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Incorporating Climate Change into Supply Chain Risk Assessment
Neodymium Magnet Supply Chain Proof of Concept

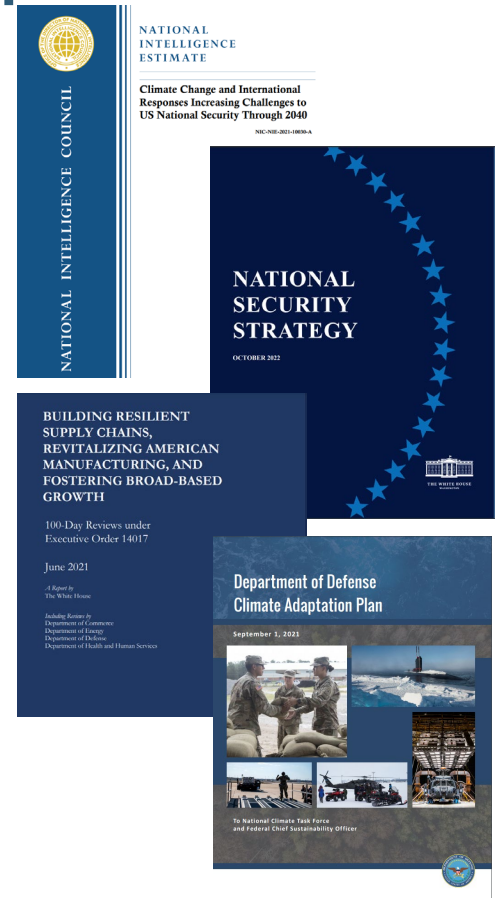
Principal Investigators: Adam Turbett, Michael Bruckner

Support Team: Casey Intrator, Clark Bee, Kolin Beam, Dana Fahey

28 March 2023

The move to achieve net zero emissions has national security and supply chain resilience implications

- In order to achieve net zero, demand for critical materials will rise dramatically
  - Defense technologies will compete with demand from decarbonization technologies, adding stress to supply chains
  - Countries will compete to control resources and dominate new technologies needed for clean energy transition
  - Must be able to forecast and proactively resolve supply chain roadblocks
- More resilient supply chains are essential for our national security, our economic security, and our technological leadership
- The COVID-19 pandemic and resulting economic dislocation revealed long-standing vulnerabilities
- Climate change may further exacerbate these shortages

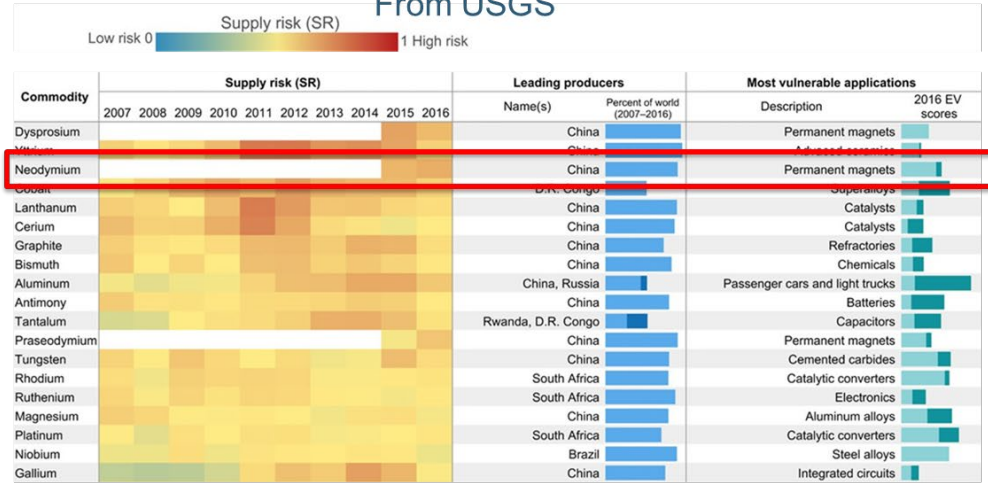


Government policy is driving Federal agencies to consider climate change impacts to achieve resilient supply chains

- **Executive Order (EO) 14008 (2021)** requires agencies, as part of their climate plans, to increase resilience to supply chain disruptions
- **EO 14017 (2021)** identifies multiple climate related risks to supply chain disruption
- **EO 14030 (2021)** identifies climate change as leading to increasing supply chain disruptions and transitional risk in global shift away from carbon-intensive energy sources

Start by identifying existing assessment methodologies and relevant supply chains

From USGS



Commodity	Supply risk (SR) 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016	Leading producers Name(s)	Leading producers Percent of world (2007–2016)	Most vulnerable applications Description	Most vulnerable applications 2016 EV scores
Dysprosium		China		Permanent magnets	
Yttrium		China		Advanced ceramics	
Neodymium		China		Permanent magnets	
Cobalt		D.R. Congo		Superalloys	
Lanthanum		China		Catalysts	
Cerium		China		Catalysts	
Graphite		China		Refractories	
Bismuth		China		Chemicals	
Aluminum		China, Russia		Passenger cars and light trucks	
Antimony		China		Batteries	
Tantalum		Rwanda, D.R. Congo		Capacitors	
Praseodymium		China		Permanent magnets	
Tungsten		China		Cemented carbides	
Rhodium		South Africa		Catalytic converters	
Ruthenium		South Africa		Electronics	
Magnesium		China		Aluminum alloys	
Platinum		South Africa		Catalytic converters	
Niobium		Brazil		Steel alloys	
Gallium		China		Integrated circuits	

Supply Risk	
DP	Disruption Potential Ability and willingness to supply US
TE	Trade Exposure Dependence on non-US supply
EV	Economic Vulnerability Severity of impact

Nedal T. Nassar et al. Sci Adv 2020;6:eaay8647

From DLA Strategic Materials

Aluminum

Dysprosium

Yttrium

Neodymium

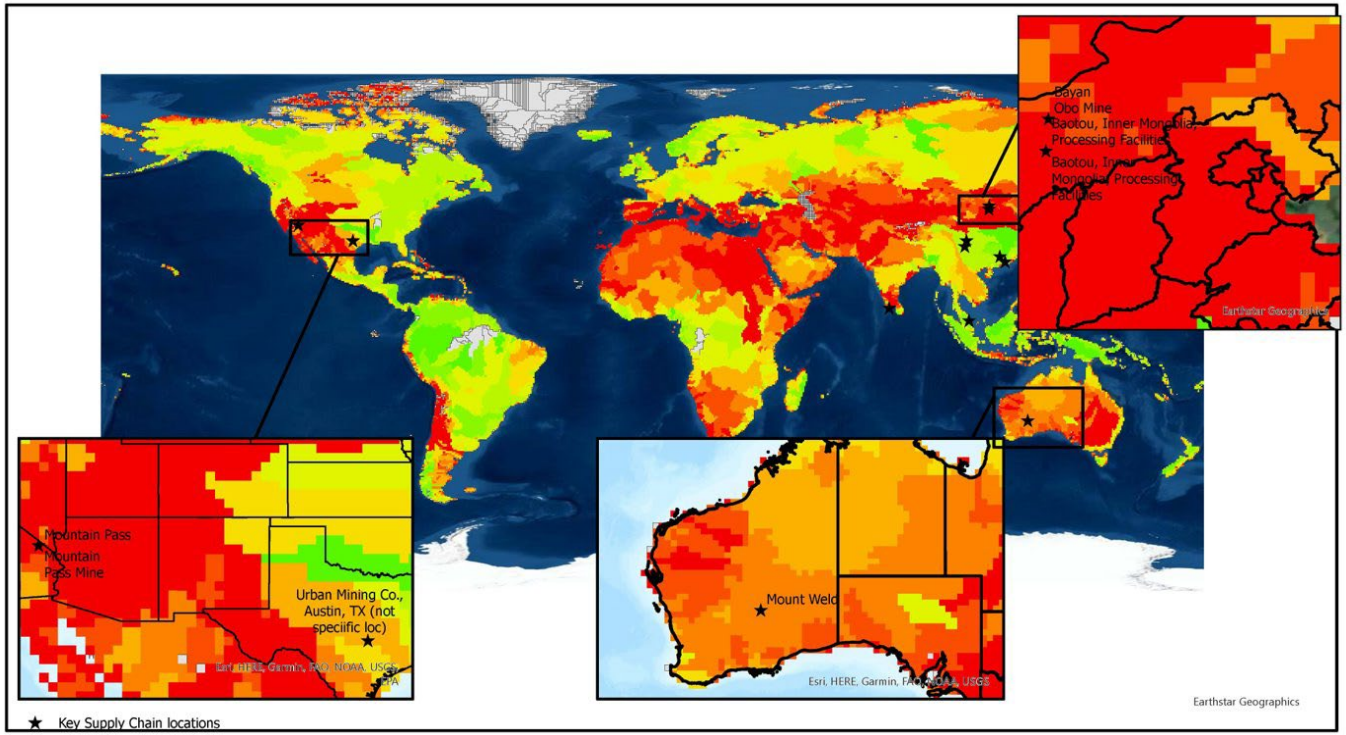
Material Description

Neodymium (Nd, Z=60) is a soft, bright silvery metal. It is one of the most reactive REEs and quickly oxidizes in air. Neodymium averages ~ 27 mg/kg in the earth crust. The primary source of neodymium is from carbonatites and bastnasite, and a secondary source is in monazite. It is found in minerals such as cerite and allanite. The pure metal has limited application. Its mixture with praseodymium is called didymium. Neodymium has 7 natural isotopes and 23 radioisotopes.

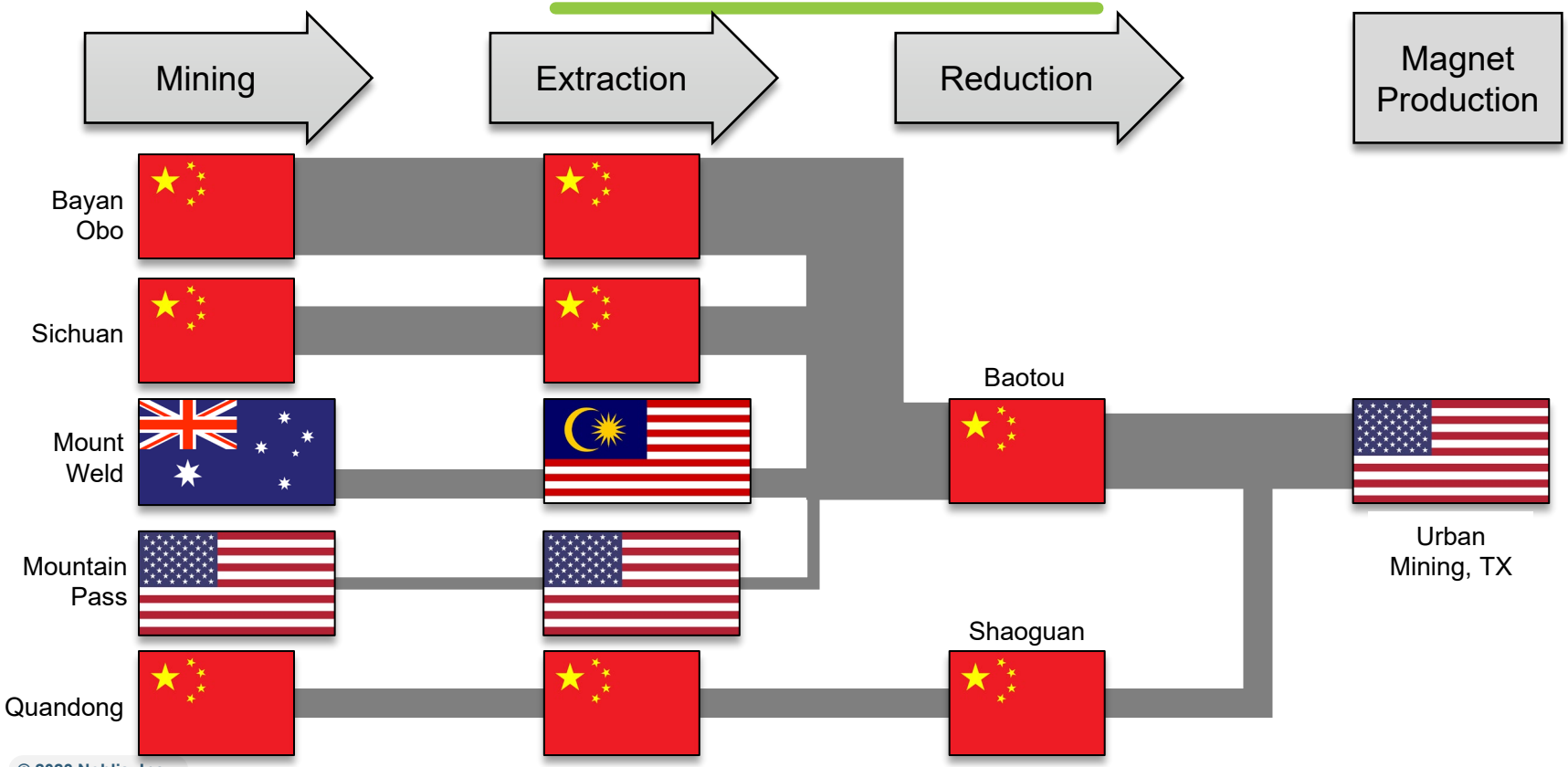
What are the common uses of neodymium?

- Glass production
- Incandescent light bulbs
- Cathode ray tubes
- Ceramic capacitors, semiconductors and other components for LCDs and electronics
- NdFeB magnets in smartphones, hard drives, other consumer electronics and in propulsion of DDG-51

Identify Relevant Climate Impacts: Water Vulnerability



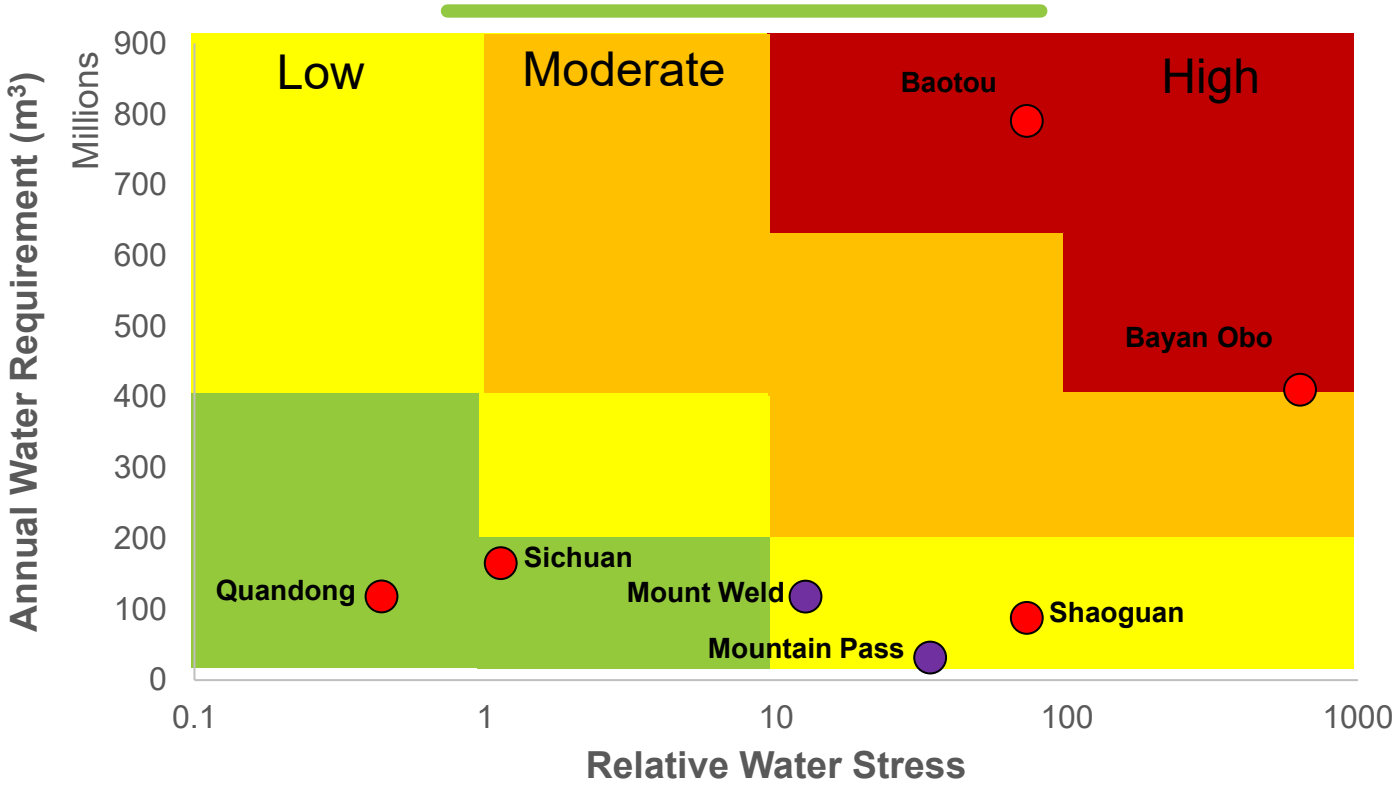
Characterize Supply Pathways for Domestic Magnet Production



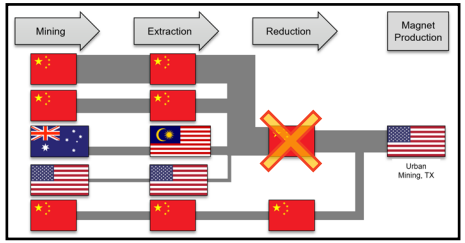
Assess Water Scarcity Impact

- Water Scarcity Model (AWARE) overview
  - Based on the quantification of the relative available water remaining per area once the demand of humans and aquatic ecosystems has been met
- Measures the amount of available water remaining in a specific watershed, basin, or country with respect to the world average on a monthly or yearly timescale
- Characterization factors (CF) are on a scale from 0.1-1000
  - Value < 1 = region with more water remaining than the world average
  - Value of 1 = region with the same amount of remaining water per area than the world average
  - Value of 10 = region with 10 times less water remaining than the world average OR it would take 10 times as long to generate an amount of unused water in this region than the world average

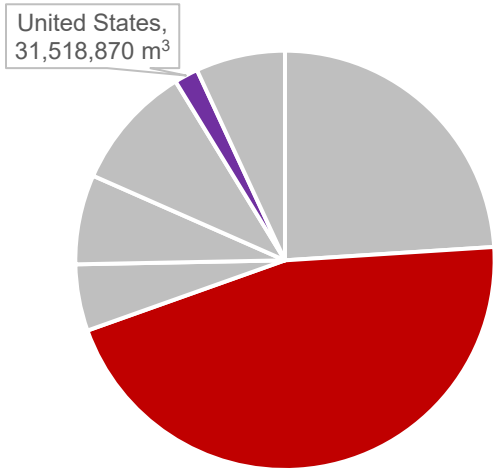
Map Neodymium Supply Chain Water Scarcity Risk



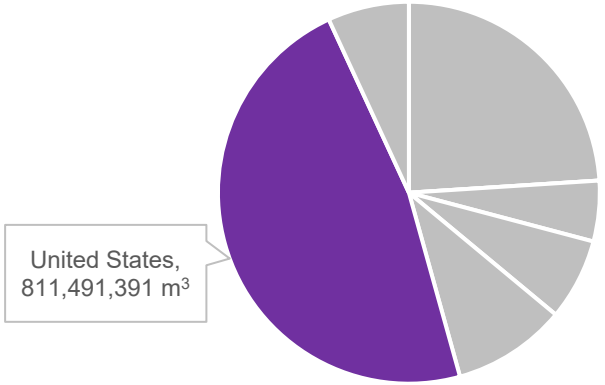
Assess Domestic On-Shoring Critical Node: Water Footprint



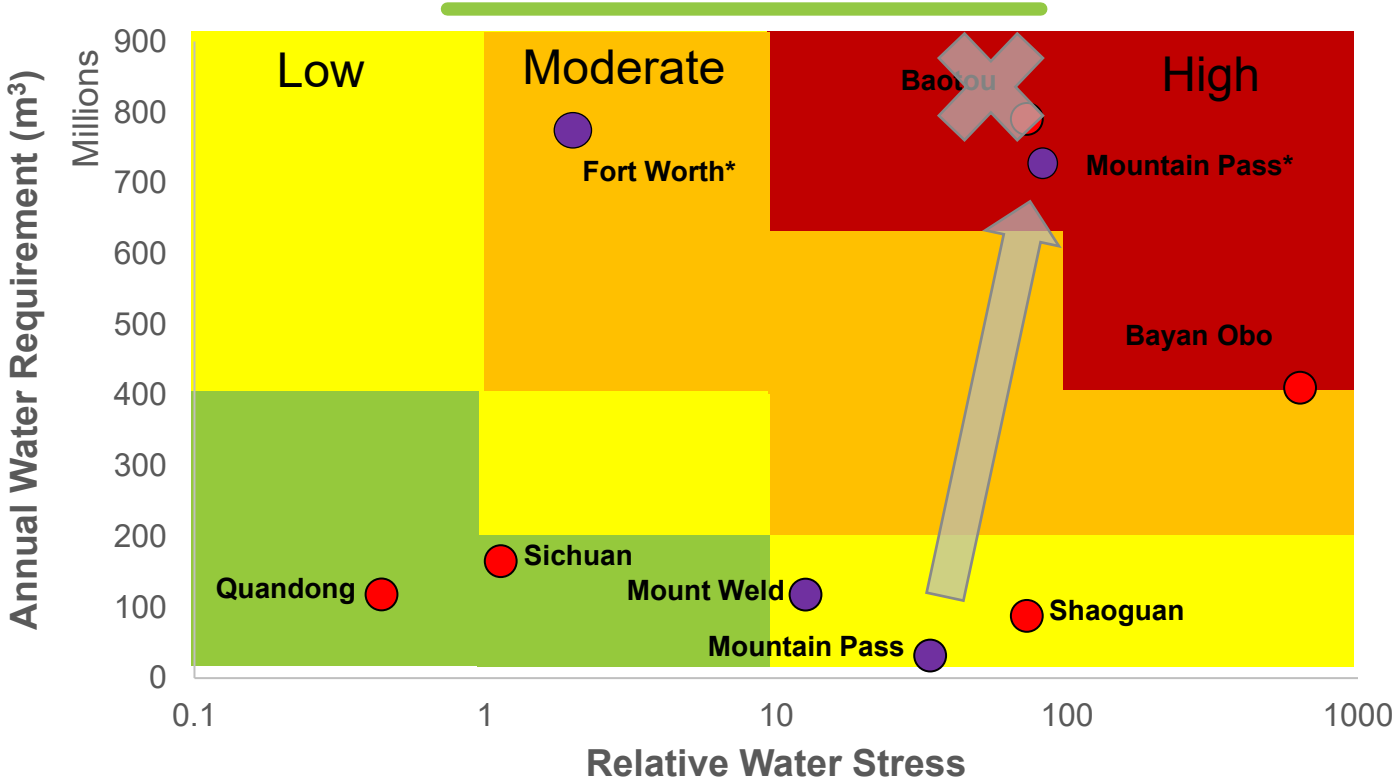
Status Quo



Scenario 1
On-Shore Reduction Step



Assess Domestic On-Shoring Critical Node: Water Footprint of Complete Onshoring



*On-shoring alternative scenarios forecast water footprint at two potential new reduction U.S. facilities

Conclusion

- The Neodymium supply chain is vulnerable to water scarcity impacts exacerbated by climate change
- As Neodymium demand increases, impacts to water resources will increase
- Onshoring Neodymium mining, extraction, and production will require large amounts of domestic water resources
  - Can be partially mitigated through recycling the water used in these processes
  - Will make Neodymium production more expensive in the U.S. than other countries
- Government agencies can analyze climate impacts to other critical materials and minerals to understand their challenges