

# Rare Earths and the Future of the U.S. Wind Industry

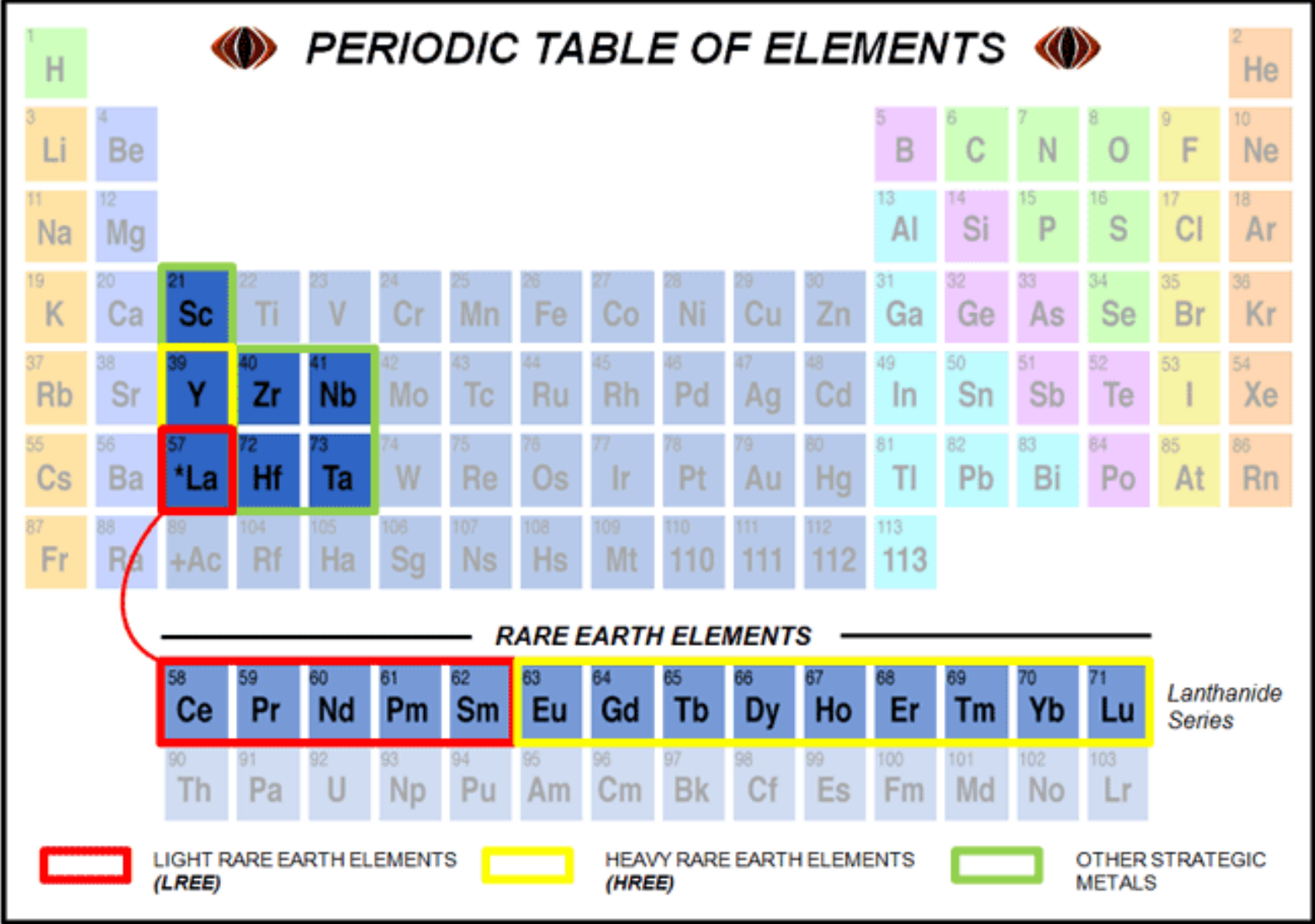
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WESEP 594

# Outline

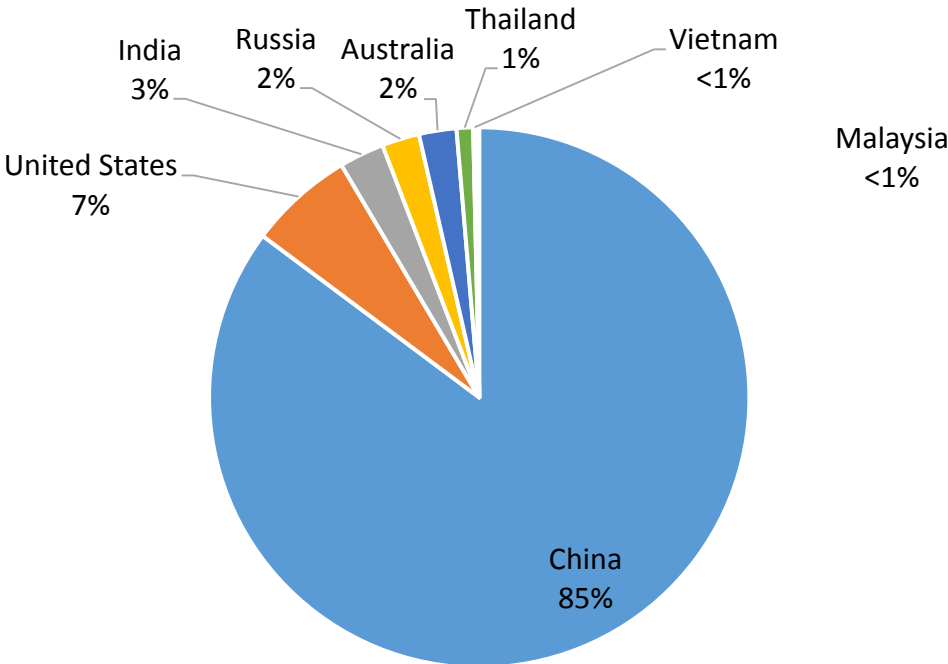
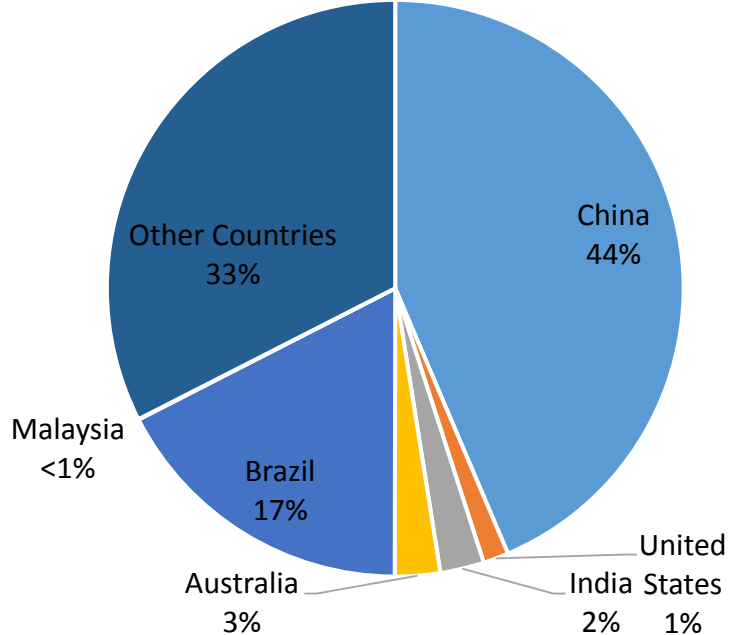
- Introduction to rare earths
- Importance to wind energy
- “Rare earth crisis”
- Barriers to congressional strategy
- Recommendations
- Rare earths and future of the U.S. wind industry

# Rare Earth Elements



# Distribution of Resources

Estimated World Reserves in 2014



Estimated Mine Production in 2014

# Applications of Rare Earths

- Auto catalysts
- Petroleum refining catalysts
- Electronics
  - Cell phones
  - Computers
  - Television screens
  - Computer monitors
  - Silicon chips
- Glass polishing
- Metallurgical additive and alloys
- Phosphors for fluorescent light bulbs
- Military applications
  - Guidance and control systems
  - Electric motors
  - Communication devices
  - Lasers
- Permanent Magnets
  - Electric machines
  - Hard disk drives

# Importance to Renewable Energy

- NdFeB permanent magnets
  - Permanent magnet generators in wind turbines
  - Permanent magnet motors in electric and hybrid vehicles
- NdFeB alloy contains partial substitution of Dy for high temperature operations
  - Nd: light rare earth
  - Dy: heavy rare earth
- NdFeB permanent magnets currently drive rare earth market
- Only 1% of utility scale wind turbines use permanent magnets in the U.S.
- Globally, permanent magnets used in ~28% of all wind turbines
  - China ~20% of total installations

# “Rare Earth Crisis”

- U.S. once self sufficient in rare earth production
- China flooded market, driving U.S. mines out of business
- In 2010, two major events
  - China cuts all exports of rare earth to Japan for four months
  - Price spike of Nd and Dy
    - Nd: \$108 to \$245 per kg
    - Dy: ... to \$1200 per kg
  - Chinese practices of export quotas and tariffs may have contributed to price spike
  - World Trade Organization has since ruled these practices violated international trade law

# Federal Recommendations

- Department of Energy (DOE) issued “Critical Materials Strategy” in 2010, updated in 2011
  - Dy is most critical element
    - Demand is expected to exceed supply
  - Nd one of top five identified critical elements
  - Recommendations:
    - Domestic investment
    - Diversification of global supply chains
    - Heavy research and development
- Department of Defense (DOD) issued “Strategic and Critical Materials 2013 Report on Stockpile Requirements”
  - Recommendations: stockpiling of Dy



# Research and Development

- ARPA-E solicited research for substitution of Dy with non-critical materials
- Critical Materials Institute, Ames Lab
  - Recycling of manufacturing swarf for direct reuse in SmCo permanent magnets
  - Partial substitution of Nd with Ce and Fe with Co for high temperature permanent magnets
    - Industrial scale sintered magnets not yet achieved

# Current U.S. Strategy

- Molycorp reopened mine at Mountain Pass, CA in 2012
  - U.S. annual mine production increased 800 to 4,000 tons from 2012 to 2013
    - Decreased imports by ~\$259 million
  - Molycorp filed for bankruptcy
- U.S. explored development of mines in 10 additional states in 2013
- No stockpiles of rare earths
- No congressional strategy

# Barriers to Congressional Strategy

- The U.S. currently has no congressional strategy to secure a long-term, sustainable supply of rare earths despite recommendations from DOE and DOD
- Research question:
  - What are the barriers to passage of U.S. congressional strategy?
- Approach:
  - Literature review
  - Media content analysis
  - Policy analysis

# Environmental Barriers

- Mining
  - Rare earths found in combined mineral deposits
  - Movement of rare earths through environment not yet well understood
- Refinement
  - Baotou, China (Inner Mongolia)
  - There is no “Nd ore” or “Dy ore”
    - Rare earth elements are found combined in ore
    - VERY chemically similar
    - Separation processes are chemical and energy intensive
  - Acidic or basic dissolution wastewater threatens pH balance of environment
  - 1 ton of rare earths produced = 1 ton radioactive waste



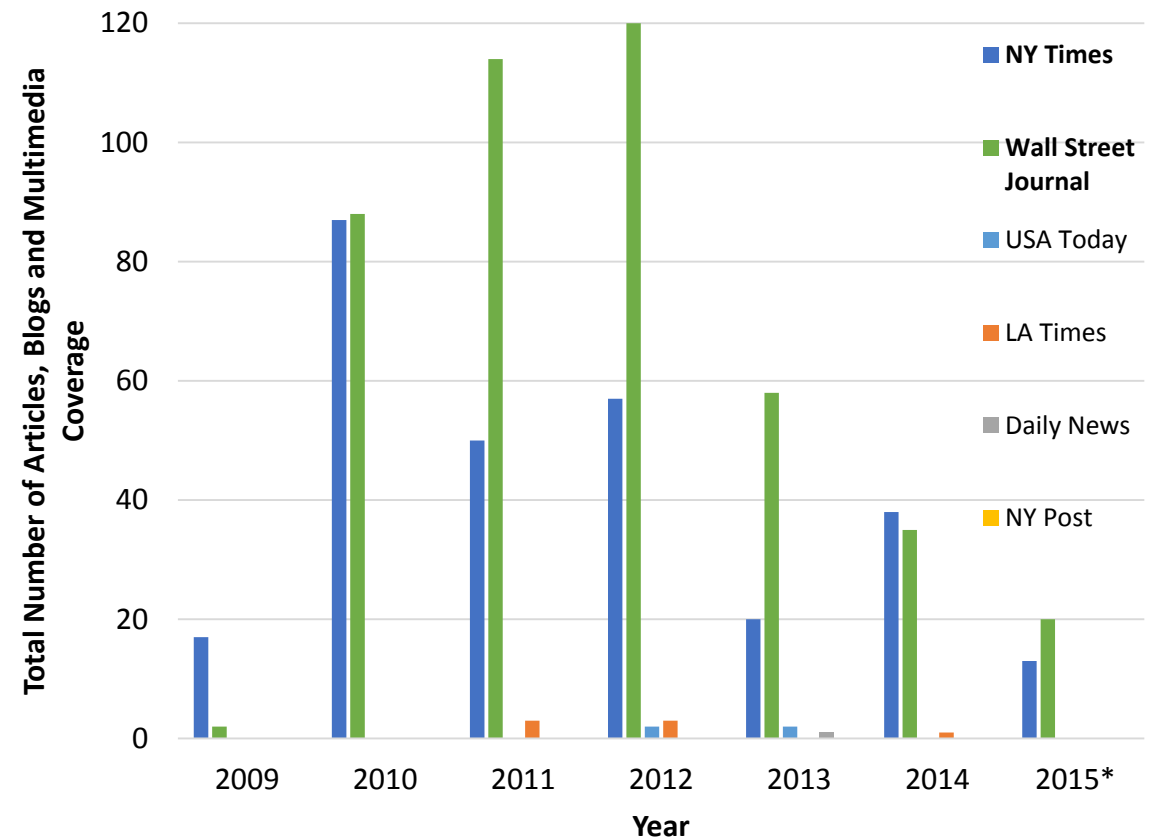
<http://www.bbc.com/future/story/20150402-the-worst-place-on-earth>

# Social Barriers

- Bayan-Obo, China
  - Bastanite deposits contain ~0.04% thorium
  - If inhaled, radioactive decay in lungs
- Tied closely to environmental degradation
  - Destruction of farmland and livelihood
  - Pollution of water
  - Rare earth mining in Africa

# Social Barriers

- Research question: Is the general public aware of rare earths?
- Approach: media content analysis
- Top six most widely circulated newspapers in U.S.
- USA Today, NY Times, Wall Street Journal, Daily News, LA,
- Search terms: rare earth(s)



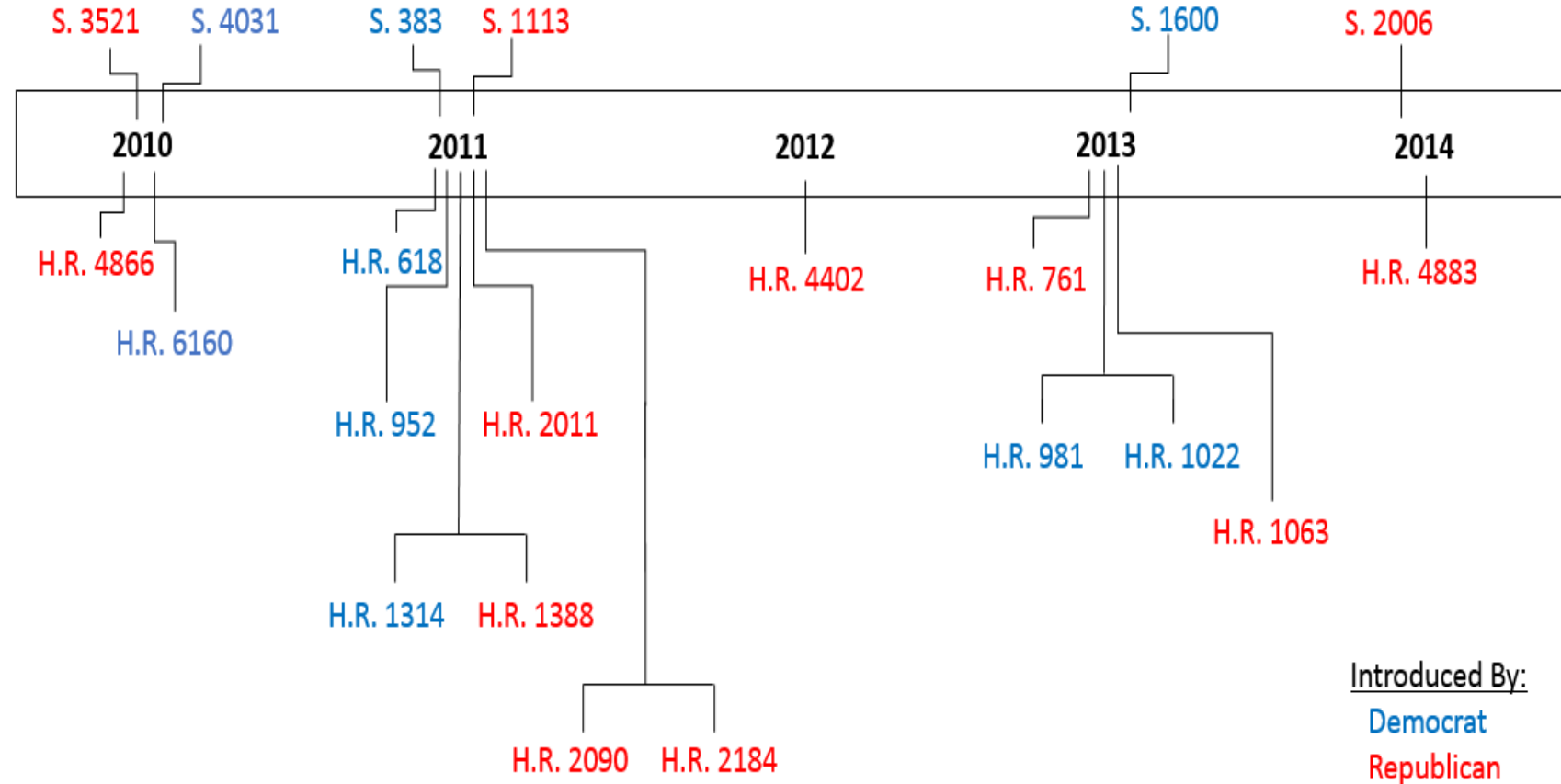
\*Through 6/26/15

# Social Barriers

- Conclusion: General public has little exposure no media coverage of rare earths
- Significance: Little public pressure on congress to pass legislation

# Political Barriers

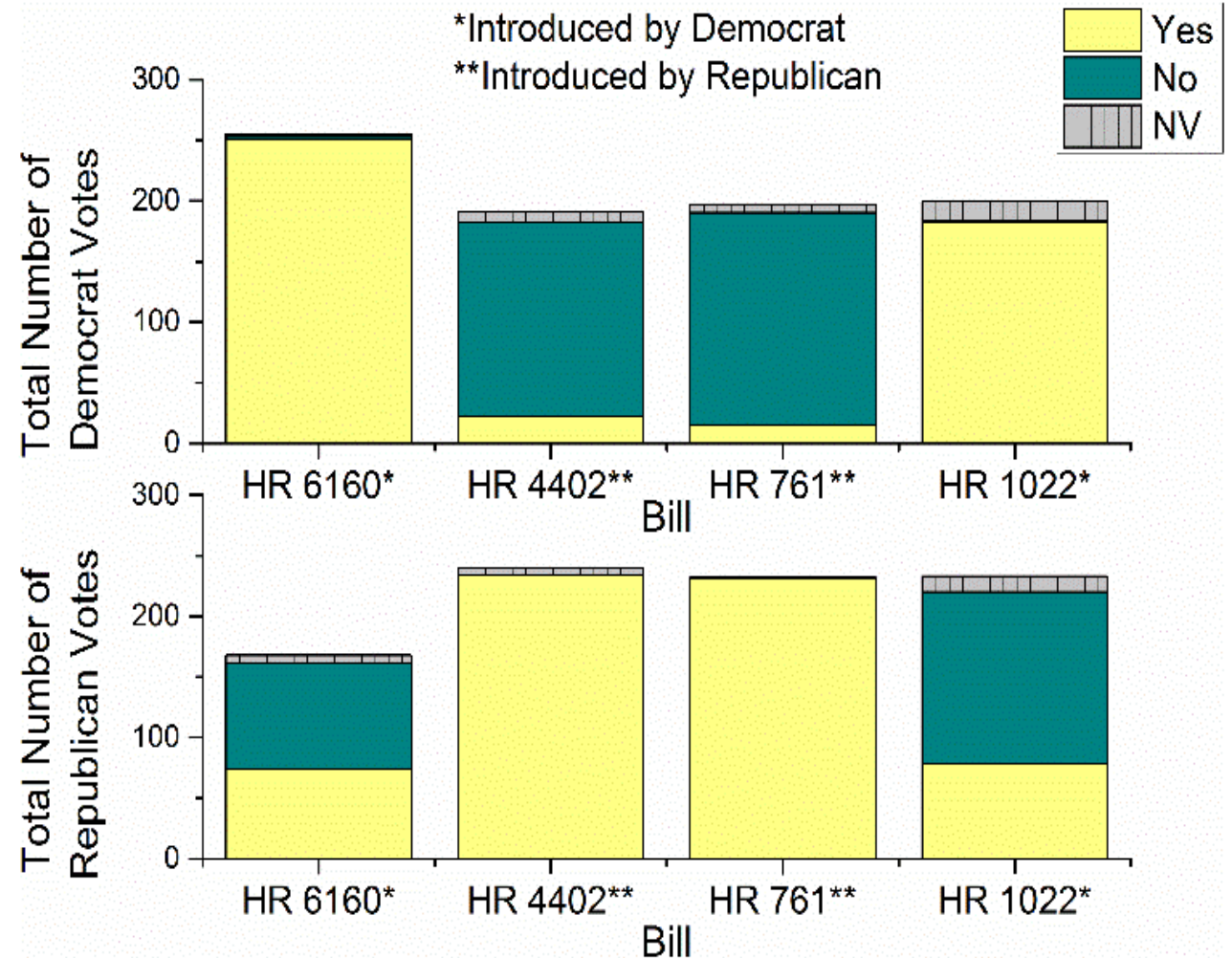
- From 2010 to 07/2015, 21 bills introduced





# Political Barriers

- 4 [of 21] bills came to a vote in House of Representatives
  - 3 passed, but never made it out of committee in Senate
  - Motivation factors investigated
    - Political affiliation
    - Rare earths deposits identified in state



# Political Barriers

- *Rare Earths and Critical Materials Revitalization Act of 2010 (H.R. 6160)*
  - Republicans do not support loan guarantees
    - Do not want to pick “winners” and “losers”
- *National Strategic and Critical Minerals Production Act of 2012 (H.R. 4402)*
  - Democrats concerned about elimination of environmental review and believed definition of “critical materials” too broad
  - President Obama threatened to veto bill
- *National Strategic and Critical Minerals Production Act of 2013 (H.R. 761)*
  - Again, Democrats concerned about environmental review and definition of “critical materials”
- *Securing Energy Critical Elements and American Jobs Act of 2014 (H.R. 1022)*
  - Elimination of loan guarantees to gain bipartisan support but didn’t pass

# Conclusions

- Barriers to U.S. congressional strategy include:
  - High environmental and social costs
  - Lack of public awareness/pressure
  - Political party divides

# Contrast: Japan

- Japan was dependent on China for 91% of imports during rare earth crisis
- Japan has since reduced its dependence to 60%
  - Stockpiling
  - Investment and development of rare earth mines in Vietnam
  - Has shown interest developing mines in North Korea, estimated ~48 million tons

# Recommendations

- Federal subsidies for mine development
- Environmental justice for global diversification and trade with China
- Public awareness campaign
- Heavy research and development
  - Substitutes
  - Recycling
- Long term: development of rare earth free permanent magnets

# Rare Earths & the Future U.S. Wind Industry

- Current state of industry: 1.9MW Type 3 wind turbines
- More direct drive (DD) in the future
- Permanent magnet generators (PMGs) are preferred over DFIGS for direct drive
- GE has been committed to DFIGs, but now has offshore 4MW DDPMGs
- Siemens has onshore and offshore DDPMGs
- Materials research critical especially with regard to Dy substitution

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