Western Minerals, (5) Alkane Resources, (6) Vietnamese govt./Toyota Tsusho/Sojitz, (7) Arafura Resources, (8) Avalon Rare Metals, (9) Kazatomprom/Sumitomo, (10) Stans Energy, (11) Greenland Minerals and Energy, (12) Rare Element Resources, (13) Pele Mountain Resources, (14) Quest Rare Metals, (15) Ucore Uranium, (16) US Rare Earths, (17) Matamec Explorations, (18) Etruscan Resources, (19) Montero Mining, (20) Tasman Metals, (21) Neo Material Technologies/Mitsubishi

Source: Industrial Minerals

Rare earth metals are not rare –
found in many countries including the United States

Current and Projected Rare Earth Supply by Element

Rare Earth Supply by Element: Production Sources and Volume (tonnes/yr)										
		Assumed Additional Production by 2015								
	Estimated 2010 Production	Mt. Weld (Australia)	Mountain Pass (USA)	Dubbo Zirconia (Australia)	Nolans Bore (Australia)	Dong Pao (Vietnam)	Hoidas Lake (Canada)	Nechalacho (Canada)	Total Additional Production by 2015	Estimated 2015 Production
Lanthanum	33,887	3,900	6,640	585	2,000	1,620	594	845	16,184	50,071
Cerium	49,935	7,650	9,820	1,101	4,820	2,520	1,368	2,070	29,349	79,284
Praseodymium	6,292	600	868	120	590	200	174	240	2,792	9,084
Neodymium	21,307	2,250	2,400	423	2,150	535	657	935	9,350	30,657
Samarium	2,666	270	160	75	240	45	87	175	1,052	3,718
Europium	592	60	20	3	40	0	18	20	161	753
Gadolinium	2,257	150	40	63	100	0	39	145	537	2,794
Terbium	252	15	0	9	10	0	3	90	127	379
Dysprosium	1,377	30	0	60	30	0	12	35	167	1,544
Yttrium	8,750	0	20	474	0	4	39	370	907	9,657
TOTAL	**127,315**	14,925	19,968	2,913	9,980	4,924	2,991	4,925	60,626	**187,941**

Sources: Kingsnorth, Roskill, and USGS

Current and Projected Supply of Non-Rare Earth Elements

Supply of Other Elements Assessed: Production Sources and Volume (tonnes)				
	Estimated 2010 Production	Potential Sources of Additional Production between 2010 and 2015		Estimated 2015 Supply
		Additional amount	*Sources*	
Indium	1,345	267	Recovery (co-produced) from additional zinc production mainly and recycling	1,612
Gallium	207	118[76]	Recovery (co-produced) from additional alumina and bauxite production and recycling[77]	325
Tellurium	500	720	Recovery (co-produced) from copper anode Slimes	1,220
Cobalt	75,900	197,830	Mines	273,730
Lithium (carbonate equivalent)	134,600	115,400	Mines[78]	250,000

Sources: USGS 2008a-e and Evans 2010.

[76] For indium, the additional amount is only the difference between the 2010 production and the maximum current production capacity for mining and refining the material. No new capacity is projected by 2015.

[77] Based on multiple correspondences with USGS, October 4-7, 2010.

[78] USGS, external review of Critical Materials Strategy draft, November 17, 2010.

Material Demand Factors

	Market Penetration	Material Intensity
Trajectory D	High	High
Trajectory C	High	Low
Trajectory B	Low	High
Trajectory A	Low	Low

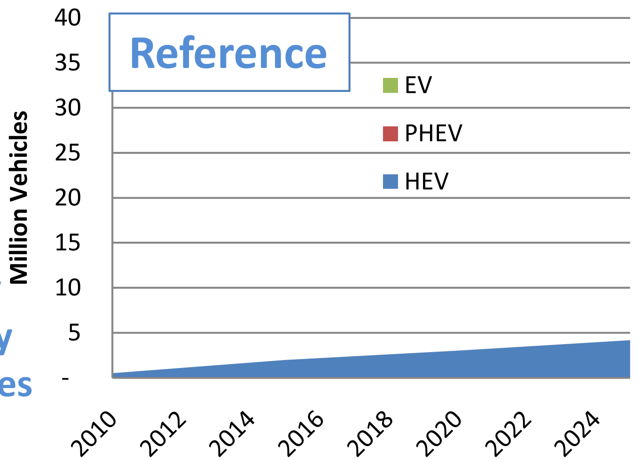


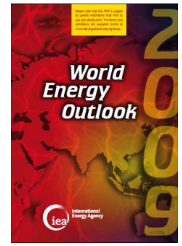

- ***Market Penetration = Deployment*** (total annual units of a clean energy technology) ***X Market Share*** (% of units using materials analyzed)
- ***Material Intensity =*** Material demand per unit of the clean energy technology

Low Technology Deployment Scenarios

IEA Energy Technology Perspectives

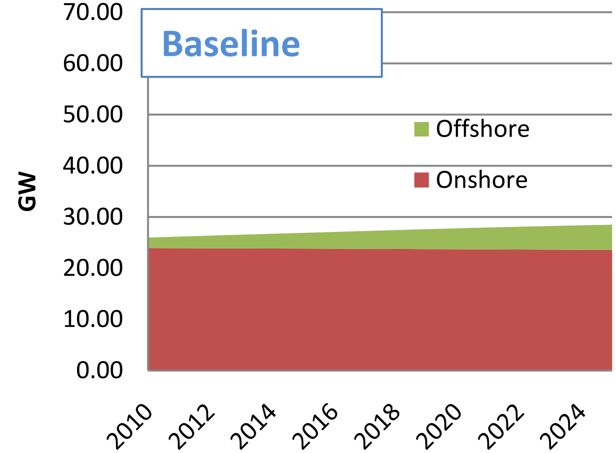
Electric Drive Vehicle Additions





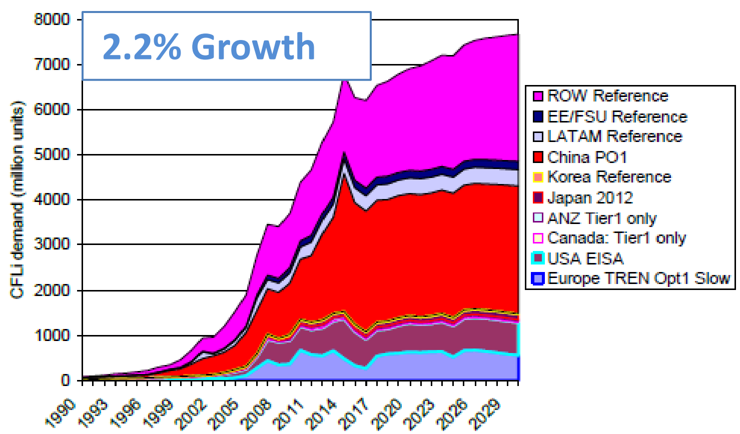
IEA World Energy Outlook

Wind Additions



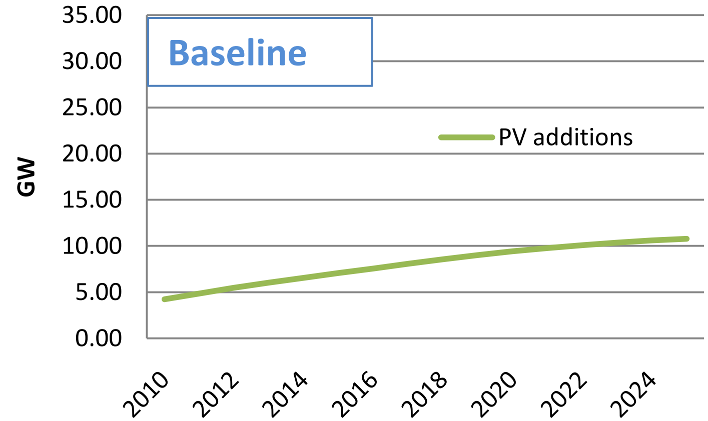
IEA: Phase Out of Incandescent Lights

Global CFL Demand



Source: IEA estimated.

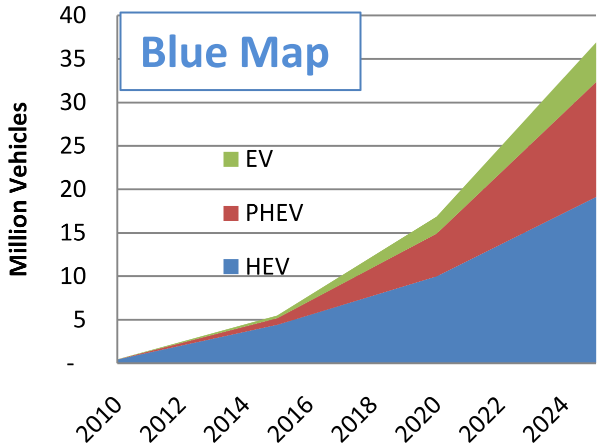
Global PV Additions



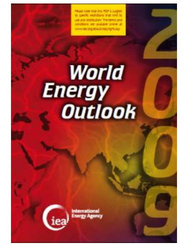
High Technology Deployment Scenarios

Electric Drive Vehicle Additions

IEA Energy Technology Perspectives



Wind Additions



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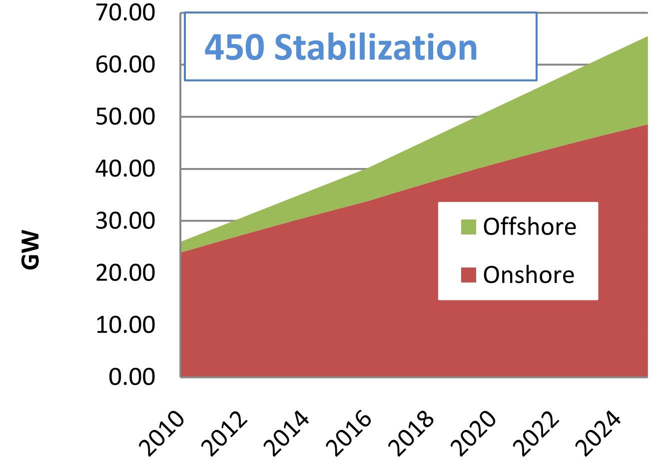
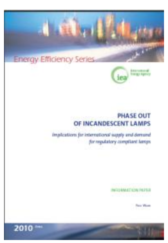


Global CFL Demand



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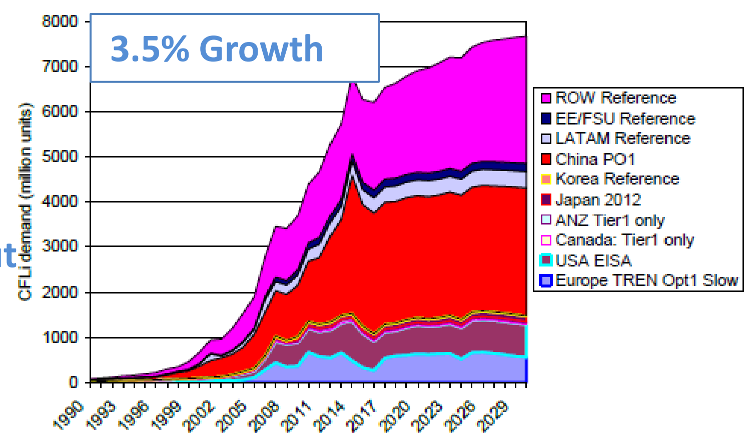
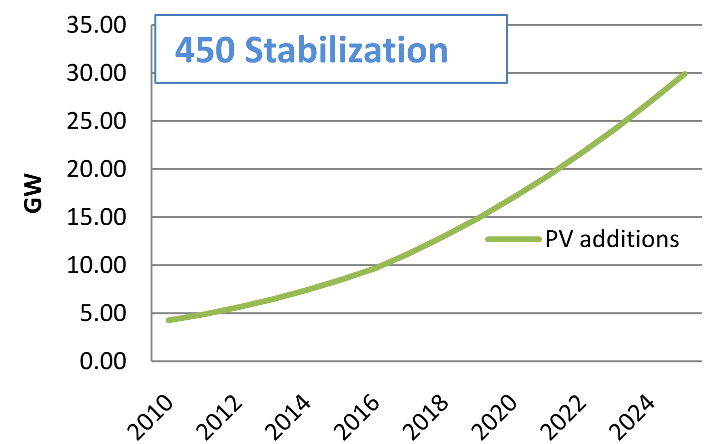


Source: IEA estimated.

Global PV Additions



Material Intensity

Technology	Component	Material	High Intensity	Low Intensity
Wind	**Generators**	Neodymium	186 kg/MW	124 kg/MW
		Dysprosium	33 kg/MW	22 kg/MW
Vehicles	**Motors**	Neodymium	0.62 kg/vehicle	0.31 kg/vehicle
		Dysprosium	0.11 kg/vehicle	0.055 kg/vehicle
	Li-ion Batteries (PHEVs and EVs)	Lithium	5.1-12.7 kg/vehicle	1.4-3.4 kg/vehicle
		Cobalt	9.4 kg/vehicle	0 kg/vehicle
	NiMH Batteries (HEVs)	Rare Earths (Ce, La, Nd, Pr)	2.2 kg/vehicle	1.5 kg/vehicle
		Cobalt	0.66 kg/vehicle	0.44 kg/vehicle
PV Cells	**CIGS Thin Films**	Indium	110 kg/MW	16.5 kg/MW
		Gallium	20 kg/MW	4 kg/MW
	CdTe Thin Films	Tellurium	145 kg/MW	43 kg/MW
Lighting	**Phosphors**	Rare Earths (Y, Ce, La, Eu, Tb)	6715 metric tons* total demand in 2010, 2.2% (low) or 3.5% (high) annually	

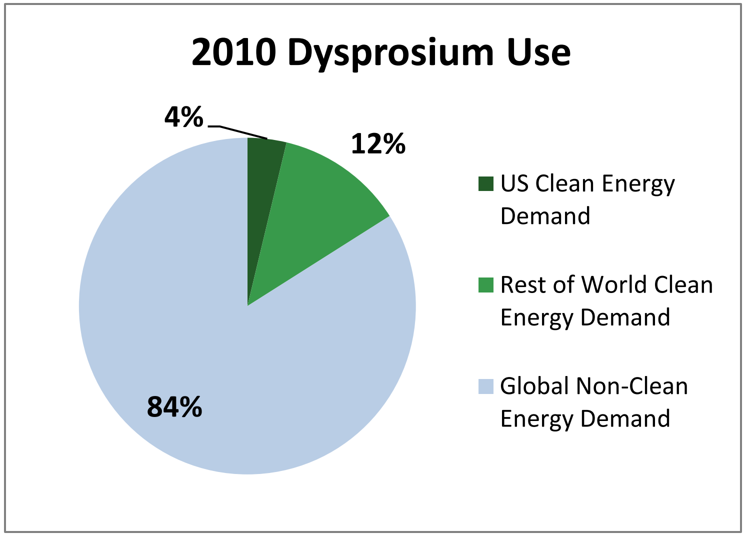
*rare earth oxide equivalent

- ***Calculation methods differed by component based on available data***
- ***High Intensity = material intensity with current generation technology***
- ***Low Intensity = intensity with feasible improvements in material efficiency***

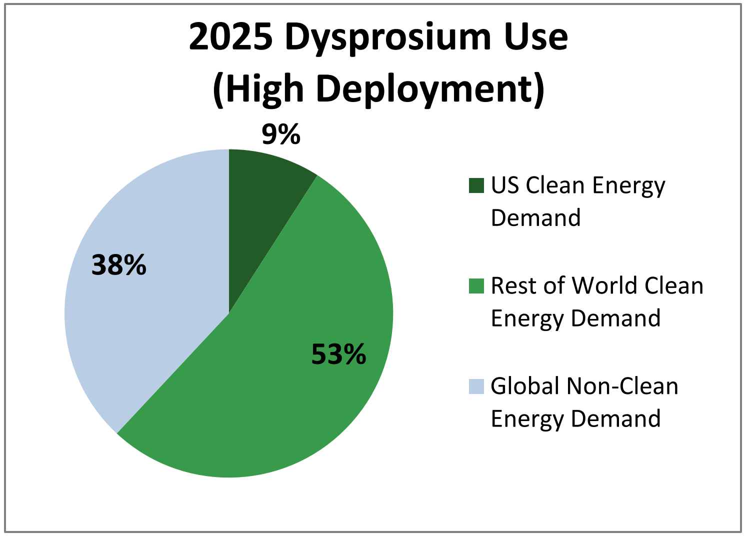
Clean Energy's share of Critical Material Use

Clean energy's share of total material use currently small

…but could grow significantly with increased deployment.



Dysprosium

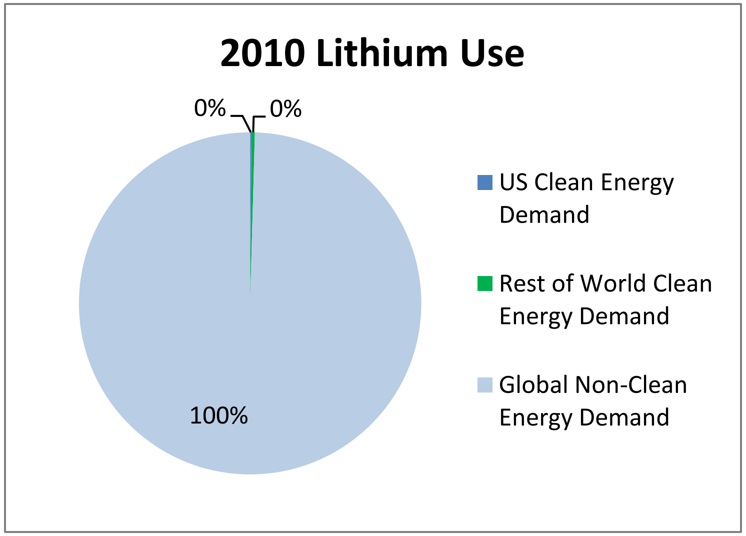


16% is for Clean Energy

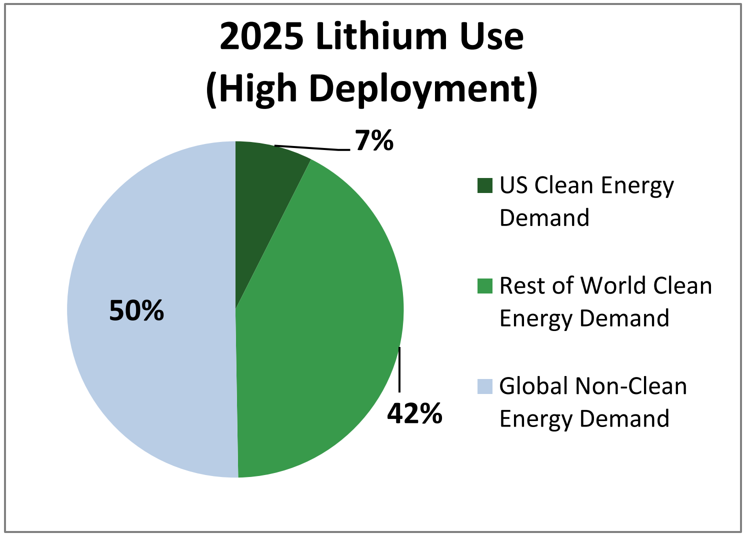
62% is for Clean Energy

Clean energy's share of total material use currently small

...but could grow significantly with increased deployment.



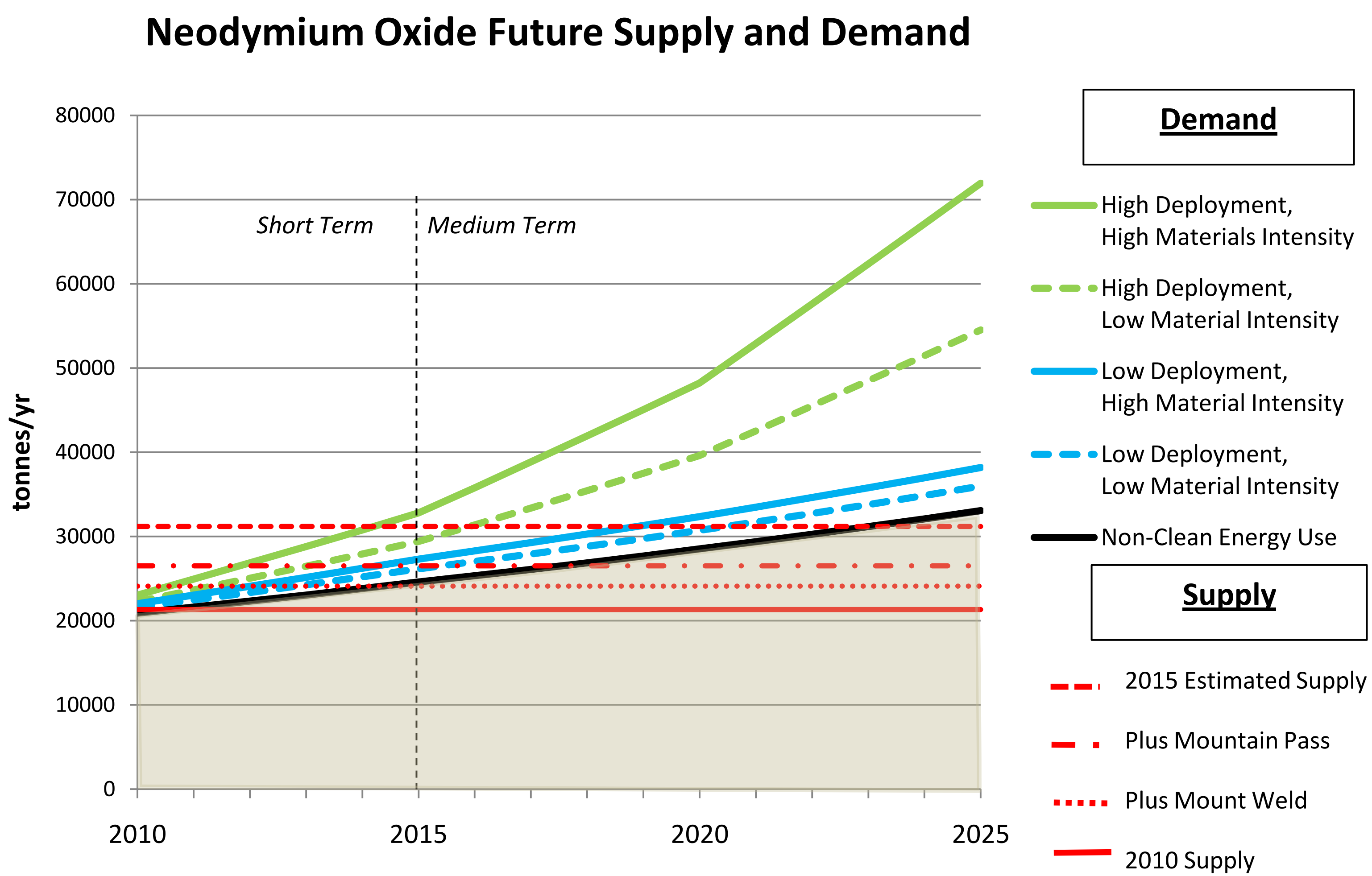
Lithium



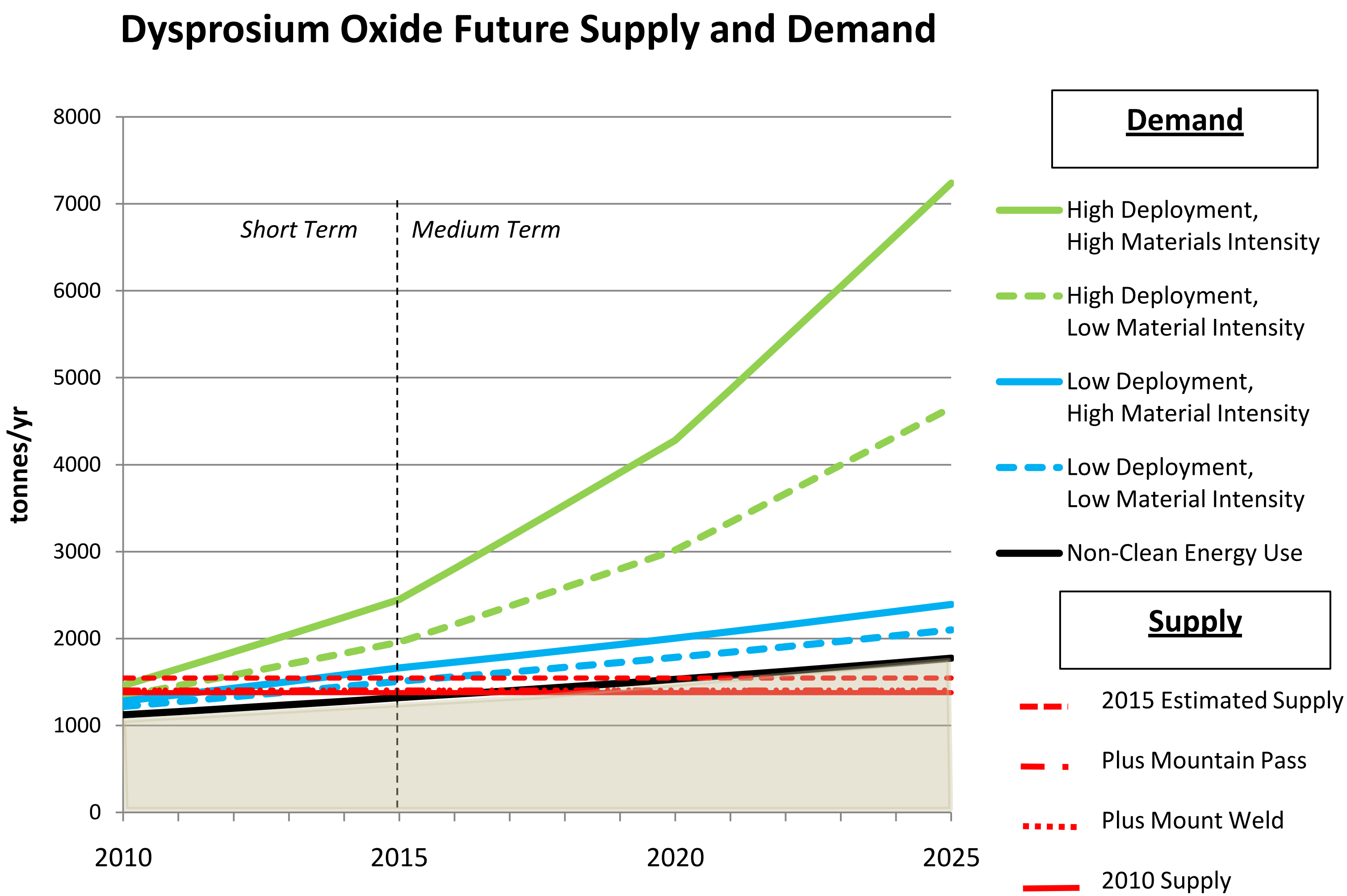
< 1% is for Clean Energy

50% is for Clean Energy

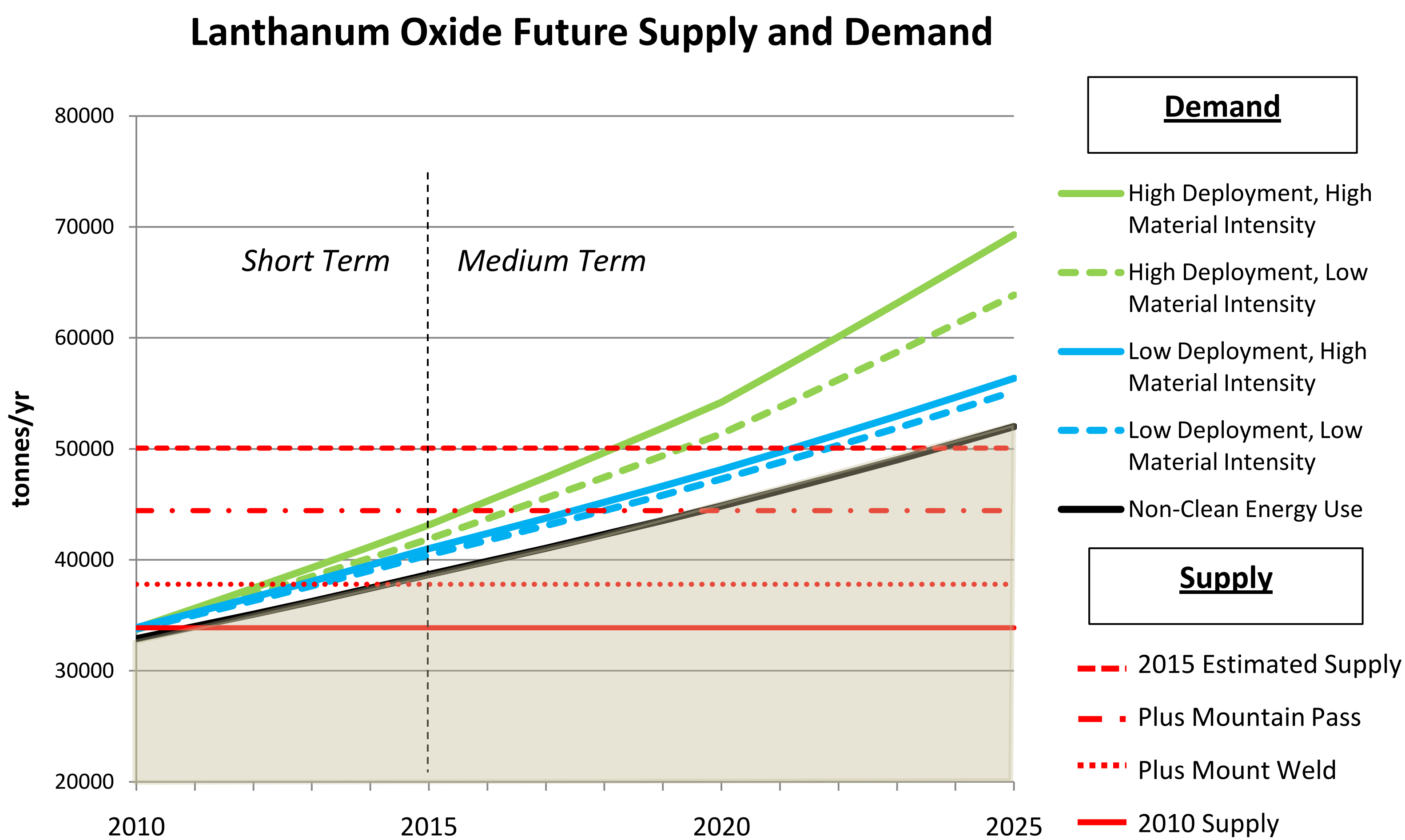
Neodymium - Supply and Demand Projections



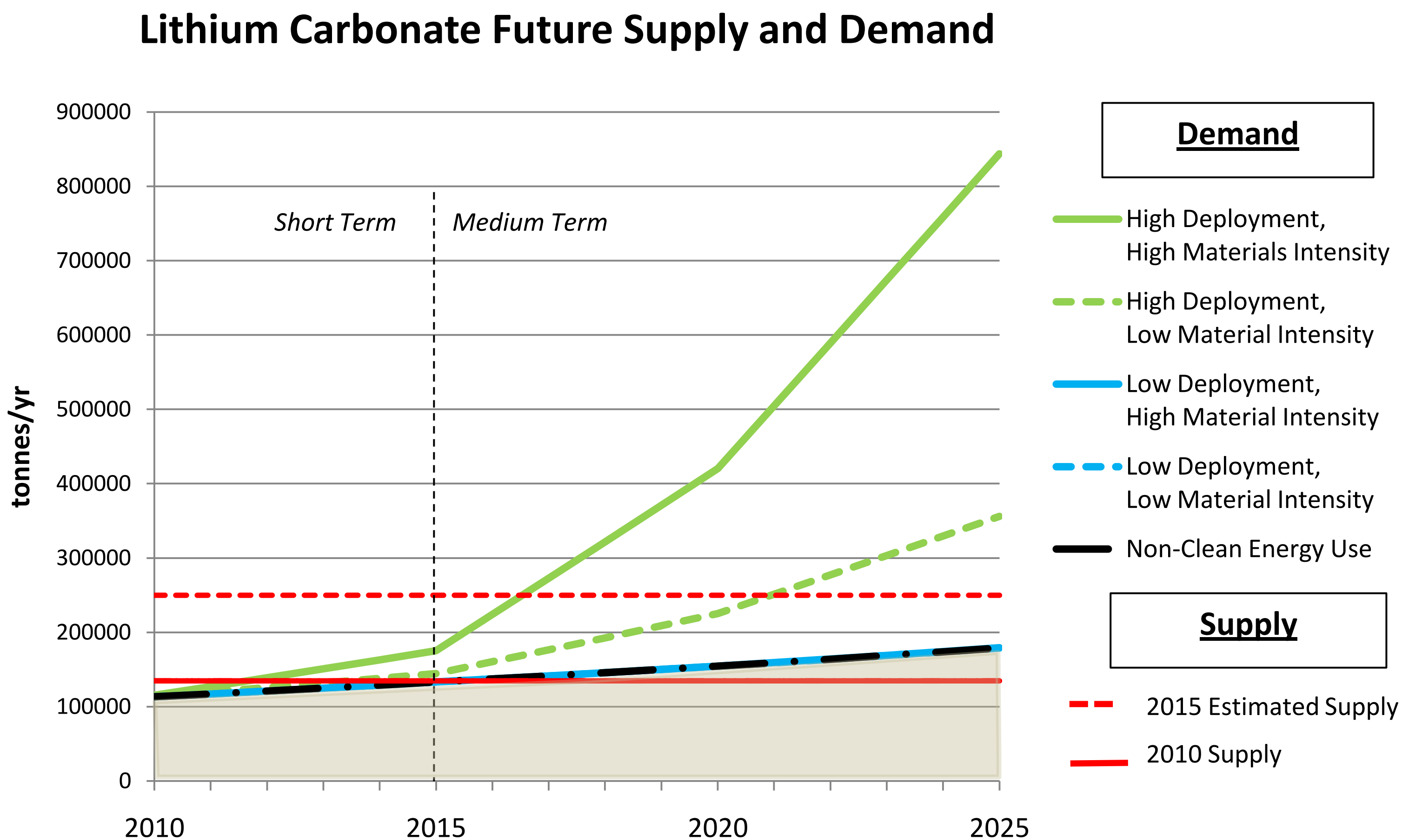
Dysprosium - Supply and Demand Projections



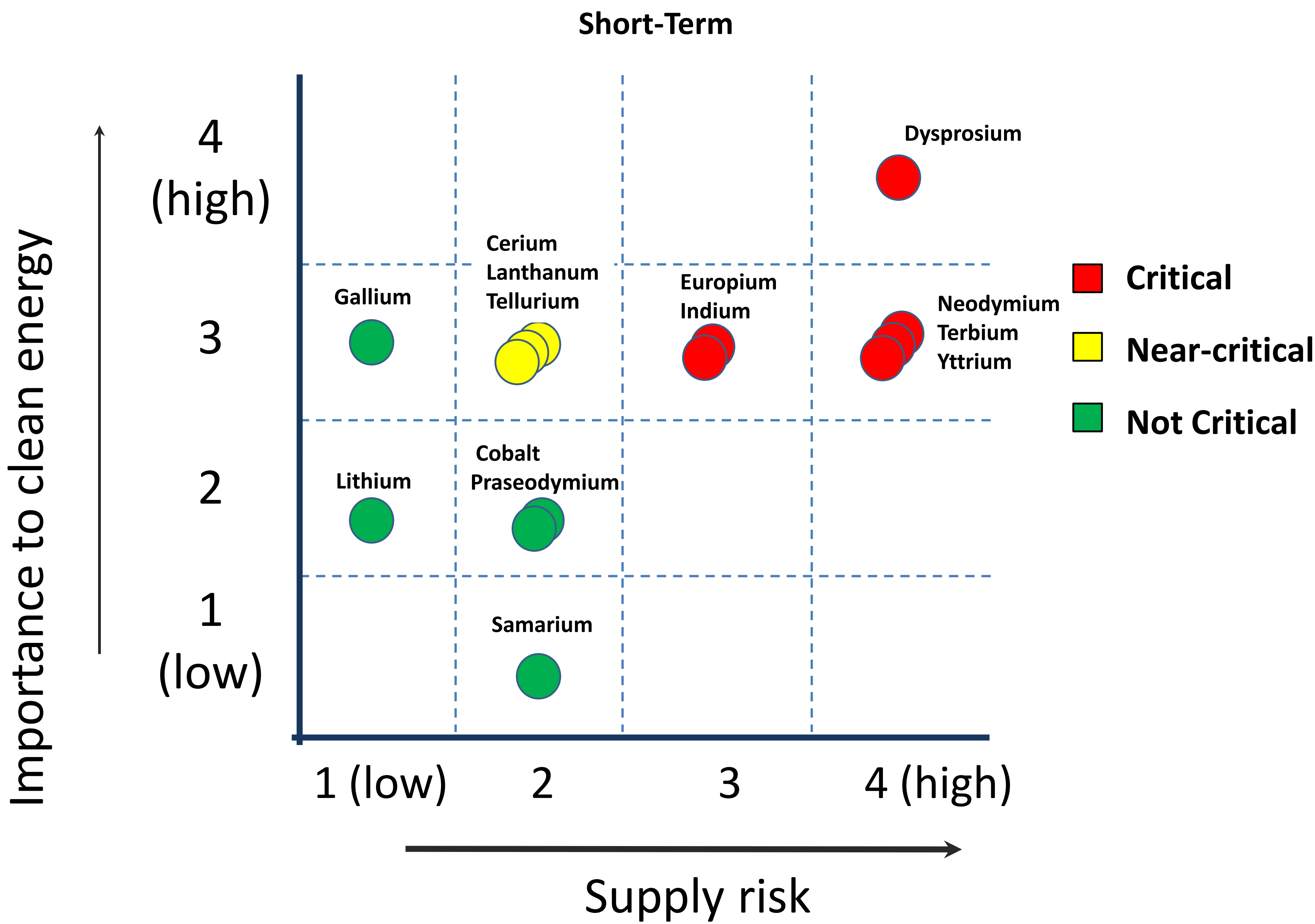
Lanthanum – Supply and Demand Projections

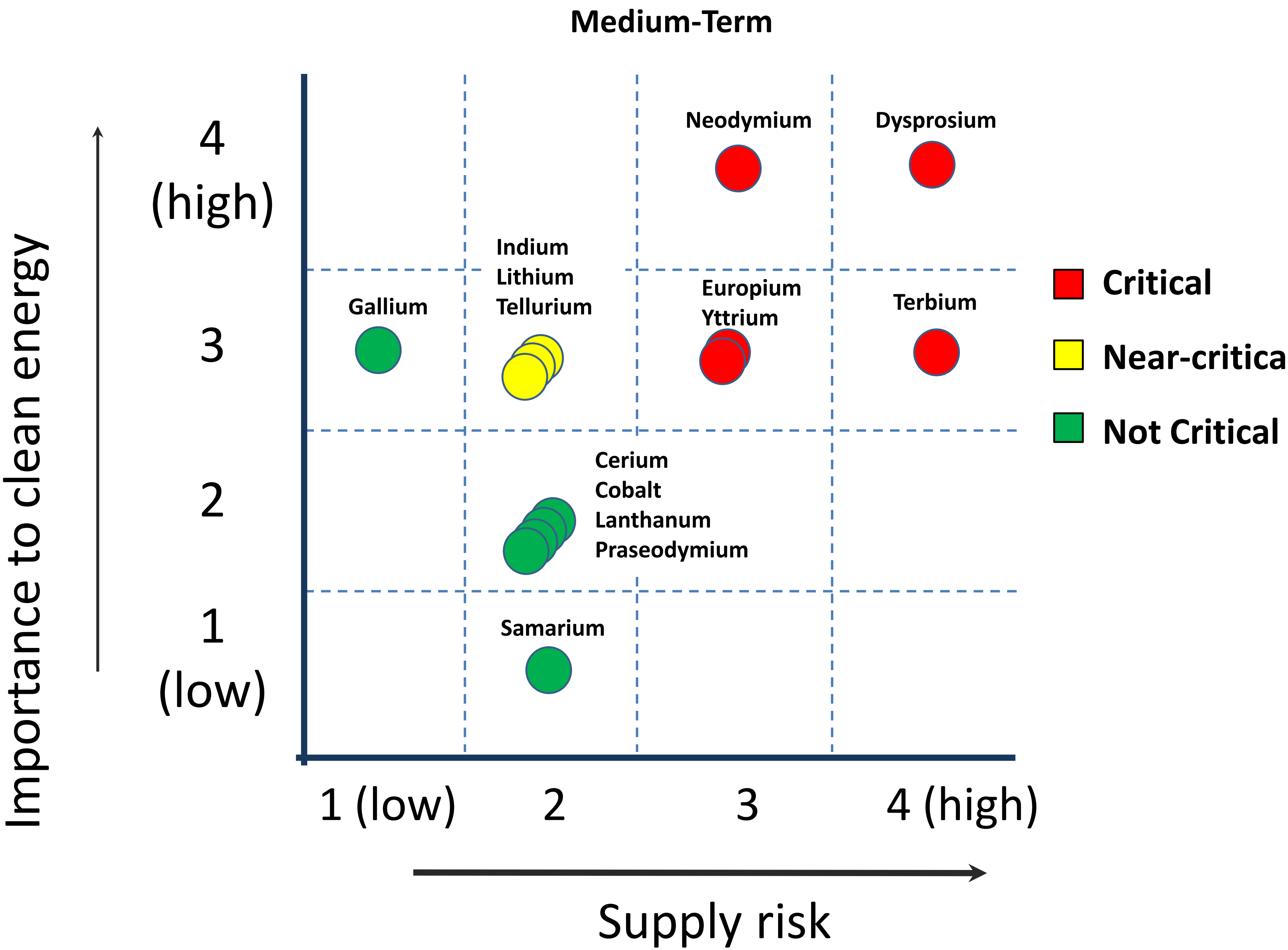


Lithium – Supply and Demand Projections

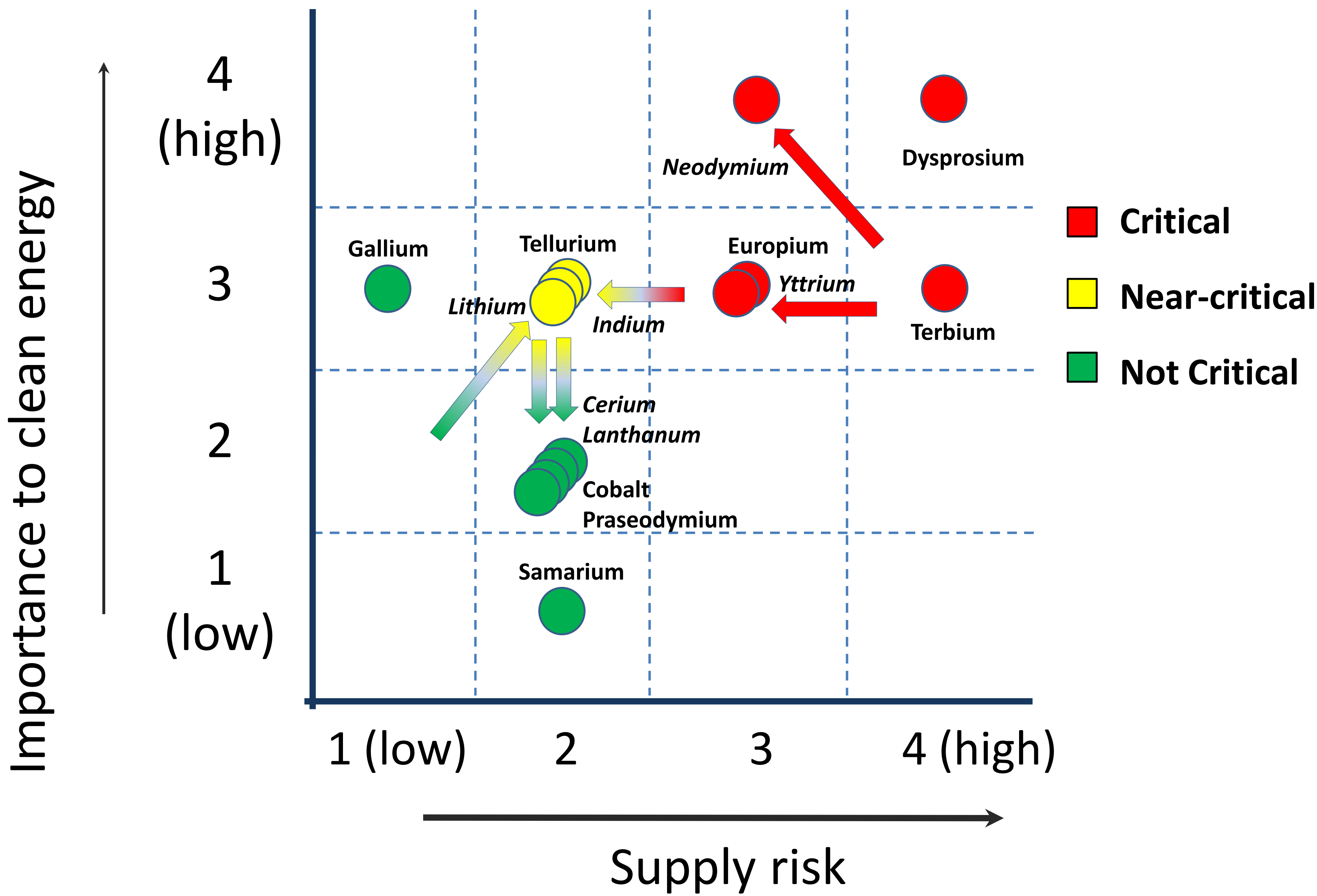


- Based on methodology developed by National Academy of Sciences
- *Criticality* is a measure that combines
  - Importance to the clean energy economy
  - Risk of supply disruption
- Time frames:
  - Short-term (0-5 years)
  - Medium-term (5-15 years)


Short-Term
Importance to clean energy
4 (high)
3
2
1 (low)
Dysprosium
Cerium
Lanthanum
Tellurium
Gallium
Europium
Indium
Neodymium
Terbium
Yttrium
Lithium
Cobalt
Praseodymium
Samarium
1 (low)
2
3
4 (high)
Supply risk
Critical
Near-critical
Not Critical


Medium-Term
Importance to clean energy
4 (high)
3
2
1 (low)
Neodymium
Dysprosium
Indium
Lithium
Tellurium
Gallium
Europium
Yttrium
Terbium
Cerium
Cobalt
Lanthanum
Praseodymium
Samarium
1 (low)
2
3
4 (high)
Supply risk
Critical
Near-critical
Not Critical

Criticality Movement: Short to Medium Term



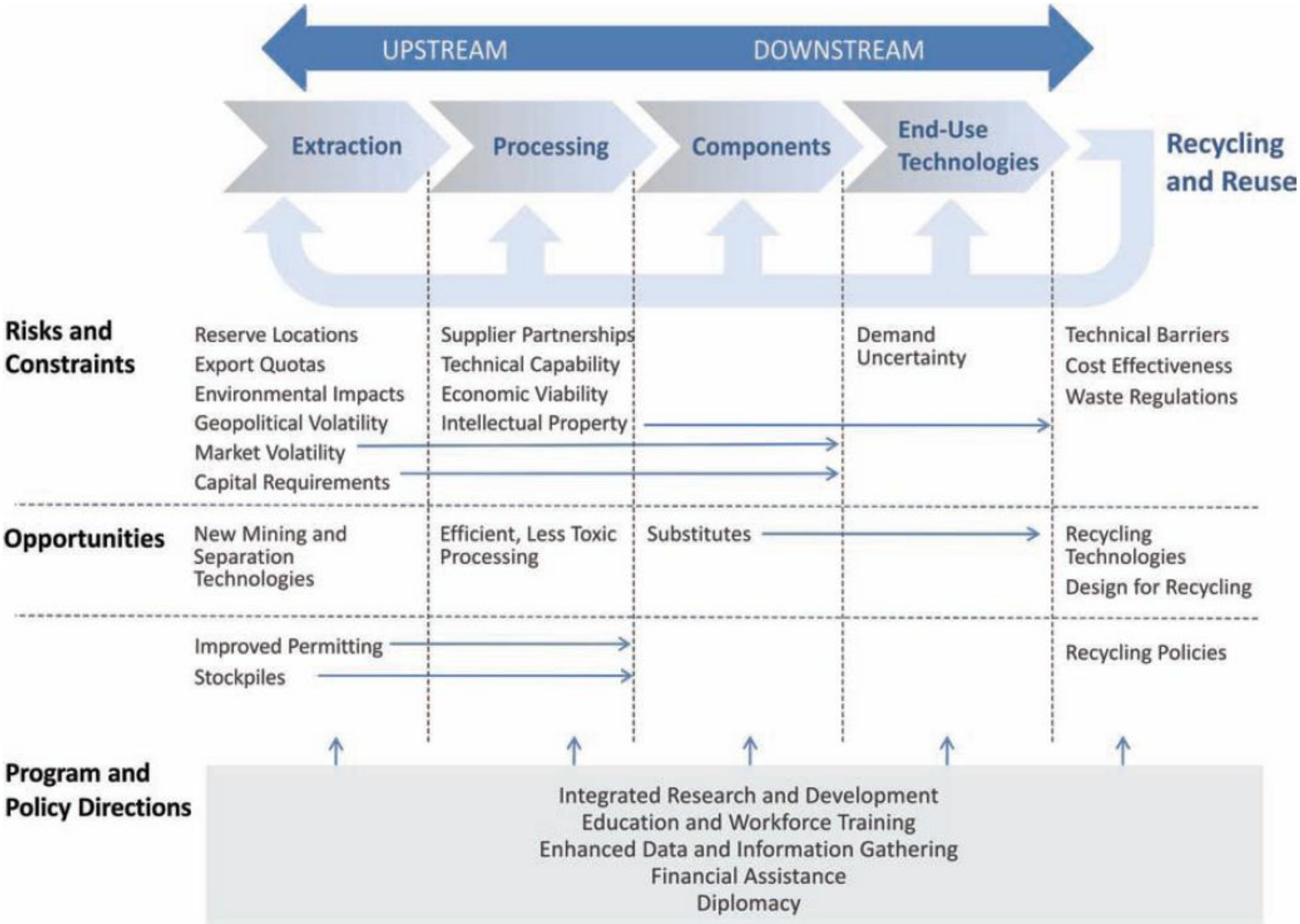
III. Program and Policy Directions

Program and Policy Directions

- Research and development
- Information-gathering
- Permitting for domestic production
- Financial assistance for domestic production and processing
- Stockpiles
- Recycling
- Education
- Diplomacy

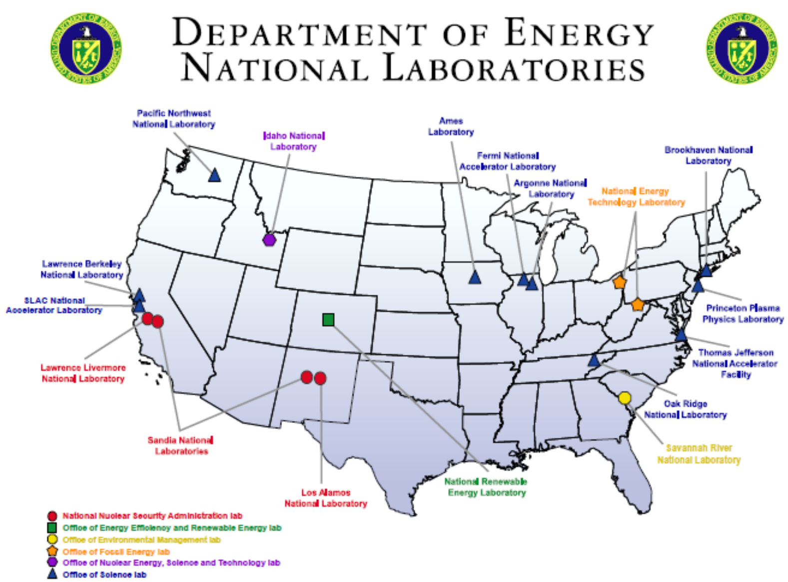
Some are within DOE's core competence, others aren't

Policy Options and Critical Materials Supply Chain



Research and Development

- DOE is the *nation's leading funder* of research on the physical sciences.
- Long history of materials work – EERE, Office of Science, ARPA-E



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

arpa·e Advanced Research Projects Agency • ENERGY

DOE’s current programs – Office of Science

Basic research at Ames Laboratory

- **Extraordinarily Responsive Rare Earth Magnetic Materials**
- **Novel Materials Preparation and Processing Methodologies**
- **Correlations and Competition Between the Lattice, Electrons and Magnetism**
- **Nanoscale and Ultrafast Correlations and Excitations in Magnetic Materials**

Permanent Magnet Development for Automotive Traction Motors

Ames Lab

A New Class of Switched Reluctance Motors

Oak Ridge

Novel Flux Coupling Machine without Permanent Magnets

Oak Ridge

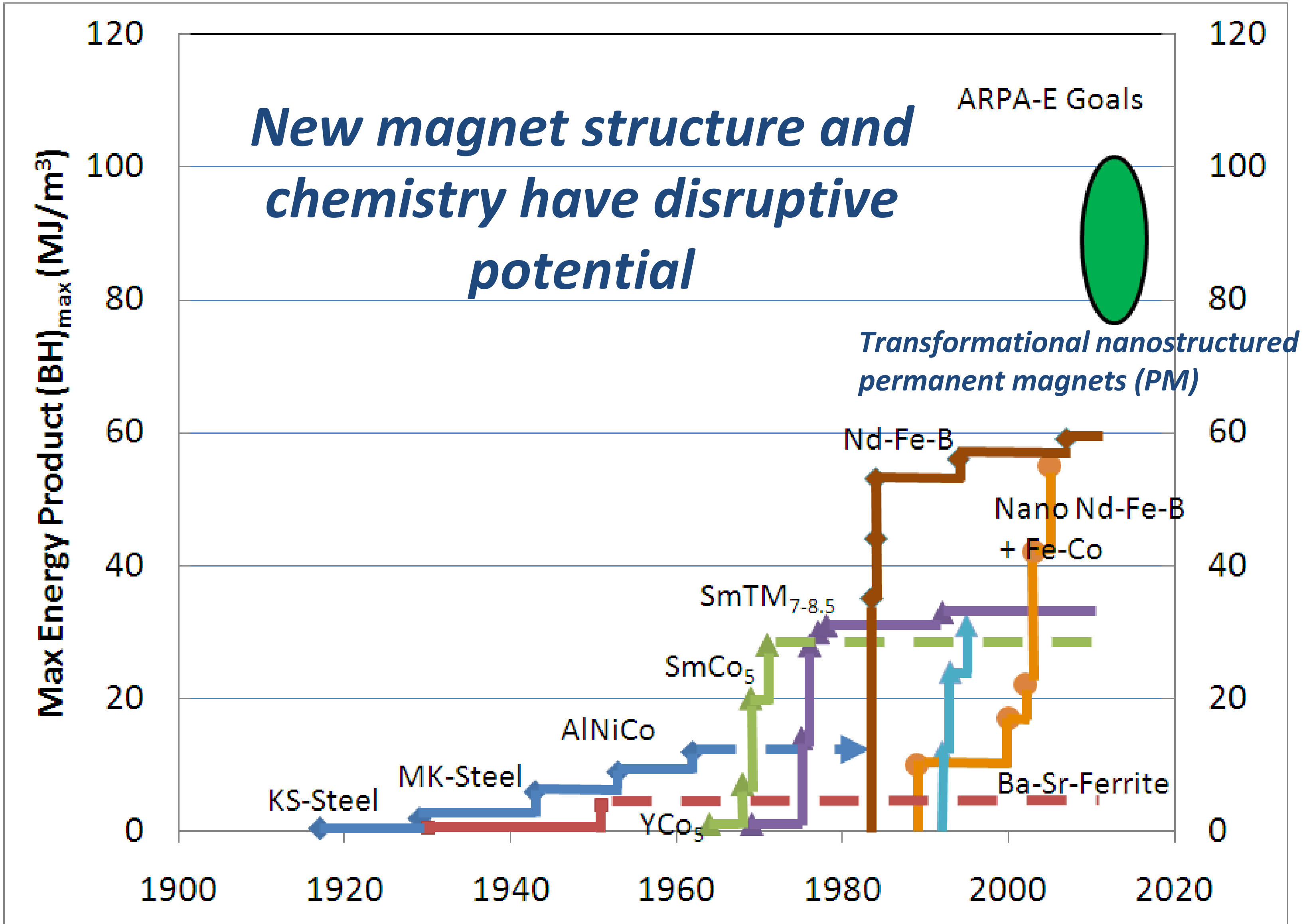
Development of Improved Powde[r] for Bonded Permanent Magnets

Ames Lab

Source: Universal (Ningbo) Magnetech Co., Ltd.

Source: Honda Civic Hybrid 2003

DOE's current programs – ARPA-E



Recent DOE Critical Materials Workshops

- Japan-US Workshop (Lawrence Livermore National Lab - Nov 18-19)

- Transatlantic Workshop (MIT - Dec 3)

- ARPA-E Workshop (Ballston, VA – Dec 6)

Information Gathering

- Data gaps
  - ***Individual materials:*** production, consumption and trading prices
  - ***Materials intensity*** of energy technologies
  - ***Potential for substitutes***
- Potential data resources
  - ***Recurring data collection:*** EIA, USGS and other stakeholders
  - ***Unique needs:*** Additional RFIs and workshops

Critical Materials Strategy Conclusions

- Some materials analyzed at risk of supply disruptions.

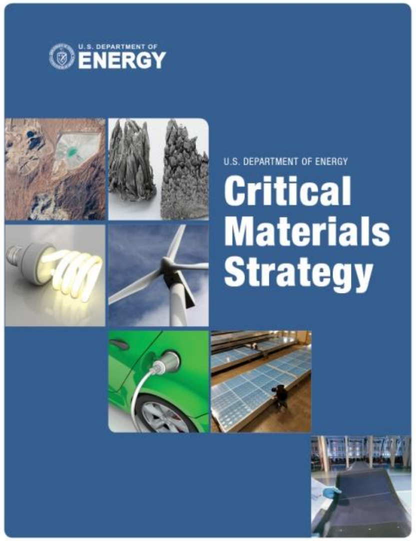
  Five rare earth metals (dysprosium, neodymium, terbium, europium and yttrium) and indium assessed as most critical.

- Clean energy's share of material use currently small

  …but could grow significantly with increased deployment.

- Critical materials are often a small fraction of the total cost of clean energy technologies.

  Demand does not respond quickly when prices increase.



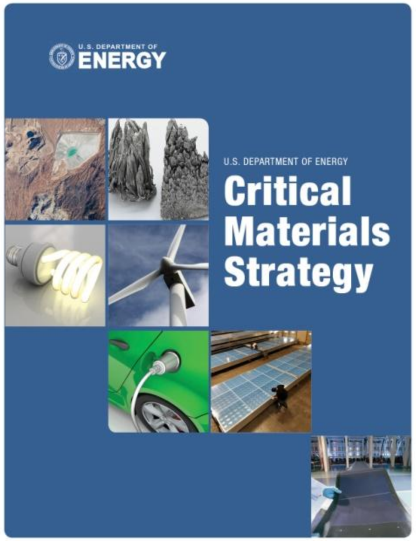
Critical Materials Strategy Conclusions (continued)

- Data are sparse.

  More information is required.

- Sound policies and strategic investments can reduce risk.

  …especially in the medium and long term.



IV. Next Steps

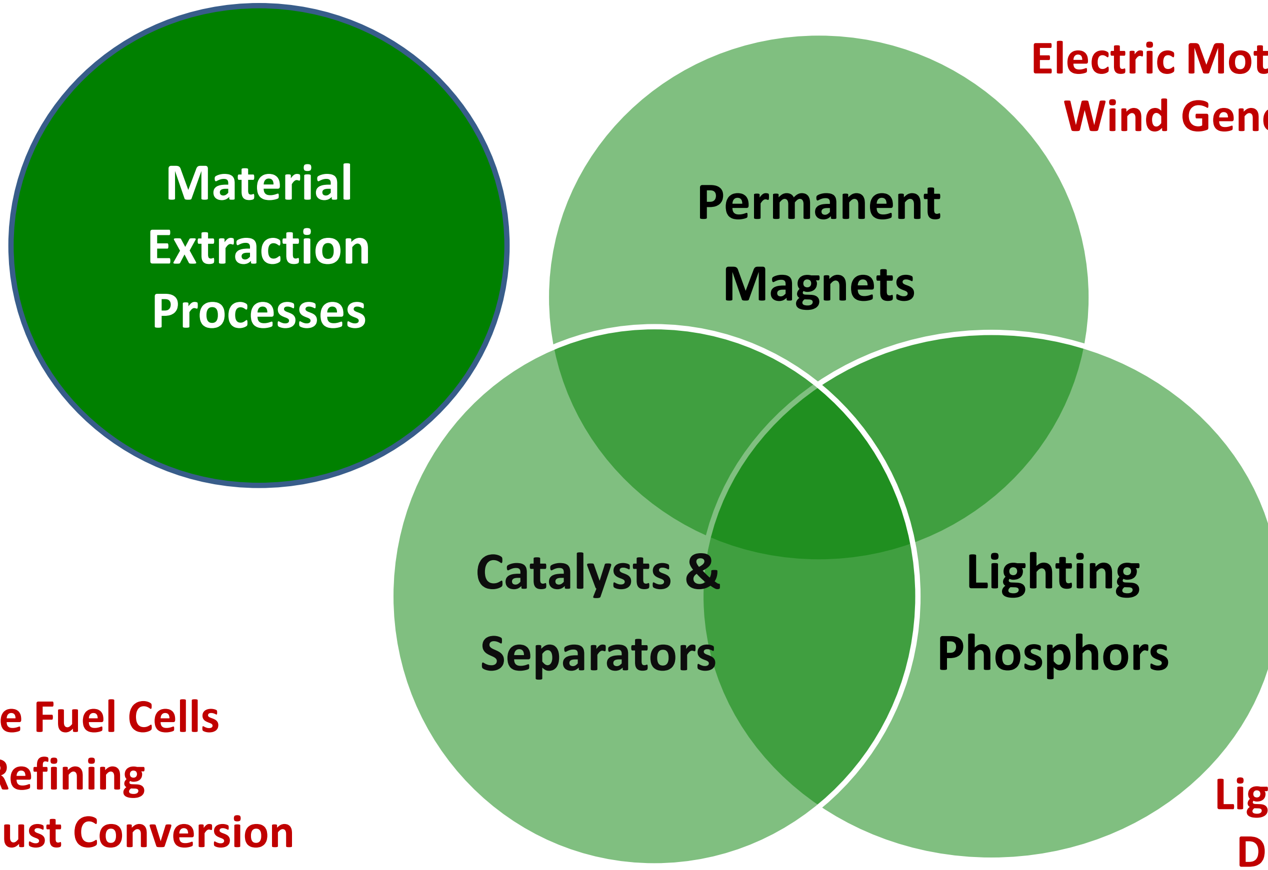
Next Steps for U.S. Department of Energy

- Develop an *integrated research plan*, building on three recent workshops.
- Strengthen *information-gathering capacity.*
- *Analyze additional technologies .*
- Continue to work closely with:
  - *International partners*
  - *Interagency colleagues*
  - *Congress*
  - *Public stakeholders*
- *Update the strategy* by the end of 2011.

Critical Materials Technology R&D Topics from ARPA-E Workshop

Geologic or Recycled Feedstocks

Electric Motors
Wind Generators



Solid Oxide Fuel Cells
Gasoline Refining
Auto Exhaust Conversion

Light Emitting Diodes (LED)
Compact Fluorescent Lights (CFL)

Supply Technologies ⟷ **Application Technologies**

Critical Materials Innovation Hub: President's FY 2012 Budget

- Novel approaches to reducing dependencies on critical materials.
  - Including strategies for *recycling*, *reuse* and more *efficient use* that could significantly lower world demand
- Energy Efficiency and Renewable Energy (EERE) Industrial Technologies Program.
- $20 Million

DOE's Second RFI on Critical Materials: Released Today

- Critical Material Content
- Supply Chain and Market Projections
- Financing and Purchase Transactions
- Research, Education and Training
- Energy Technology Transitions and Emerging Technologies
- Recycling Opportunities
- Mine and Processing Plant Permitting
- Additional Information

U.S. DEPARTMENT OF ENERGY

Critical Materials Strategy

DOE welcomes comments

Comments and additional information can be sent to *materialstrategy@hq.doe.gov*