

EVALUATING DYNAMIC FACTORS THAT AFFECT RARE EARTHS SCARCITY

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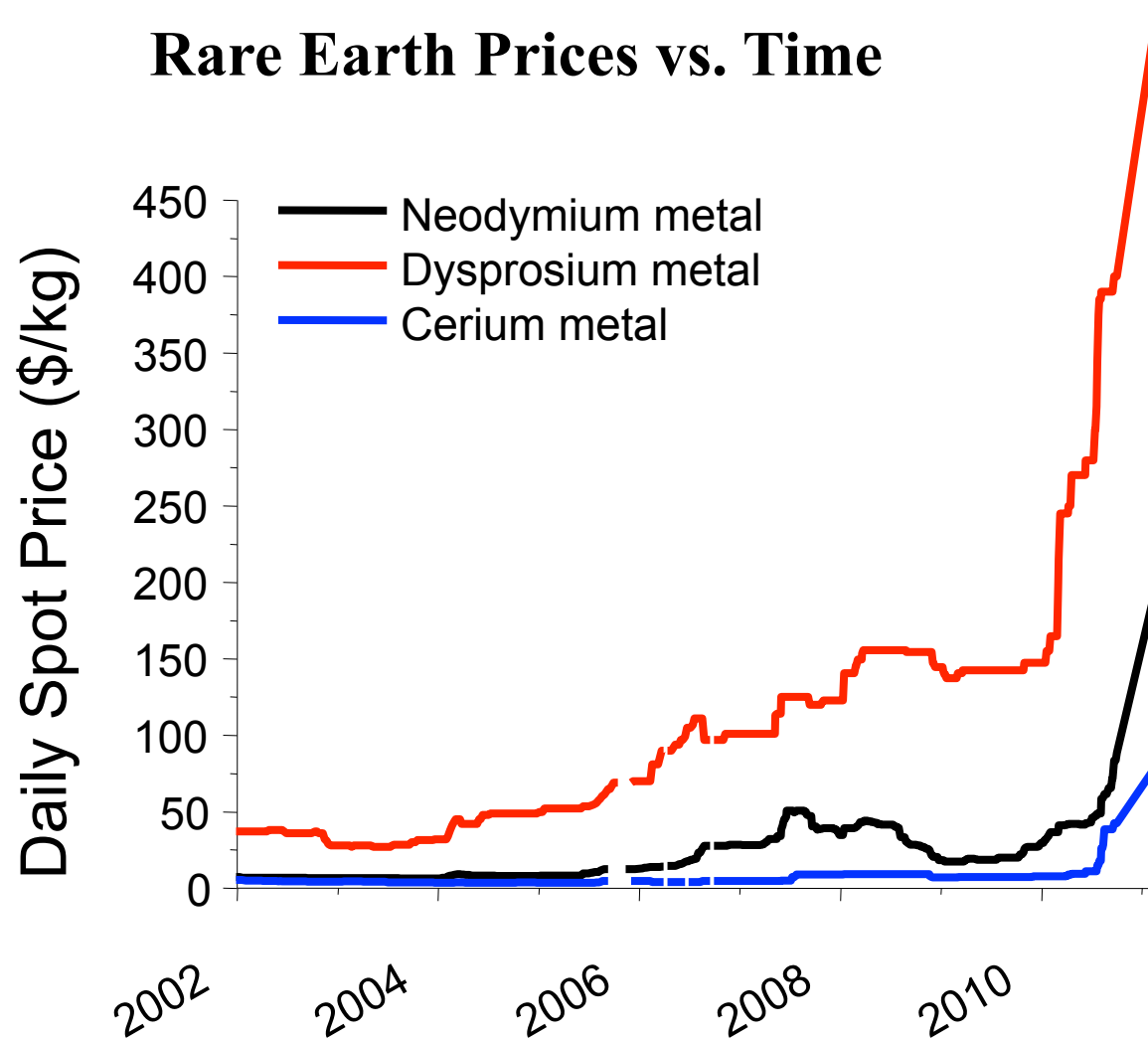
Why worry about scarcity? Scarcity affects firms through price

- Historical case studies have shown that price fluctuations can *permanently* change markets
- Preparedness reduces response delay time
 - Technical knowledge, capital investments, supply chain infrastructure are needed to respond
- Framework
 - Cost
 - Availability constraint
 - interaction of demand, supply
 - social & environmental pressures
 - Risk mitigation strategies

Start with where we are now, and evaluate where we might go

Why worry about scarcity? Scarcity affects firms through price

Rare Earth Prices vs. Time



Why Do Rare Earths Matter?

Result: Used in 700+ Auto parts

seats, door lock,
windows & sunroof:
Nd, Dy

entertainment system, navigation system:
Nd, Dy, Tb, Pr, Gd, Eu

Catalytic
converter &
oxygen sensors:
Ce, Y, La



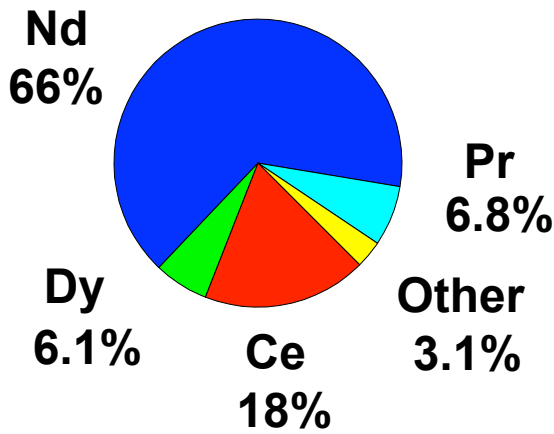
climate
control:
Nd, Dy, Pr

antitheft system,
horn: Nd

chassis, traction control, steering,
brakes: Nd, Dy, Pr

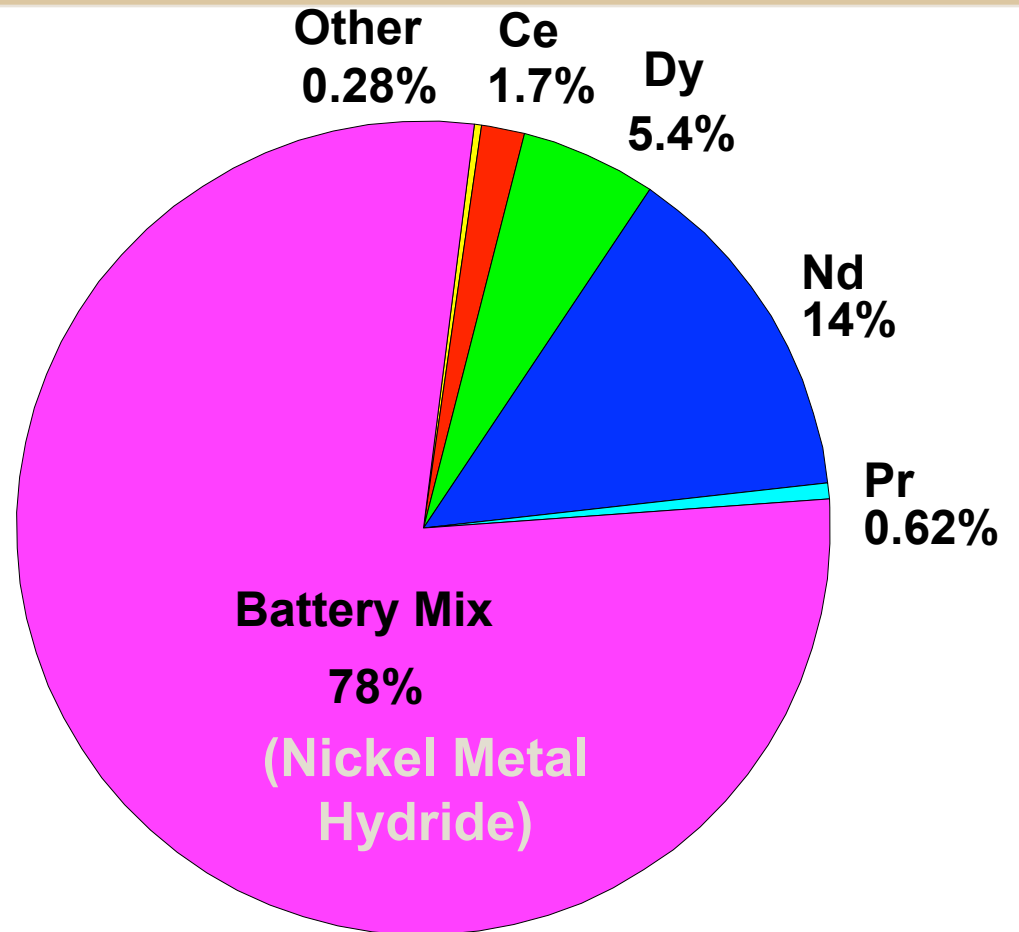
glass:
La, Ce

Result: Current Vehicles REE Portfolio



Current Conventional Car
~ 0.5 kg total

* %s show distribution of Rare Earths by mass

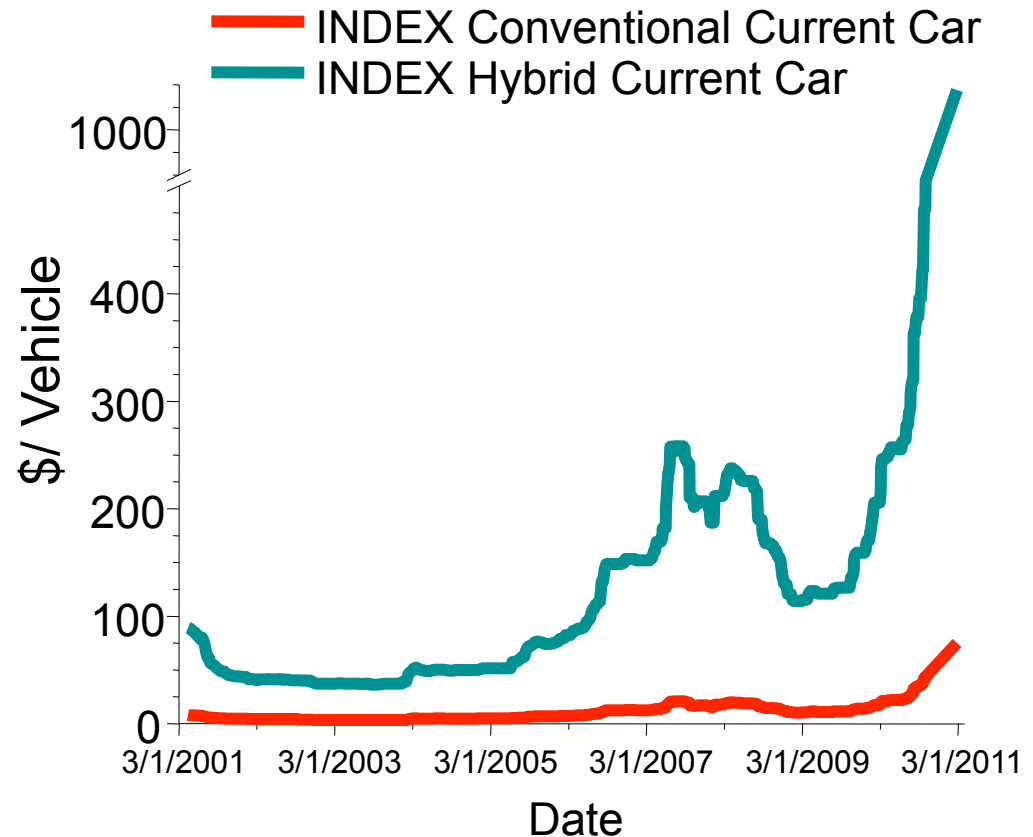


Current Hybrid Car
~ 4.5 kg total

Impact to Automakers in Terms of Material Costs

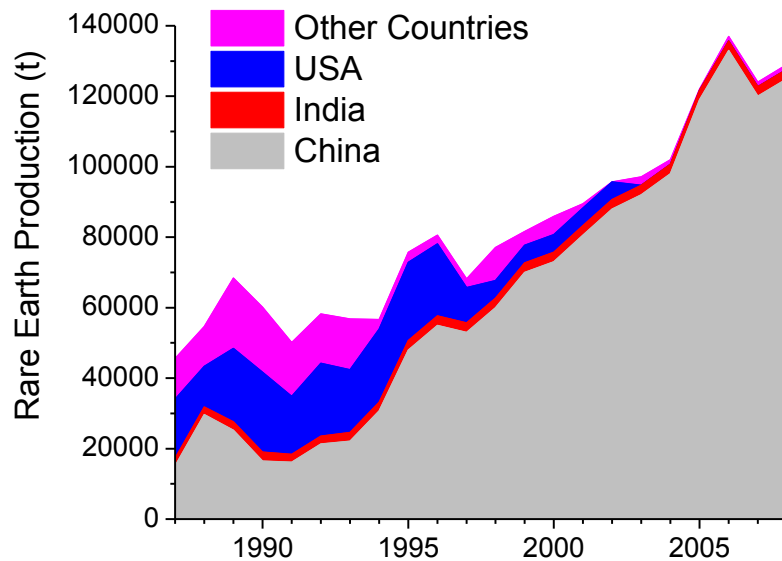
- Cost for conventional car are small fraction of vehicle price
- However, cost of rare earths per vehicle has increased by >10x in last year alone
- Rare earths account for much more significant fraction of cost of hybrid vehicle with NiMH battery than for conventional vehicle

*Costs calculated from metal spot prices: upper limit.

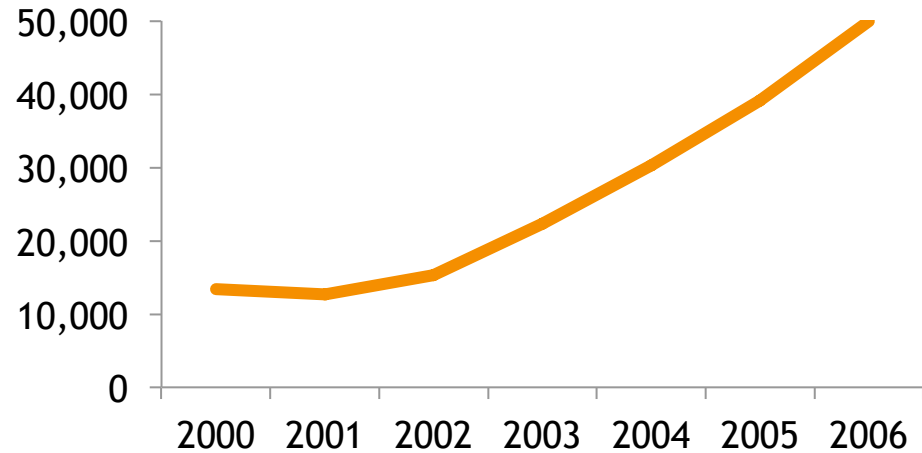


Were there any indications of the risks? Present state of RE market

Global Production vs. Time



Production of NdFeB magnets (t)

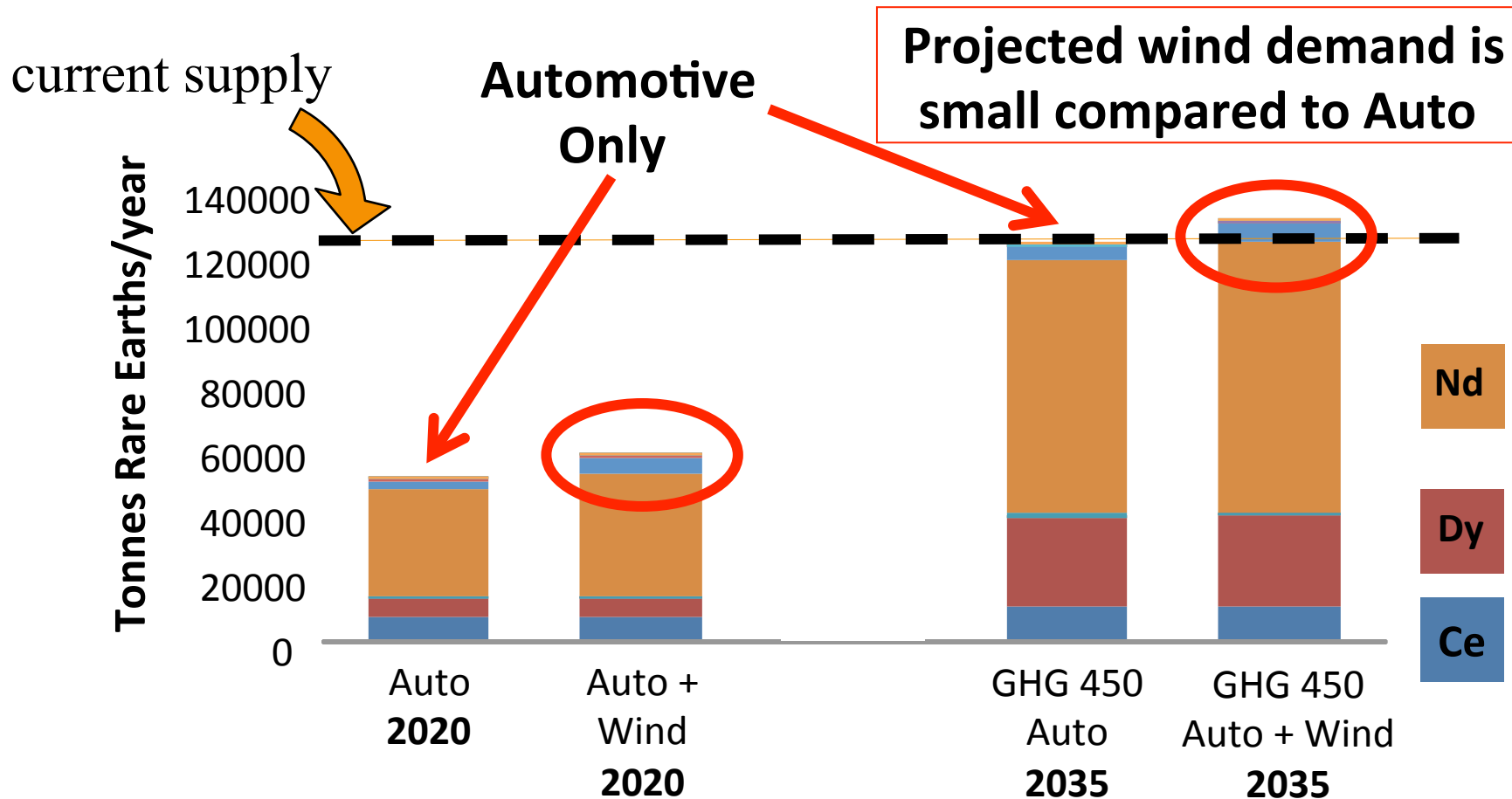


- Concentration of production in China
- Rapid growth of demand, specifically magnets
- Unsustainable environmental and labor mining practices

Evaluating Future Risks: Scenario Analysis

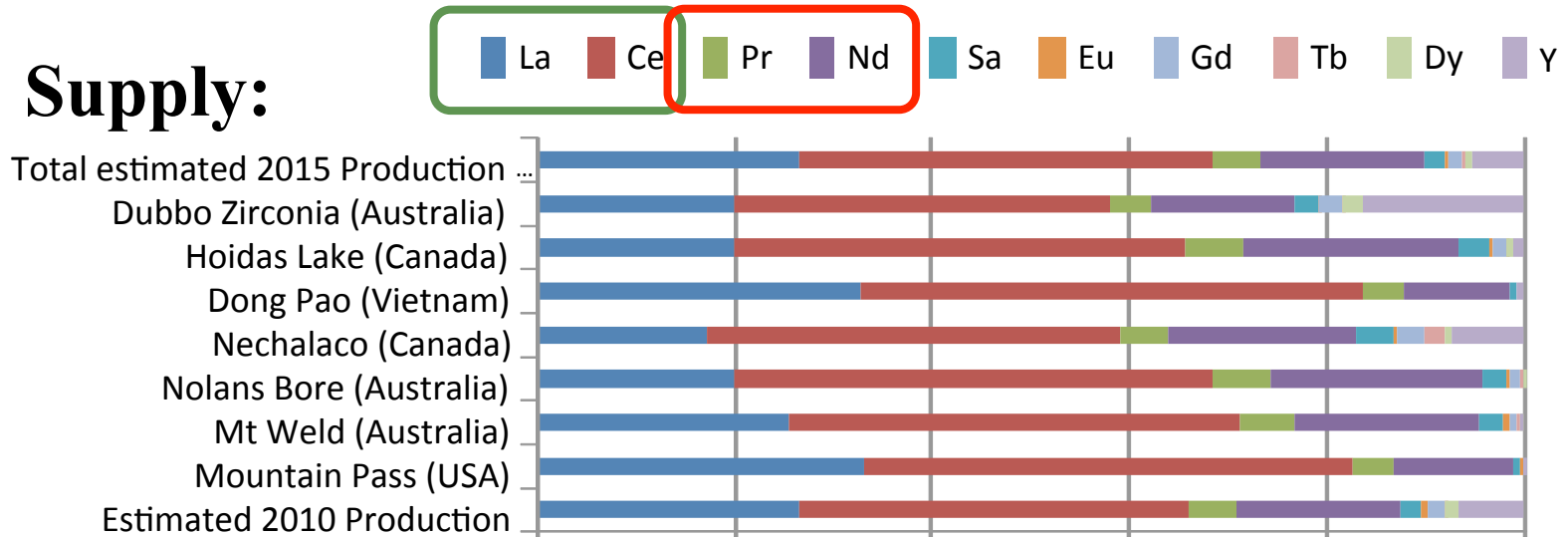
- Future electrification of vehicle fleet has implications for rare earth market
- Scenario analysis can be designed to explore possible concerns
 - Scenarios that meet GHG reduction goals based on World Energy Outlook 2010, IEA
 - 2020 and 2035 Projections
 - Rare earths demand assumptions
 - » *Conventional vehicles use ~0.5kg REE/vehicle*
 - » *Hybrid and other electric vehicles will use lithium battery by 2020 and use ~1kg REE/vehicle*
 - » *600kg REE per 3.5MW wind turbine*

Estimated Rare Earth Demand for Auto & Wind (World Energy Outlook Scenarios)

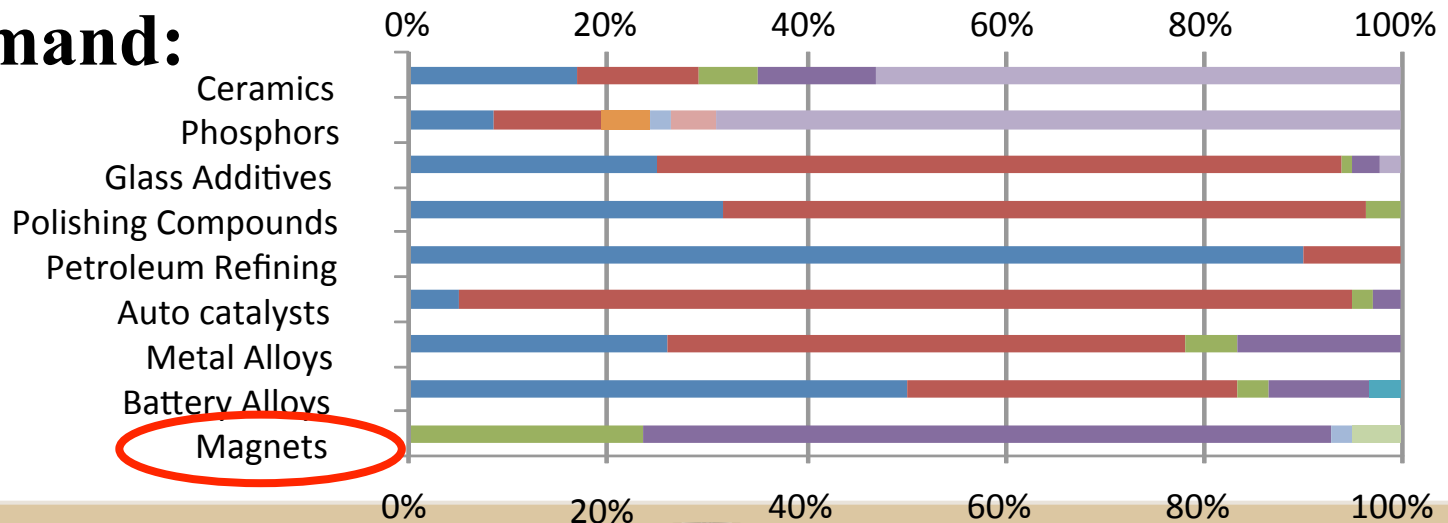


Distribution of Rare Earth: Supply at key mines vs. Demand in key applications

Supply:



Demand:



Examination of Individual Rare Earth Requirements

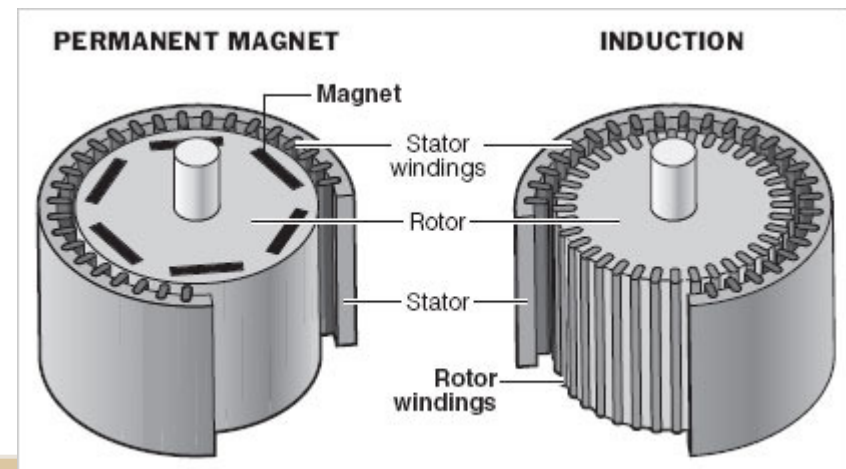
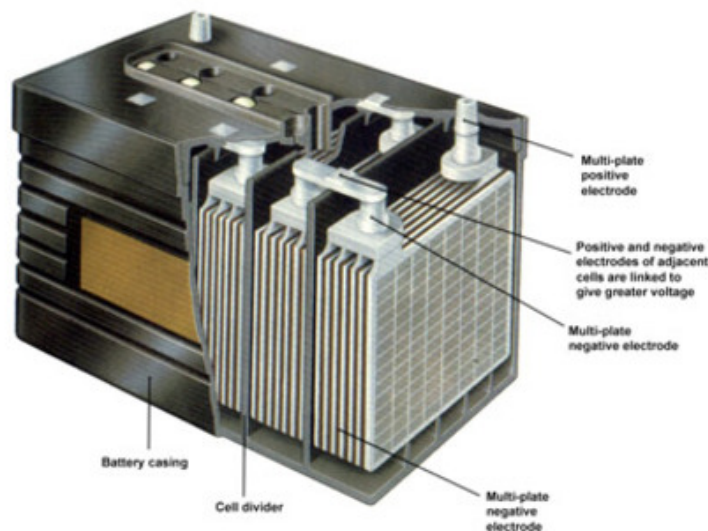
Ratio of Demand for RE in Future Scenarios to Present Supply

- Individual elements may be physically constrained
 - Dysprosium
 - Neodymium
- What actions are called for?

	2020 Automotive	2020 Automotive + Windturbines
Ce	18%	18%
Dy	378%	414%
Eu	8%	8%
Gd	2%	10%
La	2%	2%
Nd	162%	195%
Pr	53%	92%
Sa	13%	13%
Tb	0%	8%
Y	1%	1%
Total	43%	51%

Strategies under consideration

- Technological and Materials Substitution
 - NdBFe magnets with Dysprosium to other magnets
 - NiMH to Li battery
 - Permanent magnet motor to induction motor
 - Ce in sensors and catalysts to other catalyst chemistry
- Securing supply with higher environmental standards
- Recycling should be explored



Conclusions and recommendations for industries that depend on REE

- Identification of REE content of vehicles was challenging
 - REE enable many vehicle functions, in particular electrification
- Post-facto observation of crisis indicates factors of concern
 - China's monopoly on production, which is expected to change with new mines opening in US and Australia
 - Fast demand growth outpacing supply for specific rare earth elements
 - High environmental costs associated with mining rare earths
- Vehicle demand is and will likely continue to be a significant market for Rare Earths
- Reports indicate technological and materials substitution options are under consideration

QUESTIONS?