MORE PRECIOUS THAN GOLD: LIMITED ACCESS TO RARE ELEMENTS AND IMPLICATIONS FOR CLEAN ENERGY IN THE UNITED STATES

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Abstract

As the United States and the rest of the global community continue their movement into an era of green technology and towards a cleaner environment, the biggest threat to face is not a lack of renewable energy resources, hesitancy of countries to take steps towards adopting or promoting green technology, or an inability to maintain a functional clean energy infrastructure. Instead, one of the primary concerns facing the green technology movement is the potential scarcity of specific key resources necessary to bring about the type of global changes in energy infrastructure that environmental scholars aspire to. This Article examines the relationship between rare elements and green technology and considers the potential negative implications for the clean energy movement in the United States stemming from the country's looming difficulties in acquiring such elements. The Article then explores potential measures that may help successfully alleviate these barriers and allow the green technology movement to progress as efficiently and effectively as possible. Finally, the question of how to create a sustainable clean energy strategy is addressed, providing an example of the type of energy policy portfolio that will be able to meet national demands while still mitigating the risk of foreign material reliance.

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I. INTRODUCTION

The global energy landscape is currently in an impressive phase of transition. The gradual shift away from environmentally damaging fossil fuels toward cleaner, renewable energy sources[1] has ushered with it the opportunity for tremendous advancements in green technology, to such an extent that some have compared the current period of technological growth to the industrial and high-tech revolutions of previous times.[2] Technological expansion has been seen in multiple sectors of the clean energy movement, ranging from renewable energy sources that utilize environmental forces (such as wind, solar, geothermal, tidal, or hydroelectric energies) to the innovation of creative solutions to improve old technologies (such as using carbon-capture

1. *See, e.g.*, Mark Z. Jacobson & Mark A. Delucchi, *A Path to Sustainable Energy by 2030*, SCI. AM., Nov. 2009, at 58 ("The most effective step [towards cutting back on greenhouse gases] . . . would be a massive shift away from fossil fuels to clean, renewable energy sources.").

2. *See, e.g.*, *Creating American Jobs by Harnessing Our Resources: U.S. Offshore and Renewable Energy Production: Hearing Before the H. Comm. on Natural Resources*, 112th Cong. 1 (2011) (testimony of Kate Gordon, Vice President of Energy Policy, Center for American Progress Action Fund), *available at* http://www.americanprogressaction.org/issues/2011/09/pdf/gordon_testimony.pdf ("I will conclude by recommending several specific steps this Congress and administration can take to protect our land and water while putting America back on track to lead the clean-tech revolution, just as we led the Industrial and high-tech revolutions that came before."); Hemant Taneja, *The Clean Energy Economy: A New Industrial Revolution Rising From Challenging Times*, TECH. REV. (Nov. 19, 2008), http://www.technologyreview.com/ blog/cleanenergy/22199/ ("When the Telecommunications Act of 1996 was passed, entrepreneurs focused on the communications sector, and within a decade companies like Google, Yahoo and eBay became household names and changes heretofore unseen since the Industrial Revolution occurred. It's time for another Industrial Revolution, fueled by clean energy.").

technology with coal).[3]

As the United States and the rest of the global community continue its movement into an era of greener technology and towards a cleaner environment, the biggest threat is not the lack of renewable energy resources;[4] the hesitancy of countries to take steps towards adopting or promoting green technology;[5] or the inability to maintain a functional clean energy infrastructure.[6] Instead, one of the primary concerns facing the green technology movement is the potential scarcity of specific key resources necessary to bring about the type of global changes in energy infrastructure that environmental scholars aspire to.[7]

These resources, a variety of globally scarce metals, are essential parts for building the future energy landscape. In today's increasingly green technological era, such supplies are critically important for "manufactur[ing] environmentally friendly products such as electric cars and . . . alternative power generating technologies such as wind turbines."[8] Yet, as central as these materials are to this technological revolution in clean energy, the United States and other countries have only limited access to them. China, quickly gaining power as an economic leader in the world market,[9] "possesses roughly 36% of the world's rare-earth deposits [and] currently produces around 97% of the global supply."[10] Access to the element lithium, an essential component in powering certain types of green technology such as electric cars,[11] is restricted

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3. This is not to say that all forms of energy are now equally clean or beneficial to the environment. *See* Jacobson & Delucchi, *supra* note 1, at 58 ("[A] 2009 Stanford University study ranked energy systems according to their impacts on global warming, pollution, water supply, land use, wildlife and other concerns. The very best options were wind, solar, geothermal, tidal and hydroelectric power—all of which are driven by wind, water or sunlight . . . . Nuclear power, coal with carbon capture, and ethanol were all poorer options, as were oil and natural gas.").

4. *See id.* at 60 ("Today the maximum power consumed worldwide at any given moment is about 12.5 [terawatts, or TW,] . . . [with projections showing that] in 2030 the world will require 16.9 TW . . . . Even if demand did rise to 16.9 TW, [renewable] sources could provide far more power. Detailed studies . . . indicate that energy from the wind, worldwide, is about 1,700 TW. Solar, alone, offers 6,500 TW.").

5. *See* RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY, RENEWABLES 2011: GLOBAL STATUS REPORT 11 (2011), *available at* http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf ("By early 2011, at least 118 countries had some type of policy target or renewable support policy at the national level, up from 55 countries in early 2005.").

6. In reality, it seems that green technology is actually more reliable than much of the energy infrastructure that currently exists. *See* Jacobson & Delucchi, *supra* note 1, at 63 ("The average U.S. coal plant is offline 12.5% of the year . . . . Modern wind turbines have a down time of less than 2 percent on land and less than 5% at sea. Photovoltaic systems are also at less than 2 percent. Moreover, when an individual [green] . . . device is down, only a small fraction of production is affected," unlike with coal, nuclear or natural gas plants, where downtime means that "a large chunk of generation is lost.").

7. Jack Lifton, *The Battle Over Rare Earth Metals*, J. ENERGY SECURITY (Jan. 12, 2010, 12:00 AM), http://www.ensec.org/index.php?option=com_content&view=article&id=228:the-battle-over-rare-earth-metals&catid=102:issuecontent&Itemid=355.

8. *Id.*

9. China has just recently overtaken Japan as the world's second biggest economy. *China Overtakes Japan as World's Second-Biggest Economy*, BBC (Feb. 14, 2011), http://www.bbc.co.uk/news/business-12427321. Some analysts predict that "China [will] replac[e] the US as the world's top economy in about a decade." *Id.*

10. RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY, *supra* note 5, at 42.

11. Lithium is a crucial component for the batteries that are used in certain types of green technology, such as electric cars. *See* Jacobson & Delucchi, *supra* note 1, at 62 (describing the role of lithium-ion batteries in electric cars); Bryan Walsh, *Top 20 Green Tech Ideas*, TIME (Dec. 6, 2010), http://www.time.com/

largely to South American supplies.[12]

Foreign control of these rare elements puts the United States and other countries in a difficult position. Despite controlling such a substantial part of the world's usable supply, China has been strictly regulating the rare earth industry, restricting the market and limiting global distribution of the materials.[13] With the global demand of rare earths growing 10% to 15% annually,[14] such restrictions present troubling implications for the future development of green technologies and the admirable aspirations of the global community to move towards a cleaner tomorrow. A similar predicament exists with the South American lithium supply. Argentina and Chile are "the source of over half of the world's lithium output"[15] and recent findings suggest that Bolivia may be "hold[ing] the world's largest lithium bounty."[16] Fierce competition among international miners for these valuable lithium deposits could lead to price increases and shortages of the material in the United States and elsewhere.[17]

Despite the threat of foreign reliance on rare elements, the United States has the opportunity to mitigate this risk by learning from its prior experiences in the energy field. Unfortunately, the precarious position of relying on imported resources for national energy supplies is not a novel problem for the United States. Historical experience with global oil reserves has already indicated just how burdensome foreign reliance can be.[18] In the years between 1973 and 2010, the importation demands of oil in the United States rose nearly 250%,[19] while the total cost rose an extraordinary 5490%.[20] Rather than

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time/specials/packages/article/0,28804,2030137_2030135_2021670,00.html (describing the role of lithium-ion batteries in green technology).

12. *See* Mica Rosenberg & Eduardo Garcia, *Known Lithium Deposits Can Cover Electric Car Boom*, REUTERS (Feb. 11, 2010, 4:04 PM), http://www.reuters.com/article/2010/02/11/us-lithium-latam-idUSTRE61A5AY20100211 (describing existing lithium deposits in Argentina and Chile, as well as developing efforts to mine lithium in Bolivia).

It is possible that Mexico may have a sizable lithium deposit as well, though little is known about its exact size or value at this point. *See id.* ("Last year, Mexican company Piero Sutti announced the discovery of a major lithium and potash deposit in the central state of Zacatecas and is ramping up exploration on the property spanning 124,000 acres. But experts still know little about what the source could hold.").

13. *See* RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY, *supra* note 5, at 42 ("China . . . is implementing more stringent controls over its formerly under-regulated rare-earths industry, exacerbating uncertainties in global supplies.").

14. *Id.*

15. Rosenberg & Garcia, *supra* note 12.

16. *Id.* There are, however, questions about the accessibility of Bolivia's lithium supply. *See id.* ("Bolivia has a huge lithium deposit at the Uyuni salt lake, but state-run mining company Comibol may struggle to exploit it lacking know-how and capital. A high degree of magnesium and regular flooding may complicate lithium recovery.").

17. *See* Jacobson & Delucchi, *supra* note 1, at 62 (describing how increasing demands for lithium globally may raise prices significantly); Natasha Odendaal, *Next Decade to See Increase in Lithium Supply and Demand*, MININGWEEKLY.COM (Jan. 21, 2011), http://www.miningweekly.com/article/positive-forecast-for-lithium-market-2011-01-21 ("Many international mining companies, particularly junior miners in Canada and Australia, are attempting to position themselves to benefit from lithium resources.").

18. *See generally* FOREIGN TRADE DIV., U.S. CENSUS BUREAU, U.S. IMPORTS OF CRUDE OIL (2012), *available at* www.census.gov/foreign-trade/statistics/historical/petr.pdf (showing the upward trend in U.S. oil imports from 1973 to 2012).

19. *See id.* In 1973, the total amount of imported oil was 1,392,970,000 barrels, and in 2010 the total amount of imported oil was 3,377,077,000 barrels—an increase of approximately 242%. *Id.*

20. *See id.* In 1973, the total cost of imported oil was $4,592,852,000, while in 2010 the total cost of

aggressively searching to find viable alternative fuel sources over the past four decades, the United States instead solidified its reliance on the oil industry to the financial and environmental detriment of the country and its citizens.[21] In consideration of this recent historic lesson about foreign resource reliance, the future direction of clean energy in the United States should embrace policies and technologies that decrease the need for imported materials and should encourage the development of a wide range of energy alternatives rather than focusing on a select few that demand rare elements for effective deployment.

This Article examines the relationship between rare elements and green technology and considers the potential negative implications for the clean energy movement in the United States stemming from the country's looming difficulties in acquiring such elements. The Article then explores potential measures that may help successfully alleviate these barriers and allow the green technology movement to progress as efficiently and effectively as possible. Finally, it addresses the question of how to create a sustainable clean energy strategy by providing an example of the type of energy policy portfolio that will be able to meet national demands while still mitigating the risk of foreign material reliance.

II. THE UTILITY OF RARE ELEMENTS IN THE CLEAN ENERGY MOVEMENT

The importance of rare elements in the future development and distribution of green technologies in the clean energy movement cannot be overstated. In this Article, the term "rare elements" is used to describe a group containing certain metals known as rare earths as well as the element lithium, all of which are critical to the production of certain types of green technologies.[22] This part will describe the basic characteristics of these rare elements and will explore their utility in the clean energy movement.

Rare earths, at their most basic level, are "defined as those chemical elements that have atomic numbers between 57 to 71"[23] which, when added to the chemically similar elements yttrium and scandium,[24] constitute a total group of seventeen individual elements.[25] The rare earth elements have unique

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imported oil was a high $252,160,511,000—an increase of 5490%. *Id.*

21. The negative impact of oil reliance can be seen in examples ranging from the price of fuel to threats to national security. *See, e.g.*, Steve LeVine, *U.S. Reliance on Oil an 'Urgent Threat'*, BLOOMBERGBUSINESSWEEK (May 17, 2009), http://www.businessweek.com/bwdaily/dnflash/content/may2009/db20090517_930228.htm ("The dependence on oil-based fuels left the U.S. military seriously over-extended in Iraq and Afghanistan . . . ."); Elissa Robinson, *Gas Prices May Be Headed for Record Levels*, ABC 7 ACTION NEWS (Nov. 8, 2011), http://www.wxyz.com/dpp/money/business_news/gas-prices-may-be-headed-for-record-levels (predicting rising gas prices).

22. *See Factbox: What are Rare Earths? How are They Used?*, REUTERS (Feb. 14, 2011, 4:14 PM), http://www.reuters.com/article/2011/02/14/us-rareearths-uses-idUSTRE71D66520110214 [hereinafter *Factbox*] (explaining that rare earth metals are used in alternative energy, hybrid and electric cars, and more efficient battery technology).

23. Lifton, *supra* note 7.

24. *Id.* ("For reasons of chemical similarity, two additional metals, scandium and yttrium, are commonly found in rare earth metal deposits, and so are frequently referred to as rare earth metals, resulting in a total number of 17 rare earth elements . . . .").

25. *See Factbox*, *supra* note 22 (listing the seventeen rare earth elements).

"chemical properties [that are] so similar that they are difficult and expensive to separate . . . [but] once . . . separated from one another, the individual physical properties of these materials put them in today's top tier of the rarest and in many cases the most critical of metals for technological application."[26] These exceptional chemical traits are what make rare earths so incredibly valuable to the clean energy market, with the elements acting as important components in the construction of certain green technologies.[27] For instance, "[t]he battery in a single Toyota Prius [hybrid car] contains more than 20 pounds of the rare earth element lanthanum; the magnet in a large wind turbine may contain 500 pounds or more of neodymium."[28] Considering the fact that Prius sales reached one million vehicles in April 2011,[29] it is clear that scaling of green technologies has the potential to significantly impact the demand for such materials.

Rare earths are used in an extraordinary number of everyday gadgets,[30] but of particular interest to this Article is their utility in certain green technologies. As an example, the elements are particularly important in the functioning of wind energy technologies—specifically, the magnetic properties of the rare earth element neodymium are critical for ensuring that wind turbines run at peak efficiency.[31] Rare earths are also important in the development and distribution of hybrid and electric vehicles, energy-saving appliances, and solar technologies.[32]

Interestingly, use of the term "rare earths" to describe these particular elements is somewhat of a misnomer.[33] Despite the insinuation of their title, rare earths are actually "a relatively abundant group of . . . chemical

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26. Lifton, *supra* note 7.

27. *See id.* ("These metals are used to manufacture environmentally friendly products such as electric cars and in alternative power generating technologies such as wind turbines.").

28. Tim Folger, *The Secret Ingredients of Everything*, NAT'L GEOGRAPHIC (June 2011), http://ngm.nationalgeographic.com/2011/06/rare-earth-elements/folger-text.

29. *Toyota Prius Sets 1 Million Sales as Green Car Benchmark*, HYBRIDCARS (Apr. 13, 2011), http://www.hybridcars.com/news/toyota-prius-sets-1-million-sales-green-car-benchmark-29731.html.

30. *See, e.g.*, Folger, *supra* note 28 ("'They're all around you,' says Karl Gschneidner, a senior metallurgist with the Department of Energy . . . . 'The phosphors in your TV—the red color comes from an element called europium. The catalytic converter on your exhaust system contains cerium and lanthanum. They're hidden unless you know about them, so most people never worried about them as long as they could keep buying them.'").

31. *See* Jacobson & Delucchi, *supra* note 1, at 62 (containing a graphic describing the role of neodymium in wind technology); *see also Factbox*, *supra* note 22 ("Rare earth magnets are widely used in wind turbines. Some large turbines require around two tonnes of rare earth magnets. These magnets are very strong and make the turbines highly efficient. Rare earth magnets are used in turbines and generators in many alternative energy applications.").

32. *See* MARC HUMPHRIES, CONG. RESEARCH SERV., R41347, RARE EARTH ELEMENTS: THE GLOBAL SUPPLY CHAIN 3 tbl.1 (2011), *available at* www.fas.org/sgp/crs/natsec/R41347.pdf (showing the role of various rare earths in hybrid and electric cars); U.S. DEP'T OF ENERGY, CRITICAL MATERIALS STRATEGY 10 (2010), *available at* energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf ("Lanthanum, cerium, praseodymium, neodymium, cobalt and lithium are used in electric vehicle batteries. Neodymium, praseodymium and dysprosium are used in magnets for electric vehicles and wind turbines. Samarium is also used in magnets. Lanthanum, cerium, europium, terbium and yttrium are used in phosphors for energy-efficient lighting. Indium, gallium and tellurium are used in solar cells.").

33. *See* Paul Toscano, *How Are Rare Earth Elements Used?*, CNBC.COM (Nov. 5, 2010), http://www.cnbc.com/id/40027130/How_Are_Rare_Earth_Elements_Used?slide=1 ("Rare earth elements are a collection of seventeen members of the periodic table . . . but the name is somewhat misleading.").

elements."[34] In reality, these elements are "similar in abundance as more familiar elements such as copper, nickel or zinc, [with] even the least abundant naturally occurring rare earths [being] 200 times more common than gold."[35] The rarity of these elements does not come from their aggregate quantitative existence but rather the limited number of locations where commercially viable concentrations of them can be found.[36] Since only a very small number of countries have mineable quantities of rare earths, the price of the materials is highly responsive to even small political or environmental controls on the elements within those countries.[37]

The element lithium shares a couple of characteristics with rare earths. Similar to rare earths, lithium is relatively plentiful within the earth's crust.[38] The true difficulties of acquiring lithium are the ability to find a sufficiently sizeable deposit that it is cost effective to mine it[39] and finding a country with politics that are friendly enough to share it.[40] Furthermore, lithium, like the rare earths, is a naturally occurring periodic element.[41] However, unlike the rare earth elements, which are primarily lanthanides with heavy atomic weights,[42] lithium is an alkali metal with a considerably lower atomic weight.[43]

In the clean energy movement, lithium plays an important role in the development of efficient and long-lasting batteries designed to power the new wave of green technology. Due to their chemical composition, "[l]ithium batteries, which usually include cobalt and carbon in their chemical recipe, offer a number of advantages over those that contain traditional ingredients such as manganese, copper and zinc"[44] including greater life, power, and rechargeability of the battery.[45] For instance, lithium batteries can be recharged "safely and efficiently, whereas recharging alkaline ones can

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34. *Factbox*, *supra* note 22.

35. Toscano, *supra* note 33.

36. *See Factbox*, *supra* note 22 ("[R]are earths are a relatively abundant group of . . . elements, but finding them in economically viable deposits is rare."); Folger, *supra* note 28 ("Deposits large and concentrated enough to be worth mining are indeed rare."); Toscano, *supra* note 33 ("[R]are earth elements are only found in commercially viable amounts in several areas of the world.").

37. *See infra* Part III (describing the foreign control of rare earths and its implications).

38. *See Lithium*, WEBELEMENTS, http://www.webelements.com/lithium/ (last visited Aug. 24, 2012) [hereinafter WEBELEMENTS] (stating that there is an abundance of lithium around us).

39. *See* Rosenberg & Garcia, *supra* note 12 ("But all lithium deposits are not created equal and experts say the new finds may be poor quality or expensive to extract.").

40. For example, this may be an issue in Bolivia. Keith Johnson, *Peak Lithium: Will Supply Fears Drive Alternative Batteries?* WALL ST. J. (Feb. 3, 2009, 10:54 AM), http://blogs.wsj.com/environmentalcapital/2009/02/03/peak-lithium-will-supply-fears-drive-alternative-batteries/ ("Concerns about global supplies of lithium are a lot like the debate over peak oil. Some experts believe the huge increase in electric cars will actually strain the world's lithium supplies in a few years; as with peak oil, 'above-ground' factors like Bolivia's politics may be just as critical as geology.").

41. *See* WEBELEMENTS, *supra* note 38 (describing the element lithium).

42. *See Rare Earths: Statistics and Information*, U.S. GEOLOGICAL SURV. (Apr. 16, 2012), http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/ ("The rare earths are a relatively abundant group of 17 elements composed of scandium, yttrium, and the lanthanides.").

43. *See* WEBELEMENTS, *supra* note 38 (showing the atomic weight of lithium).

44. Brian Palmer, *Troves of Lithium, Valuable for Batteries, Boost Mood in Bolivia and Afghanistan*, WASH. POST, Aug. 31, 2010, http://www.washingtonpost.com/wp-dyn/content/article/2010/08/30/AR2010083003937.html.

45. *Id.*

produce dangerous hydrogen gas."[46]

Even more crucial, lithium batteries have the potential to generate considerably greater power than traditional batteries. This is evident by lithium's standard potential, which quantifies "[t]he amount of energy that a chemical can generate inside a battery by gaining or losing electrons . . . ."[47] The difference in standard potential between lithium-ion batteries and traditional rechargeable batteries is huge: "[l]ithium has a standard potential of 3.04 volts, compared with just 0.76 volts for zinc and a measly 0.4 volts for cadmium, one of the original metals used in rechargeable consumer batteries."[48]

An important consideration for the clean energy movement is that, at the current time, lithium's scientific potential as a battery for green technology is only at its beginning. Scientists are already beginning to explore new uses of lithium to make even more powerful batteries for electric cars. Current lithium-ion batteries can only send today's electric cars about 250 miles before the car runs out of power.[49] New developments in battery chemistry and experimentation with lithium-air batteries may change this distance considerably.[50] Scientists predict that "these [lithium-air] batteries will have five to 10 times the energy of lithium-ion batteries"[51] and, optimistically, may even be able to produce enough power to "rival the energy density of petroleum—one of the most energy-packed substances on earth."[52] These advances will likely increase the importance and demand for lithium in the coming years.[53]

The unique characteristics of rare elements as described above are critical to maintaining current practices in green technology. Their chemical properties and exceptional traits make them of extraordinary value to the United States as well as every other country that is interested in developing efficient and effective methods of pursuing clean energy practices.

III. THE FOREIGN CONTROL OF RARE ELEMENTS

Despite the importance of rare elements in the green technology market, the accessible global deposits of these materials are unfortunately located in only a small number of countries around the world. In order to understand the

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46. *Id.*
47. *Id.*
48. *Id.*
49. *Id.* ("Using current-generation lithium batteries, electric-only cars can travel no more than 250 miles before running out of juice.").
50. *See generally* Saqib Rahim, *Will Lithium-Air Battery Rescue Electric Car Drivers From 'Range Anxiety'?*, N.Y. TIMES, May 7, 2010, http://www.nytimes.com/cwire/2010/05/07/07climatewire-will-lithium-air-battery-rescue-electric-car-37498.html?pagewanted=all (describing the development of the lithium-air battery and its scientific implications).
51. *Id.*
52. *Id.*
53. This is a safe assumption when considered in the light of recent trends in lithium demand. *See* Palmer, *supra* note 44 ("With electric cars proliferating, demand might outstrip supply, sending prices much higher. Even after a slight retreat last year, lithium prices have more than doubled since 2003. Lithium prices are hard to pin down, though, and some estimate the increase at tenfold during that time.").

difficulties that the United States may face in acquiring rare elements, it is important to note the countries that primarily control the output of these materials and to consider the implications of their dominance of the world's rare elements supplies.

A. Which Countries Control the Global Supplies of Rare Elements?

In the global energy market, there are only a small number of countries that control the world's viable reserves of rare elements. This section lists the most significant of these countries and briefly explains the extent of their control over global rare elements supplies.

China is the world's leading producer of rare earths, making the country one of the most important suppliers of materials in the global clean energy movement.[54] When compared with the rest of the global supply, Chinese ownership of rare earth deposits far overshadows any other country, with China controlling 36% of the world's total rare earth reserves.[55] By comparison, the next greatest supply, held by the Commonwealth of Independent States, is only 19% of the global reserve total.[56] The United States remains a distant third, controlling only 13% of reserves.[57] Furthermore, not only does China hold the greatest concentration of the world's rare earth reserves, the country is also the world's biggest producer of rare earth materials, providing between 95% and 97% of the global supply.[58] The combination of these factors makes China the most dominant country in today's rare earths market.

A similar, though less extreme, situation exists with the global lithium supply. Chile holds approximately 76% of the world's currently accessible lithium reserves,[59] dwarfing Argentina and Australia, which hold a combined total of 14% of the world's reserves.[60] Additionally, recent findings in Bolivia suggest that there may be a massive supply of lithium located underneath the country, causing some "Bolivians . . . to speak of their country becoming 'the Saudi Arabia of lithium.'"[61] Though the accessibility of the Bolivian lithium

54. U.S. DEP'T OF ENERGY, *supra* note 32, at 65.

55. *Id.* at 28 tbl.3-1.

56. *Id.* The Commonwealth of Independent States is a "free association of sovereign states formed in 1991 by Russia and 11 other republics that were formerly part of the Soviet Union." *Commonwealth of Independent States (CIS)*, ENCYCLOPEDIA BRITANNICA, http://www.britannica.com/EBchecked/topic/128945/Commonwealth-of-Independent-States-CIS (last visited Sept. 7, 2012).

57. U.S. DEP'T OF ENERGY, *supra* note 32, at 28 tbl.3-1.

58. The exact amount is undetermined, though it appears to be within this range. *See* RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY, *supra* note 5, at 42 sidebar 3 (describing China as controlling 97% of the world's supply of rare earths); Keith Bradsher, *China Consolidates Grip on Rare Earths*, N.Y. TIMES, Sept. 15, 2011, http://www.nytimes.com/2011/09/16/business/global/china-consolidates-control-of-rare-earth-industry.html?pagewanted=all [hereinafter Bradsher, *China Consolidates Grip*] ("China produces nearly 95% of the world's rare earth materials . . . .").

59. U.S. DEP'T OF ENERGY, *supra* note 32, at 28 tbl.3-1.

60. *Id.* Argentina controls 8% of the world's reserves, while Australia controls 6%. *Id.*

61. Lawrence Wright, *Lithium Dreams*, NEW YORKER (Mar. 22, 2010), http://www.newyorker.com/reporting/2010/03/22/100322fa_fact_wright?currentPage=all ("And nearly half the world's known resources are buried beneath vast salt flats in southwestern Bolivia, the largest of which is called the Salar de Uyuni.").

supply is still questionable,[62] the fact remains irrefutable that South American countries currently control the vast majority of global lithium reserves.[63] As of 2009, Chile also led in the production of lithium worldwide, providing 41% of the world's total production.[64] China and Australia also provided considerable amounts of the global lithium supply, producing 13% and 24% respectively.[65]

By comparison, the United States has a very limited reach in either of these rare element markets. As noted previously, the United States controls only a very small portion of the global rare earth reserves.[66] The United States has also played a virtually nonexistent role in the production of rare earths in recent years. Ever since shutting down the rare earths mine in Mountain Pass, California,[67] the United States has not mined any of its own rare earth materials and has only produced material from some of the stockpiled ore remaining at the closed Mountain Pass mine.[68] The United States also has a limited role in the global lithium market. Although the United States is involved in some domestic production of the material,[69] the quality of South American lithium exceeds the quality of the lithium found in the United States.[70] This has forced the United States to rely on a combination of both domestic and foreign sources to meet its growing lithium needs.[71]

As can be seen from these statistics regarding the availability of rare elements, the United States is not in a position where it has the opportunity to be self-sustaining in the continued effort to develop and distribute green technology. Hopes for progress of clean energy in the United States therefore demand a considerable degree of international cooperation that may potentially raise many concerns.

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62. *See id.* ("Yet it's not clear that Bolivia is capable of making money off its trove."). Political problems, technology problems, and infrastructure problems may hinder that ability. *See id.* ("Before Bolivia can hope to exploit a twenty-first-century fuel, it must first develop the rudiments of a twentieth-century economy.").

63. *See* U.S. DEP'T OF ENERGY, *supra* note 32, at 28 (showing that, together, Chile and Argentina hold 84% of the world's lithium reserves).

64. *Id.* at 33–34.

65. *Id.*

66. *See id.* at 28 (finding that the United States controls only 13% of the world's rare earths reserves).

67. *See* Alexis Madrigal, *Worried About China's Monopoly on Rare Elements? Restart American Production*, ATLANTIC (Sept. 23, 2010, 12:25 PM), http://www.theatlantic.com/technology/archive/2010/09/worried-about-chinas-monopoly-on-rare-elements-restart-american-production/63444/ (describing the rare earths mine at Mountain Pass, California).

68. U.S. DEP'T OF ENERGY, *supra* note 32, at 28. In 2009, the United States produced 2,150 tonnes of rare earth ore from processing stockpiles at Mountain Pass. *Id.*

69. *See id.* at 34 ("The United States currently has only one active lithium brine operation in Nevada." (footnote omitted)).

70. *See id.* at 33 ("Globally, it is more economic to extract lithium in continental brines than in hard rocks or spodumene deposits. Among the continental brines, South American brines hold the most favorable lithium chemistry and are currently most economic to mine."). Mines in the United States have closed due to their inability to compete with the quality of South American lithium. *See id.* at 34 ("The United States produced lithium minerals from hard rock ores until 1997, when the spodumene mine in North Carolina closed due to its inability to compete with South American brines.").

71. *See id.* at 35 ("Two U.S. companies produce and export a large array of value-added lithium materials produced from domestic and South American lithium carbonates." (citation omitted)).

B. Implications of the Foreign Control of Rare Elements

Because so much of the global supply of rare elements is controlled by foreign powers, the United States is forced to rely on these external sources in order to meet its internal demands. The potential implications of this are far reaching for the future of clean energy policy and procedure in the United States.

One of the most alarming implications of relying on foreign powers to meet national demand for rare elements is the risk of economic harm that could stifle progress in the clean energy movement. This threat has already manifested itself considerably with the United States' reliance on the Chinese rare earths supply[72] and, to a lesser extent, with the South American lithium supply.[73]

The cost of buying rare earths from the Chinese has risen dramatically in recent years. As an example, the price of the rare earth neodymium, used primarily for its magnetic properties in the construction of certain types of wind turbines and hybrid cars,[74] has increased from $14.25 per kilogram in the first quarter of 2009 to $225 per kilogram in the second quarter of 2011[75]—over a 1500% rise in cost. These dramatic price increases are not limited to only one or two of the rare earth elements, either. In 2011 alone, "the prices of rare earth minerals have almost doubled" between the first and second quarters of the year.[76]

Part of the frustration with these extremely high prices is that the Chinese government has actively refused to allow market forces to drive the cost of rare earths back down to reasonable levels.[77] Although "[e]xcess exports from China's rare earth industry kept prices artificially low for years," Chinese authorities have more recently been applying the exact opposite tactic, "impos[ing] tougher export restrictions on domestic producers, cutting off supplies and driving up global prices."[78] The Chinese government is resolute

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72. *See generally* Dilip Kumar Jha, *China Curbs Push Prices of Rare Earth Minerals*, BUS. STANDARD (Sept. 28, 2011, 12:45 AM), http://business-standard.com/india/news/china-curbs-push-pricesrare-earth-minerals/450675/ (describing the extraordinary inflation of the cost of rare earth materials coming from China).

73. *See* Paul W. Gruber et al., *Global Lithium Availability: A Constraint for Electric Vehicles?*, 15 J. INDUS. ECOLOGY 760, 765 (2011), *available at* http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2011.00359.x/pdf (describing the generally steady rise of lithium prices over the past decade, broken by an unusual fluctuation in price in more recent years).

74. *See* Lisa Margonelli, *Clean Energy's Dirty Little Secret*, ATLANTIC (May 2009), http://www.theatlantic.com/magazine/archive/2009/05/clean-energy-apos-s-dirty-little-secret/7377/ ("[N]eodymium, the pixie dust of green tech [is] necessary for the lightweight permanent magnets that make Prius motors zoom and for the generators that give wind turbines their electrical buzz."); *Neodymium a Bone of Contention in Wind Turbines*, RENEWABLES INT'L, (May 25, 2011), http://www.renewablesinternational.net/neodymium-a-bone-of-contention-in-wind-turbines/150/435/31015/ ("Direct-drive wind turbines often use neodymium as a permanent magnet.").

75. Jha, *supra* note 72.

76. *Id.*

77. *See* Bradsher, *China Consolidates Grip*, *supra* note 58 ("By closing or nationalizing dozens of the producers of rare earth metals—which are used in energy-efficient bulbs and many other green-energy products—China is temporarily shutting down most of the industry and crimping the global supply of the vital resources.").

78. David Stanway, *Rare Earth Prices to Stay High as China Extends Crackdown*, REUTERS (Sept. 15,

in ensuring the proper enforcement of these export restrictions, with "inspection teams scour[ing] the country to enforce the quotas and industry consolidation targets, as well as new environmental regulations."[79] The government has even gone to the extreme measure of forcing certain rare earth mining companies to halt their production so as to decrease the international availability of the materials.[80] Baotou, a state-linked Chinese company and "the world's largest rare earth producer, said it has halted output for a month" in response to the country's effort to "boost prices of the sought-after commodities."[81]

China's economic controls over rare earths are severe enough that the Western world has publicly objected to Chinese practices by filing a complaint against the country with the World Trade Organization (WTO).[82] Prompted by a 2009 complaint filed by the United States, the European Union, and Mexico, the WTO ruled that China's limits on rare earth exports violated international law.[83] Because the ruling "could have implications for the legality of China's rare earth export quotas," Chinese officials have decided to appeal the WTO's ruling.[84] By choosing to appeal, the Chinese government could potentially "delay any amendments to duties and quotas by several years and create pressure for a negotiated peace,"[85] with the rest of the global community struggling to meet their own internal demands for rare earths as technology becomes increasingly reliant on these specific materials.

Though not as extreme as the economic concerns surrounding China's control of rare earths, there are similar issues with the economic consequences of the United States' inability to access the South American lithium supply. The available supply of lithium is not an apparent problem;[86] rather, the concern rests with geopolitical questions relating to a country's export controls and its trade relationship with the United States and other members of the global community.[87] It is a somewhat unsettling fact that the most plentiful and highest quality deposits of lithium are located outside of the United States'

2011), http://www.reuters.com/article/2011/09/15/us-china-rareearth-idUSTRE78E1ZY20110915.

79. *Id.*

80. *See China Rare Earths Giant Halts Output as Prices Fall*, AGENCE FRANCE-PRESSE (Oct. 18, 2011), http://www.google.com/hostednews/afp/article/ALeqM5jld-8LHN24a7qTOL6cJmk6mokvVQ (describing how the Chinese government has implemented production and export controls for rare earth metals in order to "burnish its green credentials and tighten its grip over the metals" and how the state-controlled industry has therefore reduced its production).

81. *Id.*

82. Michael Martina & Ben Blanchard, *China to Reform Rare Earth Exports After WTO*, REUTERS (July 6, 2011, 9:17 AM), http://www.reuters.com/article/2011/07/06/us-china-rareearth-idUSTRE7651RZ20110706.

83. *Id.*

84. *Id.*; Fran Wang, *China to Appeal WTO Ruling over Rare Earth Exports*, AGENCE FRANCE-PRESSE (Aug. 23, 2011), http://www.google.com/hostednews/afp/article/ALeqM5hD1hAuJkNuPhbBYkp6cEwIFECYWA?docId=CNG.1b448918665fc65b0334acb354dd9fbf.441.

85. Martina & Blanchard, *supra* note 82.

86. *See* Wright, *supra* note 61 ("'Two countries—Argentina and Chile—could supply the whole world with cheap lithium past 2060,' [said] Lucie Bednarova Duesterhoeft, a researcher for G.M.'s Global Energy Systems group . . . ."). *See generally* Rosenberg & Garcia, *supra* note 12 (describing how the current known lithium deposits can carry the world through at least the current electric car boom).

87. *See, e.g.*, Rosenberg & Garcia, *supra* note 12 (explaining the importance of Bolivia's trade relationship with the rest of the industrialized world and the stance the country has taken as a result).

jurisdiction.[88] Though the United States does have the opportunity to produce its own lithium in the direst of circumstances,[89] it is currently far more cost-effective to import lithium to meet the nation's demands for the material.[90] The preference to import reduces the United States' flexibility in negotiating with leading lithium-producing South American countries. Coupled with a historic trend of naturally increasing lithium prices,[91] changes to current export policies on lithium from countries like Chile and Argentina could have a significant impact on the United States' lithium-based technology practices.

There are also technology implications in the clean energy sector that may result from foreign dominance of the rare element supplies. So long as green technology continues to rely on rare elements,[92] the threats of reduced supplies or sharp price increases in materials could potentially affect the future design or production of those technologies.[93] Examples already exist of the dramatic price effect that rising rare element costs can have on green technologies. By instituting environmental regulations that resulted in the restriction of rare earth supplies, "China . . . sent the price of compact fluorescent light bulbs soaring in the United States," resulting in an overall 37% increase in the bulbs' average price.[94] The result has been a political schism over the future of the technology—environmentalists and politicians favoring the recent legislative push towards widespread institution of the energy-efficient bulbs[95] are left in an awkward position[96] while staunch conservatives like Michelle Bachmann have taken a firm stance against future implementation of the technology.[97] Increases in rare earth prices have also

88. *See, e.g.*, Gruber et al., *supra* note 73, at 2–9 (describing the different forms and quality of lithium deposits and their ease of accessibility).

89. *See* Palmer, *supra* note 44 ("There are also significant deposits [of lithium] in Nevada . . . .").

90. Most of the United States' lithium supply is tied up in clay, causing extraction to be far more costly than the evaporation process used in places like Chile and Argentina. *Id.*

91. *See id.* ("Even after a slight retreat . . . [in 2009], lithium prices have more than doubled since 2003. Lithium prices are hard to pin down, though, and some estimate the increase at tenfold during that time.").

92. There is every reason to believe that this reliance will continue, at least for the near future. *See, e.g.*, U.S. DEP'T OF ENERGY, *supra* note 32, at 11 ("While [rare elements] are generally used in low volumes relative to other resources, the anticipated deployment of clean energy technologies will substantially increase worldwide demand. In some cases, clean energy demand could compete with a rising demand for these materials from other technology sectors.").

93. *See* Jacobson & Delucchi, *supra* note 1, at 62 (describing the possible implications of scarcity of resources on the future of green technologies and the clean energy movement).

94. Bradsher, *China Consolidates Grip*, *supra* note 58. This is not surprising considering how much the price increased for the rare earth europium. "General Electric, facing complaints in the United States about rising prices for its compact fluorescent bulbs, . . . noted . . . that if the rate of inflation over the last 12 months on the rare earth element europium oxide had been applied to a $2 cup of coffee, that coffee would now cost $24.55." *Id.*

95. *See, e.g.*, *id.* ("In January [2011], legislation that President George W. Bush signed into law in 2007 will begin phasing out traditional incandescent bulbs in favor of spiral compact fluorescent bulbs and other technologies."). *See generally* Energy Independence and Security Act of 2007, Pub. L. No. 110-140, 121 Stat. 1492 (2007) (codified as amended in scattered sections of 42 U.S.C. (2006)).

96. Bradsher, *China Consolidates Grip*, *supra* note 58 ("[W]ith light bulbs . . . the timing of the latest price increases is politically awkward for the lighting industry and for environmentalists who backed a shift to energy-efficient lighting.").

97. *Id.* ("Michele Bachmann . . . strong[ly] oppos[ed] . . . the new lighting rules in the United States and has been a leader of efforts by House Republicans to repeal it.").

had a chilling effect in the electric vehicle and wind power sectors,[98] where companies have struggled with the difficult question of how to handle rare earth shortages.[99]

Similar problems have arisen with lithium-based technologies, though the effect has been far less pronounced than with rare earths. As the price of lithium has gradually risen over the past decade, "inflationary costs [have] escalate[d] with impacts on the production for a number of critical companies in the industry."[100] More pressing than the price, however, may be processing limitations that could fail to supply enough usable lithium to meet growing needs for the material.[101] In particular, the automotive industry is scaling up their electric and hybrid vehicle fleet at an extraordinary rate, with projections indicating that nearly half a million electric vehicles will be sold in the United States just between 2012 and 2015.[102] Though these issues do not appear to be pressing on short-term lithium accessibility,[103] they are factors that the United States and other leading countries must consider as they develop their future plans for lithium trading policy and regulation.

IV. Resolving the United States' Rare Elements Conundrum

From the discussion in Part III, it is clear that the implications of the extensive foreign control of global rare element supplies should be cause for distress in the United States. Yet as worrisome as the current circumstances are, there are a number of options available to the United States moving forward which can help to alleviate these pressing concerns. This part explores some of the opportunities available to the United States to decrease foreign reliance without sacrificing the nation's future plans for clean energy.

A. Technology-Based Solutions

There are a number of promising technology-based solutions available to resolve the United States' problems involving access to rare elements. This

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98. *See id.* ("'The high cost of rare earths is having a significant chilling effect on wind turbine and electric motor production in spite of offsetting government subsidies for green tech products,' said . . . Michael N. Silver, chairman and chief executive of American Elements, a chemical company based in Los Angeles.").

99. Many companies have explored the idea of developing new technologies that do not rely on rare earths. *See, e.g.*, Alan Ohnsman, *Toyota Readying Motors That Don't Use Rare Earths*, BLOOMBERG (Jan. 14, 2011, 3:50 PM), http://www.bloomberg.com/news/2011-01-14/toyota-readying-electric-motors-that-don-t-use-rare-earths.html [hereinafter Ohnsman, *Motors That Don't Use Rare Earths*] ("Toyota Motor Corp., the world's largest seller of hybrid autos, is developing an alternative motor for future hybrid and electric cars that doesn't need rare-earth minerals at risk of supply disruptions."). Alternatives to rare element reliance will be discussed further, *infra* Part IV.

100. Dave Brown, *Lithium Prices Continue to Climb*, LITHIUM INVESTING NEWS (July 6, 2011, 1:07 PM), http://lithiuminvestingnews.com/3738/lithium-prices-continue-to-climb/.

101. *See* Gruber et al., *supra* note 73, at 772 ("The biggest hurdles to a long-term lithium supply will be establishing lithium production facilities at the rate demanded by the automotive industry . . . .").

102. *See, e.g.*, CENT. FOR AUTO. RESEARCH, DEPLOYMENT ROLLOUT ESTIMATE OF ELECTRIC VEHICLES 2011–2015, at 19 (2011), *available at* www.cargroup.org/assets/files/deployment.pdf (predicting that, just between 2012 and 2015, there will be an aggregate total of 469,000 electric vehicles sold in the United States).

103. *See* U.S. DEP'T OF ENERGY, *supra* note 32, at 112–13 (describing a high level of material availability with the short-term lithium supply).

section explores two significant opportunities for technological innovation that may help to alleviate this problem: technology shifting and rare element recycling.

1. Technology Shifting and Rare Elements Reliance

In the field of clean energy as it currently exists, virtually all types of green technology rely upon some form of rare element in order to function.[104] Solar cells rely on the rare earths tellurium, indium, and gallium; wind turbines and electric cars demand neodymium, praseodymium, and dysprosium; electric vehicle batteries require a mixture of lanthanum, cerium, praseodymium, neodymium, and lithium; and the phosphors in energy-efficient lighting depend on lanthanum, cerium, europium, terbium, and yttrium.[105] Even this partial list of green technologies shows the overarching depth of clean energy's current need for such rare elements. Though existing green technology requires rare elements, there is the possibility that future technologies will be designed in a way that shifts material requirements towards more accessible resources.[106] This could have the impact of reducing the United States' reliance on external sources for supplies, or at least perhaps shifting its import connections to more stable countries.[107]

The prospect of alternative materials in green technology is not extreme or far-fetched—there are already prominent examples in the automotive industry indicating that the early stages of this green technology shift are already under way. Toyota, "the world's largest seller of hybrid autos, is developing an alternative motor for future hybrid and electric cars that doesn't need rare-earth minerals at risk of supply disruptions."[108] Company engineers in both the United States and Japan "are working on a so-called induction motor that's lighter and more efficient than the magnet-type motor now used in its Prius."[109] The new induction motor, which is reportedly at an advanced stage of development, would not require rare earths and would "offer higher efficiency and durability than permanent-magnet motors."[110] Moreover, other members of the automotive industry seem to be following the same path as Toyota—"General Motors . . . also is looking into alternative types of motors"[111] and the German company Continental AG "has already come up

104. Sterling Burnett, *Commentary: Rare Earth Dependence*, KERA (Aug. 19, 2011, 7:43 PM), http://keranews.org/post/commentary-rare-earth-dependence ("Key components of every green energy technology, be they wind turbines, solar cells, energy efficient lighting, high-tech batteries, and other goods, are made from of [sic] a small class of minerals known as the rare earth elements, and other rare minerals.").

105. U.S. DEP'T OF ENERGY, *supra* note 32, at 10.

106. *See* Ohnsman, *Motors That Don't Use Rare Earths*, *supra* note 99 (describing the benefits to Toyota for shifting away from reliance on China's rare earths supply).

107. *See id.* (explaining that China currently "controls more than 90% of the global market for the metals").

108. *Id.*

109. *Id.*

110. *Id.*

111. Mike Ramsey, *Toyota Tries to Break Reliance on China*, WALL ST. J. (Jan. 14, 2011), http://online.wsj.com/article/SB10001424052748703583404576080213245888864.html.

with its own motor that doesn't require rare earths."[112]

The continued development of the alternative engines that run without requiring rare earths—in particular, the induction motor—could be critical to ensuring that the United States has the materials necessary to supply the green future of the automotive industry. Luckily, induction motors are not inferior to their rare earth-laden counterparts.[113] Neodymium-free induction motors have the potential to run just as efficiently as engines requiring rare earths, if not even more so. For example, unlike permanent-magnet motors requiring rare earths, the induction motor has the capability of tolerating a wide range of temperatures.[114] In addition to reducing the weight of the vehicle, this also means that, "by being able to tolerate temperatures that cause permanent magnets to break down, an induction motor can be pushed (albeit briefly) to far higher levels of performance—for, say, accelerating hard while overtaking, or when climbing a steep hill."[115] Though Toyota has refused to divulge many details about its upcoming induction motors,[116] the possible benefits for the future of electric vehicles and clean energy that could result from a technology shift towards this type of engine are well worth continued attention.[117]

Alternatives to lithium-based technologies are also starting to develop, indicating a potential technology shift away from lithium reliance in the future. While many engineers have aimed to improve the scientific potential of lithium,[118] others have chosen a different route that focuses on an entirely different set of promising elements.[119] Toyota has revealed that it has been working on a magnesium-sulfur battery that is supposedly "capable of holding twice the energy of lithium-ion cells."[120] The company has also revealed that it is experimenting with other types of non-lithium batteries for the new wave of electric and hybrid vehicles, alternatively considering "aluminum and calcium as potential battery materials . . . ."[121] Though all of these new batteries are still in their developmental stages, Toyota engineers predict that "[v]ehicles with magnesium batteries or alternative materials may be ready by

112. Jeff Siegel, *Alternatives to Rare Earth Elements*, ENERGY & CAPITAL (Jan. 17, 2011), http://www.energyandcapital.com/articles/alternatives-to-rare-earth-elements/1397.

113. *See generally* N.V., *The Difference Engine: Nikola's Revenge*, ECONOMIST (Apr. 1, 2011, 9:36 AM), http://www.economist.com/blogs/babbage/2011/04/induction_motors (describing the advantages of the induction engine compared to other existing engine technologies).

114. *Id.* ("[T]he induction motor's big advantage—apart from its simplicity and ruggedness—has always been its ability to tolerate a wide range of temperatures.").

115. *Id.* ("Providing adequate cooling for the Toyota Prius's permanent-magnet motor adds significantly to the vehicle's weight. An induction motor, by contrast, can be cooled passively—and thereby dispense with the hefty radiator, cooling fan, water pump and associated plumbing.").

116. *See id.* ("So far, Toyota has remained mum about its neodymium-free electric motor-generator.").

117. *See id.* ("With Nikola Tesla's robust and reliable induction motor making such a successful comeback, it is puzzling to see why anyone should worry about potential shortages of neodymium and other rare-earths for alternative power and transport.").

118. *See supra* text accompanying notes 44–48 (describing the lithium-air battery).

119. *See* Alan Ohnsman, *Toyota Studies Magnesium Battery as Lithium Alternate*, BLOOMBERG (Jan. 10, 2011), http://www.bloomberg.com/news/2011-01-10/toyota-developing-magnesium-battery-as-lithium-alternate.html [hereinafter Ohnsman, *Magnesium Battery*] (describing Toyota's experimentation with the magnesium-sulfur battery).

120. Ohnsman, *Motors That Don't Use Rare Earths*, *supra* note 99.

121. Ohnsman, *Magnesium Battery*, *supra* note 119.

about 2020 . . . ."[122] Considering the substantially lower price of magnesium and its impressive chemical attributes,[123] this type of battery could be an excellent alternative to lithium. Based on these projections, if over the next decade the price of lithium begins to increase in a way that is comparable to the price of rare earths, green technology leaders will be able to respond by shifting material reliance away from lithium and onto alternative resources.

Though much of the debate about exploring rare element alternatives has focused on the technological requirements of electric and hybrid vehicles,[124] the potential for designing alternative requirements in other clean energy sectors is also promising. Similar efforts are also being made in the wind[125] and solar[126] sectors to reduce reliance on rare earth elements. Additionally, governments are making investments throughout the clean energy sector to promote technology shifts away from rare element reliance.[127] Though rare element alternatives are still developmentally young,[128] their continued growth indicates a promising future for affordable green technology in the United States and abroad.

2. Rare Elements and Recycling Technology

Another potential opportunity for the United States to decrease its reliance on foreign powers to obtain the materials for green technology is improving rare element recycling technology. While not the leading consumer of rare elements worldwide,[129] the United States is still one of the global

122. *Id.*

123. *See High-Energy Density Magnesium Batteries for Smart Electrical Grids*, PHYSORG (June 28, 2011), http://www.physorg.com/news/2011-06-high-energy-density-magnesium-batteries-smart.html ("Magnesium (Mg) is cheap, safe, lightweight, and its compounds are usually non-toxic. Mg is less expensive (metallic lithium [Li] costs about 24 times more than metallic Mg) because Mg is abundant in the Earth's crust. Mg is safer because it is stable when exposed to the atmosphere.").

124. *See, e.g.*, Ohnsman, *Magnesium Battery*, *supra* note 119; Ohnsman, *Motors That Don't Use Rare Earths*, *supra* note 99.

125. *See* Anne Haas, *PNNL Awarded $3.8 Million for Advanced Energy Projects*, PAC. N.W. NAT'L LABORATORY (Sept. 30, 2011), http://www.pnnl.gov/news/release.aspx?id=891 ("[Pacific Northwest National Laboratory] materials scientist Jun Cui and others will receive $2.3 million to develop a replacement for rare earth magnets—commonly used in wind turbines and electric vehicles—based on an innovative nano-composite using manganese-based alloys.").

126. *See id.* ("The heat from the sun needs to be stored as efficiently as possible to be used upon demand . . . . [Pacific Northwest National Laboratory] scientists Ewa Ronnebro and Kevin Simmons, along with metallurgical materials scientist Zak Fang at University of Utah will receive $700,000 to investigate a metal hydride material that can store 10 times the amount of heat per mass than conventional molten salt.").

127. *See Department of Energy Awards $156 Million for Groundbreaking Energy Research Projects*, ADVANCED RES. PROJECTS AGENCY-ENERGY (Sept. 29, 2011), http://arpa-e.energy.gov/media/news/tabid/83/itemId/39/vw/1/default.aspx ("With $156 million from the Fiscal Year 2011 budget, the new ARPA-E selections focus on accelerating innovations in clean technology while increasing America's competitiveness in rare earth alternatives and breakthroughs in biofuels, thermal storage, grid controls, and solar power electronics.").

128. *See* Larry Bell, *China's Rare Earth Metals Monopoly Needn't Put an Electronics Stranglehold on America*, FORBES (Apr. 15, 2012, 5:45 PM), http://www.forbes.com/sites/larrybell/2012/04/15/chinas-rare-earth-metals-monopoly-neednt-put-an-electronics-stranglehold-on-america/2 ("[A] host of current government policies will likely continue to delay development[,] . . . and successful demonstration of alternatives remains theoretical and uncertain.").

129. Consider the relationship between Chinese and American demand for rare earth elements. In 2008, the United States used 15,500 tonnes of rare earth oxide, or 12.5% of the global consumption in that year.

community's largest consumers of rare elements.[130] Though the United States currently only recycles a small amount of the rare elements it consumes,[131] efforts to improve recycling technology may help reduce some of the material concerns related to importation issues.

Unfortunately, in the current state of green technology, there is very little recycling of rare elements.[132] Presently, "only around 1% of these crucial high-tech metals are recycled, with the rest discarded and thrown away at the end of a product's life."[133] This is at least in part because the process is too inefficient—in the present state of recycling technology, there is insufficient material recovery to cost-justify extensive use of the technique.[134] Yet, as the supply of rare elements becomes increasingly strained by rising global demand over the coming years, it seems plausible that "future shortages that could cause sustained higher prices for these materials can likely be mitigated by this recycling."[135]

In order to reduce the negative economic and technological impacts of such material shortages, forward-looking engineers worldwide have already started to note the importance of developing methods to improve the recycling process for rare elements.[136] For rare earths, as a result of "the sharp increase of the rare earth prices in 2010 and the high media coverage of possible supply shortages and export restrictions . . . China [has managed to] put the issue of recycling rare earths on the agenda worldwide."[137] With "[c]urrent recycling rates . . . thought to be below 1%" for many rare earths,[138] pro-clean energy

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U.S. DEP'T OF ENERGY, *supra* note 32, at 37. By comparison, China used 19,000 tonnes back in 2000 and an astonishing 73,000 tonnes in 2009. W. David Menzie & Alex Demas, *Technical Announcement: The Facts of China's Rare Earth Industry*, U.S. GEOLOGICAL SURV. (Mar. 1, 2011, 3:11 PM), http://www.usgs.gov/newsroom/article.asp?ID=2712.

130. *See* U.S. GEOLOGICAL SURVEY, MINERAL COMMODITY SUMMARY 2011, at 128 (2011), *available at* http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf ("The United States continued to be a major consumer . . . of rare-earth products in 2010.").

131. According to the U.S. Department of Energy, as of 2010 the United States only recovered a small amount of the rare earth oxide from spent permanent magnets and lithium recycling practices were "insignificant but increasing." U.S. DEP'T OF ENERGY, *supra* note 32, at 37.

132. *See* THOMAS G. GOONAN, U.S. GEOLOGICAL SURVEY, RARE EARTH ELEMENTS—END USE AND RECYCLABILITY 2 (2011), *available at* http://pubs.usgs.gov/sir/2011/5094/pdf/sir2011-5094.pdf ("[T]here is currently very little recycling of [rare earth oxides]."); *see also* U.S. GEOLOGICAL SURVEY, *supra* note 130, at 94 ("Recycled lithium content has been historically insignificant . . . .").

133. *Recycling of "Specialty Metals" Key to Boom in Clean-Tech Sector, From Solar and Wind Power to Fuel Cells and Energy Efficient Lighting*, U.N. ENV'T PROGRAMME (May 13, 2010), http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=624&ArticleID=6564&l=en&t=long [hereinafter *Recycling of "Specialty Metals"*].

134. *See, e.g.*, GOONAN, *supra* note 132 ("[T]he value of [rare earth oxides] that could potentially be recovered from recycling is insufficient to cover the cost to do so based on current technology . . . .").

135. *Id.*

136. *See Recycling of "Specialty Metals"*, *supra* note 133 ("Unless future end-of-life recycling rates are dramatically stepped up [sic] these critical, specialty and rare earth metals could become 'essentially unavailable for use in modern technology,' warn experts.").

137. DORIS SCHÜLER ET AL., STUDY ON RARE EARTHS AND THEIR RECYCLING: FINAL REPORT FOR THE GREENS/EFA GROUP IN THE EUROPEAN PARLIAMENT 105 (2011), *available at* www.oeko.de/oekodoc/1112/2011-003-en.pdf.

138. *See* MATTHIAS BUCHERT ET AL., OEKO-INSTITUTE E.V., RECYCLING CRITICAL RAW MATERIALS FROM WASTE ELECTRONIC EQUIPMENT 2 (2012), *available at* http://ewasteguide.info/files/Buchert_2012_Oeko.pdf (presenting a study giving an overview of current end-of-life recycling rates for 60 metals including many rare earth metals showing an end-of-life recycling rate of less than 1%).

groups like the United Nation's Environment Programme have also spoken up in favor of increasing recycling practices around the world.[139]

Part of the present difficulty with rare earth recycling is that no single process stands out as the most efficient way to recover rare earths from products.[140] Companies have needed to experiment with different tactics to improve recycling; Hitachi, for example, uses "[f]our refrigerator-sized devices . . . to open up compressors without damaging the rare earth magnets inside. A separate conveyor belt feeds disk drives into a machine about the size of a ship container."[141] These drives then "come out the other end in pieces ready for rare earth harvesting."[142] Regardless of the ultimate means used to remove the rare earths, "[f]or recyclers, extracting components is the [universal] first step."[143] Hopefully, with continued attention being paid to the topic of recycling rare earths, governments and private industry will continue to seek methods to improve and simplify rare earth recycling technology.

Similar efforts to improve the processes for recycling lithium are also underway. At present, statistics for total global lithium recycling rates are unfortunately unavailable,[144] but statistics from countries like the United Kingdom and Canada indicate that current lithium-based "disposable and rechargeable battery recycling rates are estimated to be near 5% . . . ."[145] Currently, "[l]ithium recovery from recycling [is] assumed to be 90% . . . [and] is expected to increase as recycling technologies improve."[146] Steps to improve these technologies are already being driven by government investments and private industry; in 2009, "[t]he [U.S.] Department of Energy . . . granted $9.5 million to [Toxco,] a company in California that plans to build America's first recycling facility for lithium-ion vehicle batteries."[147] Unlike with rare earths, there is "currently little economic need to recycle lithium-ion batteries," but continued efforts to improve lithium recycling processes and to establish a "recycling infrastructure . . . will ease concerns that the adoption of vehicles that use lithium-ion batteries could lead to a shortage of lithium carbonate and a dependence on [other] countries."[148]

Thankfully, some forward-looking politicians have started to advocate for early efforts to improve recycling technology in the United States. In June

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139. *See generally, e.g.*, MATHIAS SCHLUEP ET AL., U.N. ENV'T PROGRAMME, RECYCLING—FROM E-WASTE TO RESOURCES (2009), *available at* www.unep.fr/shared/publications/pdf/DTIx1192xPA-Recycling%20from%20ewaste%20to%20Resources.pdf.

140. *See* SCHÜLER ET AL., *supra* note 137, at 108–10 (listing challenges with various rare earth recycling methods).

141. Jason Clenfield et al., *Hitachi Leads Rare Earth Recycling Efforts as China Cuts Access to Supply*, BLOOMBERG (Dec. 8, 2010, 2:46 AM), http://www.bloomberg.com/news/2010-12-08/hitachi-recycles-rare-earth-as-china-crimps-supply.html.

142. *Id.*

143. *Id.*

144. *See* Gruber et al., *supra* note 73, at 10 ("Global recycling rates were not available . . . .").

145. *Id.* (internal citation omitted).

146. *Id.*

147. Tyler Hamilton, *Lithium Battery Recycling Gets a Boost*, TECH. REV. (Aug. 12, 2009), http://www.technologyreview.com/energy/23215/.

148. *Id.*

2011, H.R. 2284[149] was brought before Congress proposing the Responsible Electronics Recycling Act.[150] The Act, intended to amend the Solid Waste Disposal Act,[151] is designed to:

> (1) prohibit the export of restricted electronic waste to countries that are not members of the Organization for Economic Cooperation and Development (OECD) or the European Union (EU), or Liechtenstein; (2) require the Administrator of the Environmental Protection Agency (EPA) to develop and promulgate procedures for identifying certain electronic equipment as well as additional restricted toxic materials contained in such equipment which poses a potential hazard to human health or the environment; and (3) establish criminal penalties for knowingly exporting restricted electronic waste in violation of this Act.[152]

The Act is also designed to "require persons who handle restricted electronic wastes to permit appropriate EPA and state officials access to such wastes upon request."[153]

Furthermore, H.R. 2284 "[d]irects the Secretary of Energy to establish the Rare Earth Materials Recycling Research Initiative to provide grants for research in the recycling of rare earth materials found in electronic devices."[154] Legislative efforts like H.R. 2284 offer insight into the political agenda regarding the future of rare element recycling in the United States and provide an encouraging forecast of future policies aimed towards further refining such technologies.

Though recycling technology is still in its relative infancy, its importance is becoming an unavoidable reality to the international community. With global attention shifting towards the prospect of improving rare element recycling, the potential for improved technology and more efficient processes seems increasingly promising.

B. Geopolitical Solutions: Discovering New Rare Element Deposits, Reopening Known Ones

There are also a variety of geopolitical opportunities that may allow the United States to avoid the prospect of future difficulties with rare element accessibility. It is undeniable that the known rare element deposits that still produce usable materials are principally owned and operated by other countries—namely, China for rare earths[155] and Chile and Argentina for lithium.[156] Yet, although these countries control the majority of the world's

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149. Responsible Electronics Recycling Act, H.R. 2284, 112th Cong. (2011).
150. *Id.* § 1.
151. *Id.* §§ 2–3.
152. *H.R. 2284, Responsible Electronics Recycling Act*, GOVTRACK.US, http://www.govtrack.us/congress/bill.xpd?bill=h112-2284&tab=summary (last visited Aug. 25, 2012) (providing a summary by the Congressional Research Service).
153. *Id.*
154. H.R. 2284 § 4.
155. *Supra* Part III.A.
156. *Supra* Part III.A.

production of rare elements, this does not mean that other known sources are no longer available for production or that all rare element deposits have been discovered yet. Alternative sources may be able to satisfy some of the United States' need for these valuable materials, thereby reducing the nation's dependence on foreign sources to satisfy its material demands.

For rare earths, one notable option that remains is the opportunity to reopen the mine at Mountain Pass, California. The site "used to be the world's main mine for rare earth elements,"[157] though the mine was closed back in 2002 due to, among a number of reasons, its inability to compete with the then-inexpensive rare earths coming out of China.[158] Recently, however, Molycorp Minerals, the owner of the mine,[159] has undertaken efforts to reopen the mine and to once again continue production of rare earths locally in the United States.[160]

In 2010, the company suggested that the mine could be reopened and expanded for the price of $500 million and registered with the Securities and Exchange Commission to prepare an initial public offering (IPO) designed to raise funds for the project.[161] During its July 2010 IPO, Molycorp managed to raise an impressive $393.8 million, though this amount was not quite substantial enough to meet the costs necessary to reopen Mountain Pass.[162] Since July 2010, Molycorp has continued to raise money for the purposes of reopening and expanding its operation at Mountain Pass.[163] The company has also made significant operational advances: Molycorp has gained the necessary permits, began the construction necessary to get the mine to peak efficiency, and has recommenced mining operations.[164]

The reopening of Mountain Pass would provide a number of notable advantages to the United States regarding its rare earth policy. According to Molycorp, the mine would be able to supply rare earths for another thirty to forty-five years,[165] which could give the United States ample time to both

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157. Keith Bradsher, *Challenging China in Rare Earth Mining*, N.Y. TIMES, Apr. 22, 2010, http://www.nytimes.com/2010/04/22/business/energy-environment/22rare.html?pagewanted=all [hereinafter Bradsher, *Challenging China*].

158. *See id.* ("Low prices for rare earth elements from China contributed to cuts at the Mountain Pass mine before it closed in 2002."). Other reasons for shutting the mine down included that "a mine pipeline leaked faintly radioactive water in a nearby desert and because state regulators delayed renewal of its operating permit." *Id.*

159. *Id.*

160. *See generally* MOLYCORP, MEETING THE GLOBAL RARE EARTH CHALLENGE: MOLYCORP'S FULLY INTEGRATED, MINE-TO-MAGNETS MANUFACTURING SUPPLY CHAIN (Mar. 2011 ed.), *available at* files.eesi.org/ davis_031111.pdffiles.eesi.org/davis_031111.pdffiles.eesi.org/davis_031111.pdf (describing the steps that Molycorp has taken to reopen and strengthen production at the mine).

161. Bradsher, *Challenging China*, *supra* note 157.

162. *See* Josie Garthwaite, *Molycorp IPO Raises $394M for Greentech Metals*, GIGAOM (July 29, 2010, 10:46 AM), http://gigaom.com/cleantech/molycorp-ipo-raises-394m-for-greentech-metals/ ("Molycorp, a company that controls one of the largest deposits of rare earth elements . . . outside of China, is off to a rocky start on the public markets after pricing its shares below expectations, raising $393.8 million in its IPO on Thursday.").

163. *See* MOLYCORP, *supra* note 160, at 5 (describing steps that Molycorp has taken since its IPO regarding its mining operation in Mountain Pass).

164. *Id.*

165. *Id.* at 12.

reduce its dependence on other countries and to continue developing new green technologies that are less reliant on rare earth elements.[166] The new mine was also designed with recycling technology in mind,[167] providing further advantage to the United States as it will be able to use rare earths produced at the mine to their utmost capacity.

Another opportunity that is viable for both rare earths and lithium is the possibility of finding entirely new material deposits in areas that are more accessible to the United States, either geographically or due to the location's political climate. For example, considerable amounts of rare earths have recently been discovered in the oceanic mud of the North Pacific east and west of the Hawaiian Islands.[168] Even more importantly, rare earth "[d]eposits in this region are much thicker than those of the eastern South Pacific,"[169] suggesting that the materials available through this resource would be more available to the United States than China, already a rare earth powerhouse. These muds are also enriched with other important elements, with transition metals vanadium, cobalt, nickel, copper, zinc, molybdenum, and manganese supplied "up to two orders of magnitude greater than average continental crustal contents."[170] The mud also contains small but valuable levels of the radioactive elements thorium and uranium.[171] It is possible that the mud would become an even more valuable resource if these additional elements could be recovered in addition to the rare earth materials.[172]

Similarly, there is always the prospect of finding new lithium deposits that are practical sources for extraction. In 2010, the United States discovered "nearly $1 trillion in untapped mineral deposits in Afghanistan, far beyond any previously known reserves and enough to fundamentally alter the Afghan economy and perhaps the Afghan war itself."[173] The Afghan deposits are rich in numerous materials, "including huge veins of iron, copper, cobalt, gold[,] and critical industrial metals like lithium."[174] Although these minerals are not property of the United States government,[175] the value to the United States is undeniable: not only will the minerals help bring some level of economic

166. For technology shifting, see, *supra* Part IV.A.1.

167. MOLYCORP, *supra* note 160, at 17.

168. Yasuhiro Kato et al., *Deep-Sea Mud in the Pacific Ocean as a Potential Resource for Rare-Earth Elements*, 4 NATURE GEOSCIENCE 535, 535 (2011), *available at* www.nature.com/ngeo/journal/v4/n8/pdf/ngeo1185.pdf ("The [rare earth]-rich mud in the North Pacific east and west of the Hawaiian Islands . . . has moderate [rare earth] contents.").

169. *Id.*

170. *Id.* at 536 ("In addition to REY, the mud is enriched in transition metals including V [vanadium], Co [cobalt], Ni [nickel], Cu [copper], Zn [zinc], Mo [molybdenum], and Mn [manganese] . . . .").

171. *Id.* ("Moreover, the Th [thorium] and U [uranium] contents are a small fraction of average crustal abundances.").

172. *Id.*

173. James Risen, *U.S. Identifies Vast Mineral Riches in Afghanistan*, N.Y. TIMES, June 13, 2010, http://www.nytimes.com/2010/06/14/world/asia/14minerals.html?pagewanted=all (further explaining that the deposits were discovered "by a small team of Pentagon officials and American geologists").

174. *Id.*

175. Although the United States discovered the minerals, they still belong to the Afghan government and people. *See id.* ("'[These minerals] will become the backbone of the Afghan economy,' said Jalil Jumriany, an adviser to the Afghan minister of mines.").

stability to Afghanistan,[176] but they will also be able to help reduce the monopolistic influence of other material-rich countries by flooding the market with additional elements. Though there are certainly roadblocks that may stand in the way to efficient mineral collection in Afghanistan,[177] these findings provide hope that significant quantities of rare elements can still be discovered and indicate that the future may provide better options for the United States to meet its material demands.

V. THE FUTURE OF GREEN TECHNOLOGY IN THE UNITED STATES: POLICY AND PRACTICE

As the United States continues to develop and produce progressively cleaner technologies, the country will have to make important and difficult decisions regarding the particular technologies that it will support and the policies it will introduce to promote efficient transition towards a greener tomorrow. Section A explores some of the options available to the United States and makes recommendations for developing an effective strategy for handling the future of the nation's green technology and clean energy policy. Section B will consider the Tesla Roadster, a real world example of a green technology whose alternative design has resulted in a technology shift away from reliance on the rare earths that similar types of electric vehicles depend upon. This section will also describe the policies and factors that have contributed to the Roadster's success.

A. The Future Direction of Clean Energy Policy in the United States

From a technological perspective, the best option moving forward is to continue developing a widely-varied portfolio of green technologies while placing a central emphasis on those technologies that do not require rare elements to function. As the previous parts of this Article have discussed, there are a broad range of green technologies available that draw from an equally varied number of energy sources. Because "[g]reen demand comes from all sectors—consumers, business and government—and is in every instance intensifying,"[178] there is no single green technology that can possibly meet all of the diverse needs for clean energy in the United States.[179]

176. *See id.* ("[P]otential [development of the mining industry] is so great that officials and executives in the industry believe it could attract heavy investment even before mines are profitable, providing the possibility of jobs that could distract from generations of war.").

177. *See id.* There are a number of hurdles that may stand in the way of efficient collection in Afghanistan. For example, there are "[e]ndless fights [that] could erupt between the central government in Kabul and provincial and tribal leaders in mineral-rich districts." *Id.* Furthermore, "because Afghanistan has never had much heavy industry before, it has little or no history of environmental protection either." *Id.* There is also a question of time: "[w]ith virtually no mining industry or infrastructure in place today, it will take decades for Afghanistan to exploit its mineral wealth fully." *Id.*

178. PRICEWATERHOUSECOOPERS, TECHNOLOGY EXECUTIVE CONNECTIONS VOL. 5: GOING GREEN: SUSTAINABLE GROWTH STRATEGIES 11 (2008), *available at* www.pwc.com/en_GX/gx/technology/pdf/going-green.pdf.

179. *Compare* UNITED STATES – ANNUAL AVERAGE WIND SPEED AT 80 M, NAT'L RENEWABLE ENERGY LABORATORY 1 (2011), *available at* www.windpoweringamerica.gov/pdfs/wind_maps/us_windmap_

Similarly, not all environmentally powered technologies are equally well suited for the various regional conditions that can be found throughout the United States. For example, while wind may be capable of providing ample power in the central regions of the United States,[180] solar power is a better alternative for those seeking a renewable energy source in the southwestern part of the country.[181] Though some green technologies will function equally well in all circumstances,[182] the overall effort to reduce environmental damage and to promote clean, efficient energy on a broad scale cannot rely solely on those few technologies. Achieving pervasive change demands that a wide-ranging portfolio of green technologies continue to be developed and deployed.

The major drawback to using this portfolio of green technologies under our current circumstances is that almost all existing technologies rely on rare elements in order to function.[183] As use of the technology scales, this would mean increasingly greater reliance on foreign sources to power the United States' clean energy initiative.[184] However, in light of recent developments such as the induction motor[185] and magnesium-based batteries,[186] it is becoming increasingly apparent that green technology design is capable of shifting away from reliance on rare elements. While improvements in recycling technology will help reduce the importation burden,[187] it will be the development of these alternative designs that will ultimately bring the United States to its most advantageous position for effectively realizing a future based on clean energy.

Historical experience in the United States' energy sector also suggests that using a portfolio approach with technology designed to limit foreign material reliance would be beneficial to the future of American green technology. The sharp rise of oil prices at various points during the past forty years can be at least partially attributed to the impact of foreign control of the market.[188] Because the United States did not make strong efforts to diversify

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80meters.pdf [hereinafter AVERAGE WIND SPEED] (showing wind speeds across the United States from a height of eighty meters), *with* SOLAR MAPS, NAT'L RENEWABLE ENERGY LABORATORY 1 (2011), *available at* http://www.nrel.gov/gis/solar.html [hereinafter SOLAR MAPS] (providing a variety of maps showing the concentration of solar energy in the Southwest).

180. AVERAGE WIND SPEED, *supra* note 179, at 1.

181. *See generally* SOLAR MAPS, *supra* note 179 (providing a variety of maps showing the concentration of solar energy in the Southwest).

182. For instance, electric vehicles can function anywhere in the nation because of their inherent nature.

183. *See supra* Part II (describing the utility and necessity of rare elements in the clean energy movement).

184. *See supra* Part III (describing foreign reliance on rare elements).

185. *See supra* Part IV.A.1 (describing, in part, the induction motor and its advantages for expanding the electric vehicle fleet).

186. *See supra* Part IV.A.1 (describing, in part, the development of magnesium-sulfur batteries as an alternative to lithium-based batteries).

187. *See supra* Part IV.A.2 (describing recent advancements in rare element recycling technology).

188. *See, e.g.*, LAWRENCE C. KUMINS, CONG. RESEARCH SERV., RL 32583, GASOLINE SUPPLY: THE ROLE OF IMPORTS 9 (2004), *available at* crs.ncseonline.org/NLE/CRSreports/04Sep/RL32583.pdf ("Dependence on imports to meet over 10% of national gasoline needs has begun to cause concern that these imports might contribute to 2004's high prices."); ROBERT PIROG, CONG. RESEARCH SERV., RL 32530, WORLD OIL DEMAND AND THE EFFECT ON OIL PRICES 6 (2004), *available at* crs.ncseonline.org/NLE/CRSreports/04Aug/RL32530.pdf ("On a regional level, the most important change between 1993 and 2003 is the weakening reserve position of North America, and the reserve position of the United States . . . . As [United

its energy portfolio as its reliance on foreign sources increased,[189] the stability of the nation's market has become dependent on global oil reserves[190] rather than on internally available resources and, consequently, on the often unstable political conditions of oil-supplying countries.[191] Under these circumstances, "the likelihood of an oil apocalypse is no longer implausible,"[192] the implications of which would be dire for the United States' energy stability.

In order to avoid a similar scenario with green technology resulting from heavy reliance on countries like China and South America to acquire the nation's supply of rare elements, American practice and policy needs to be focused on developing technologies that circumvent detrimental reliance on imports. The materials for technologies like the induction engines[193] and magnesium-based batteries, discussed above in Part IV.A.1, are readily available within the United States.[194] Though these technologies should not be the only developmental focus of the energy field, they are noteworthy early steps taken towards the ultimate goal of diversifying the United States' energy portfolio. Moving forward, energy research and development should continue to explore technologies that, like those mentioned above, also utilize locally available supplies.

The United States government also has an important role to play in the future energy landscape. Legislative acts like H.R. 2284[195] can provide helpful guidelines in shaping clean energy policy in the United States and can operate as the impetus driving individual and corporate compliance with national expectations for green technology use and procedure. The federal government can also incentivize green innovation by providing different types of tax incentives that encourage business investment in the sector.[196] Tax credits can be designed so as to reward technological innovation rather than just promote

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States] total consumption has increased over the period, the result has been that U.S. imports of oil have increased along with our dependence on other nations and the world oil market.").

189. *See* U.S. DEP'T. OF ENERGY, ANNUAL ENERGY REVIEW 2010, at 5 (2011), *available at* www.eia.gov/totalenergy/data/annual/pdf/aer.pdf (showing that, as reliance on fossil fuels increased significantly between 1949 and 2010, the use of nuclear electric power and renewable energy increased only minimally during the same time period).

190. *See* PIROG, *supra* note 188, at 19 ("Effective policies to mitigate high oil prices are difficult to define at the national level. The price of oil is determined on a world market. It is unlikely that any consuming nation can insulate itself from the forces driving the world market.").

191. *See* Edward L. Morse, *Oil and Unrest: What Uprising in the Arab World Means for Energy Supplies*, FOREIGN AFF. (Mar. 8, 2011), http://www.foreignaffairs.com/articles/67563/edward-l-morse/oil-and-unrest ("With political unrest spreading across the Middle East and North Africa, 2011 might turn out to be as momentous a year for the global geopolitics of oil as was 1971.").

192. *Id.*

193. Induction motors do not require rare earth materials and are by their design "cheap and rugged." N.V., *supra* note 113.

194. *See* U.S. GEOLOGICAL SURVEY, *supra* note 130, at 96–97 ("Seawater and natural brines accounted for about 54% of U.S. magnesium compounds production in 2010. Magnesium oxide and other compounds were recovered from seawater by three companies in California, Delaware, and Florida; from well brines by one company in Michigan; and from lake brines by two companies in Utah.").

195. *See supra* Part IV.A.2 (describing, in part, H.R. 2284, also known as the Responsible Electronics Recycling Act).

196. *See generally* Michael Haun & Kevin Young, *An Overview of Federal Tax Incentives for Green Technology*, BLOOMBERG L. REP. (2010), www.paulhastings.com/assets/publications/1490.pdf (describing various federal tax incentive schemes that have been implemented to promote green technology in various clean energy sectors).

adoption of existing technologies. For example, the investment tax credit (ITC) is a reduction in the overall tax liability for individuals or businesses that make investments in solar energy generation technology which provides critical policy certainty to the private sector to catalyze private investment in manufacturing and solar project construction and ensure the growth of the solar industry in the United States.[197] Tax incentives like the ITC have a federal legislative origin[198] and can help encourage continued private development of green technologies if expanded into other clean energy sectors. By combining tax incentives with other federal acts that encourage rare element recycling and alternatives, the federal government has the opportunity to play a significant role in driving green technology development in the proper direction.

Direct government funding can also be an important source of development money in the clean energy sector.[199] By funding alternative development opportunities, the government can "focus on accelerating innovations in clean technology while increasing America's competitiveness in rare earth alternatives,"[200] simultaneously encouraging scientific breakthroughs in fields such as biofuels, thermal storage, grid controls, and solar power electronics.[201] The government also has the option of offering federal grants in lieu of tax incentives as another means of providing direct funding to clean energy projects. Such a program already exists under the American Recovery and Reinvestment Act of 2009[202] and is enticing for certain businesses because "no tax liability is necessary to utilize the grants."[203] Considering these recent forms of investment, it seems likely that government funding will continue providing economic support for green technology development over the coming years[204] and may therefore be an effective way for the government to guide innovators towards designs that do not rely on rare elements.

Additionally, state governments can encourage local investments in selected green technologies, driving innovation in a state-to-state capacity.[205]

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197. *Solar Investment Tax Credit (ITC)*, SOLAR ENERGY INDUSTRIES ASS'N, http://www.seia.org/cs/solar_policies/solar _investment_tax_credit (last visited Aug. 24, 2012).

198. *See id.* ("The Energy Policy Act of 2005 (P.L. 109-58) created a 30% investment tax credit (ITC) for commercial and residential solar energy systems that applied from January 1, 2006 through December 31, 2007."). Subsequently, "[t]hese credits were extended for one additional year in December 2006 by the Tax Relief and Health Care Act of 2006 (P.L. 109-432)," resulting in double the amount of solar energy being installed in 2007 than in 2006. *Id.* The last major legislative action regarding renewable energy ITCs occurred in 2008, when "[i]n response to the dramatic downturn in the economy[,] . . . Congress enacted the Emergency Economic Stabilization Act of 2008 (P.L. 110-343) . . . [which] included an eight-year extension of the commercial and residential solar ITC." SOLAR ENERGY INDUS. ASS'N, BACKGROUNDER: SUCCESS OF THE SECTION 1603 TREASURY PROGRAM 2 (2011), *available at* http://www.solarinstallationslosangeles.com/wp-content/uploads/2012/02/factsheet _Backgrounder_Success_of_1603_Treasury_Program.pdf.

199. *See, e.g.*, *Department of Energy Awards $156 Million*, *supra* note 127 (describing the $156 million in grants handed out by the U.S. Department of Energy to fund renewable energy projects).

200. *Id.*

201. *Id.*

202. American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, 123 Stat. 115 (2009).

203. Haun & Young, *supra* note 196.

204. *See, e.g.*, *id.* ("Grants are available for projects placed in service before 2011, or those that commence construction before 2011 and are placed in service prior to 2013 for wind energy, 2017 for solar energy or 2014 for other qualified technologies.").

205. *See, e.g.*, CENT. FOR AUTO. RESEARCH, *supra* note 102, at 26–36 app. (detailing state-by-state policies that have been instituted for energy efficient vehicles, such as tax incentives and high occupancy

As a prime example, California is considered to be one of the nation's leading innovators of green technology and policy,[206] with its "longtime commitment to clean energy . . . put[ting] the state far ahead of the pack in terms of technology deployment and capital creation."[207] The state has produced an extraordinary number of grants, programs, tax incentives, and government regulations designed to encourage clean energy.[208] These benefits range from immediate rewards like rebates and High Occupancy Vehicle lane access for low-emissions vehicle drivers[209] to the state's Renewables Portfolio Standard, designed to foster clean energy growth over an extended period of time.[210]

Because California has created a political atmosphere that embraces green technologies, the state has risen as a prominent example of success for state involvement in promoting clean energy. The state holds "a disproportionate share of U.S. solar energy patents (39% of those issued from 2007 to 2009), battery technology patents (20% in the same time period) and wind energy patents (16% in that period),"[211] providing the state with a technological advantage in the clean energy sector.[212] Additionally, California's role in green technology is so pronounced that "[t]he state's burgeoning clean-energy industry brings in more venture capital than all other states combined,"[213] attracting billions of dollars in investments.[214] As indicated by these facts,

vehicle (HOV) lane access).

206. *See State Clean Energy Leadership Index Summary*, CLEAN EDGE, http://cleanedge.com/subscriptions/state-index-details (last visited Aug. 25, 2012) (labeling California as the leading state for clean energy). The index rankings are based on a number of key market indicators. *California, Oregon, Massachusetts, New York and Colorado Top the Nation in Clean-Energy Leadership*, PRWEB (May 18, 2011), http://www.prweb.com/releases/2011/5/prweb8441833.htm ("Key market indicators tracked by Clean Edge include total electricity produced by clean-energy sources, hybrid and electric vehicles on the road, clean-energy venture and patent activity, and policy regulations and incentives.").

207. PRWEB, *supra* note 206.

208. *See California: Incentives/Policies for Renewables & Efficiencies*, DSIRE: DATABASE OF ST. INCENTIVES FOR RENEWABLES & EFFICIENCIES, http://www.dsireusa.org/incentives/index.cfm?state=CA (last visited Aug. 25, 2012) (listing the various grants, programs, incentives, and regulations related to clean energy and green technology in California).

209. *See* Tiffany Kaiser, *CA Volt Drivers to Receive $1,500 Rebate, HOV Access; GM Charges EVs via Solar Tree*, DAILYTECH (Nov. 17, 2011, 10:45 AM), http://www.dailytech.com/CA+Volt+Drivers+to+Receive+1500+Rebate+HOV+Access+GM+Charges+EVs+via+Solar+Tree/article23312.htm ("In addition to HOV lane stickers, California Volt drivers with the Low Emissions Package are eligible to receive $1,500 in state rebates via the California Clean Vehicle Rebate Project. Volt drivers will also receive the $7,500 tax credit from the federal government.").

210. *See Renewables Portfolio Standard*, DSIRE: DATABASE OF ST. INCENTIVES FOR RENEWABLES & EFFICIENCIES, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA25R&re=1&ee=1 (last visited Aug. 25, 2012) ("California's Renewables Portfolio Standard (RPS) was originally established by legislation enacted in 2002. Subsequent amendments to the law have resulted in a requirement for California's electric utilities to have 33% of their retail sales derived from eligible renewable energy resources in 2020 and all subsequent years.").

211. Carolyn Said, *California Leads Nation in Green Tech*, SFGATE, Oct. 7, 2010, http://articles.sfgate.com/2010-10-07/business/24115289_1_clean-tech-green-manufacturing-jobs-green-technology.

212. This does not mean that California is the only state with a notable number of green technology patents. In fact, Michigan issued more clean energy patents than California in 2010. *See* PRWEB, *supra* note 206 ("Michigan held the top spot in clean-energy patents for 2010 with 192 patents. Leading the charge is General Motors, which is reinventing itself as a sustainable transportation leader. GM received more clean-energy patents last year than any other company in the [United States], with 135 patents registered in 2010.").

213. *Id.*

214. *See* Said, *supra* note 211 ("The state has attracted $11.6 billion in clean-tech venture capital since 2006, about one-quarter of all global investment in the sector. In the first half of [2010] . . . it drew 40% of all

promoting green technology and clean energy policy can be mutually advantageous to both the environment and the fiscal needs of the state.

Notably, other states have also begun to follow California's lead and have started to foster their own clean energy initiatives. Besides California, two other states "now generate more than 10% of their utility-scale electricity from wind, solar, and/or geothermal. Iowa leads the nation with 15.4% of its electricity now generated from wind power, followed by North Dakota (11.99% from wind)."[215] With the support of General Motors, Michigan has started to promote the technology necessary to increase electric vehicle use within the state.[216] Even states such as Mississippi, which scored poorly on the 2011 United States Clean Energy Leadership Index, are making efforts to reform their clean energy practices, "attract[ing] a host of clean-tech companies to build manufacturing facilities and plants there, including California-based solar company Stion Solar Panels and Texas-based biofuel company KiOR."[217] This indicates that acceptance of clean energy is spreading across the nation.[218] It is critical that, as state governments continue to recognize the value of clean energy, efforts are made by the authorities to promote technologies that reduce rare element reliance and to encourage recycling practices.

By continuing to introduce progressive green technology-focused legislation and by providing additional funding to development projects in the clean energy sector that emphasize recycling technology and alternatives to rare elements, the state and federal governments of the United States can provide the guidance and incentive necessary to effectively drive the future of green technology.

B. The Tesla Roadster: A Lesson in Green Technology Design, Reinforced by Policy

The Tesla Roadster, the "world's first highway-capable electric vehicle,"[219] is an excellent example of how proper design can be combined with progressive policies to encourage consumers to purchase green technologies that have a diminished reliance on foreign material sources.[220]

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global clean-tech VC. More than half that money was invested in Silicon Valley.").

215. PRWEB, *supra* note 206.

216. *See* Kaiser, *supra* note 209 ("Michigan has a solar charging canopy called the Tracking Solar Tree, which moves with the sun and helps to charge GM's EVs [electric vehicles]."). According to General Motors, "the Tracking Solar Tree is able to increase renewable energy production by about 25% . . . [and] will produce up to 30,000-kilowatt hours per year and generate enough solar energy to charge six EVs daily." *Id.*

217. PRWEB, *supra* note 206.

218. *See id.* ("'This year's Leadership index shows that clean-energy activity is dispersed across the nation, with leaders on both coasts and in between,' says Clean Edge managing director Ron Pernick.").

219. *Tesla Opens Gallery in Houston*, TESLAMOTORS.COM (Oct. 19, 2011), http://www.teslamotors.com/about/press/releases/tesla-opens-gallery-houston.

220. Though there has been discussion of Tesla reducing its production of the Roadster, the lessons learned from its design and the policies implemented to support the technology are nonetheless valid and pertinent to this discussion. For more information about Tesla's future plans regarding the Roadster, see John O'Dell, *Tesla Plans New Roadster for 2014*, AUTOOBSERVER (Nov. 1, 2011), http://www.autoobserver.com/2011/11/tesla-plans-new-roadster-for-2014.html.

Compared to most other electric vehicles on the market, the Roadster stands out as a remarkably innovative piece of technology. Though its performance specifications are independently impressive compared to other electric vehicles,[221] what is truly noteworthy about the Roadster is the unique design of its engine. While other electric vehicles use engines that still rely at least partially on rare earth elements,[222] the Roadster is entirely free of rare earths, instead relying on a simple "three-phase Alternating Current (AC) Induction motor"[223] and a non-toxic lithium-ion battery pack that "weighs 990 pounds, stores 56 kWh of electric energy, and delivers up to 215 kW of electric power."[224]

Though its use of an advanced lithium-ion battery still indicates some level of rare element reliance, the Tesla Roadster is well beyond its competition in terms of reducing overall reliance on foreign materials. As a point of comparison, Toyota's Prius "requires 20 to 25 pounds of rare earths, about twice as much as a standard automobile."[225] This number becomes considerably more worrisome when scaled to account for the fact that there have been over a million sales of Toyota's hybrid.[226] The Roadster, however, is not subject to the troubling implications of rare earth reliance due to its engine design.[227] As a result, the prospect of scaling the induction motor is far less contentious.

In addition to progressive design, legislative policy at both the state and federal level has been designed to encourage consumers to purchase the Roadster and other types of electric vehicles. The federal government offers two tax incentives to encourage the adoption of this technology: a "$7,500 federal tax credit with the purchase of a new Tesla acquired for personal use"[228] and a federal charging infrastructure tax credit refunding "up to 30% of the purchase and installation costs of qualified electric vehicle charging infrastructure acquired in 2011, with a maximum credit of $1,000 for Individuals and $30,000 for Businesses."[229] In addition to federal tax

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221. *Compare Roadster: Features and Specs*, TESLAMOTORS.COM, http://www.teslamotors.com/roadster/specs (last visited Sept. 10, 2012) (describing how the car accelerates from 0 miles per hour to 60 miles per hour in 3.7 seconds and can drive approximately 245 miles per charge), *with The New Car: Features and Specifications*, NISSANUSA.COM, http://www.nissanusa.com/leaf-electric-car/specs-features/index#/leaf-electric-car/specs-features/index (last visited Sept. 10, 2012) (describing how the charge for the Nissan Leaf only lasts approximately 100 miles).

222. *See Will Toyota's Plans Sink Rare Earth Metal ETFs?*, BUS. INSIDER (Jan. 19, 2011), http://articles.businessinsider.com/2011-01-19/markets/29964914_1_rare-earth-lithium-metals ("Rare earths are used in the Nissan Leaf, the Chevy Volt, Honda Insight, and Toyota Prius, creating a broad base of companies in needs [sic] of rare earth metals to drive growth of new product lines.").

223. *Roadster Innovations: Motor*, TESLAMOTORS, http://www.teslamotors.com/roadster/technology/motor (last visited Aug. 25, 2012).

224. *Id.*

225. Tudor Van Hampton, *For E.V.'s and Hybrids, a Free-Spinning Alternative to Rare Earths*, N.Y. TIMES, June 23, 2011, http://wheels.blogs.nytimes.com/2011/06/23/for-e-v-s-and-hybrids-a-free-spinning-alternative-to-rare-earths/.

226. *Toyota Prius Sets 1 Million Sales as Green Car Benchmark*, *supra* note 29.

227. *See Roadster Innovations: Motor*, *supra* note 223 (discussing Roadster engine design).

228. *Electric Vehicle Incentives Around the World*, TESLAMOTORS, http://www.teslamotors.com/goelectric/incentives (last visited Aug. 25, 2012).

229. *Electric Vehicle Incentives Around the World*, 4EVRIDERS.ORG, http://www.4evriders.org/2011/03/electric-vehicle-incentives-around-the-world (last visited Aug. 25, 2012) (referencing that federal

incentives, some state governments also provide benefits to purchasers of Roadsters. For example, in New Jersey, "[e]lectric car purchases are not subject to state sales tax" and are allowed certain HOV lane privileges;[230] in California, "[e]lectric vehicle purchasers . . . are eligible for a $2,500 rebate from the Clean Vehicle Rebate Project (CVRP) during FY2011–2012 (ending June 30, 2012), or until funds are exhausted," and many localities offer additional benefits;[231] and in Maryland, "a Tax Credit of up to $2,000 [is available] for the purchase of an Electric Vehicle."[232] In one particularly generous incentive scheme that ended in 2009, a zero-emissions car tax incentive in the state of Colorado resulted in a $42,000 tax credit discount specifically for the Tesla Roadster.[233] By providing multiple levels of incentives, the federal and state governments play an active role in encouraging American consumers to purchase the Roadster and similar vehicles, helping to provide the type of push that is often necessary for the widespread success of new technologies.

Admittedly, the Tesla Roadster is not a car that is entirely free of faults. As a sports car, the Roadster is well beyond the price range of the typical consumer with a base price of about $109,000 for the 2011 model,[234] making the technology unaffordable to a large majority of Americans. Additionally, only slightly more than 2,000 of the cars have been produced, indicating that Tesla has had difficulty scaling the vehicle to cater to a broader market.[235] Yet, despite these troubles, the lessons provided by the Tesla Roadster are important to remember as the United States continues to develop and improve its clean energy practices. Technology can be effectively designed to reduce (and, perhaps in the future, entirely eliminate) the reliance on imports from foreign sources to meet our material demands without sacrificing quality. Furthermore, both levels of government can play an active role in supporting such technology by providing incentives to persuade consumers to purchase products that are either free of rare elements or use limited quantities of them. Moving forward, it is imperative that the United States adheres to these principles and continues to develop and promote the types of green technologies that decrease foreign reliance as a matter of national security and

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charging infrastructure tax credit only applies if the qualified electric vehicle is purchased in 2011). The federal charging infrastructure tax credit is even greater for infrastructure acquired in 2009 and 2010; in these instances, "a tax credit can be claimed for up to 50% of infrastructure cost with a maximum credit of $2,000 for Individuals and $50,000 for Businesses." *Id.*

230. *Id.* (for "State" field, input "New Jersey").

231. *Id.* (for "State" field, input "California"). For examples of some of the local incentives, Los Angeles offers "free parking up [sic] for electric vehicles at charging stations ($900 monthly value, typically $30 day)" at Los Angeles International Airport (LAX), and Santa Monica "offers free metered parking for electric vehicles at any meter for maximum time limit." *Id.*

232. *Id.* (for "State" field, input "Maryland").

233. Tim Hoover & John Ingold, *Colorado Tax Credit Gives $42,000 Discount on Tesla Roadster*, DENVER POST, Oct. 23, 2009, http://www.denverpost.com/ci_13622627.

234. *See* Jake Holmes, *2011 Tesla Roadster 2.5*, CAR & DRIVER (July 2010), http://www.caranddriver.com/news/tesla-roadster-news-2011-tesla-roadster-25-info (describing MSRP pricing for the 2011 Tesla Roadster 2.5).

235. *See* Edward Niedermeyer, *Tesla Roadster: 1,650 Down, 750 To Go*, THETRUTHABOUTCARS.COM (June 9, 2011), http://www.thetruthaboutcars.com/2011/06/tesla-roadster-1650-down-750-to-go/ (describing Tesla's production troubles with the Roadster).

stability.

VI. CONCLUSION

The United States is currently in a difficult position due to its reliance on external suppliers to meet its internal demands for rare elements. With China controlling the vast majority of the global production of rare earths and South America largely controlling most of the world's currently accessible lithium, the United States has little choice but to cater to the economic penalties resulting from foreign dominance of the rare element markets. For the green technologies that rely on these materials, this means the possibility of unpredictable price fluctuations, material shortages, and greater hesitancy from potential investors in clean energy.

Despite these concerns, recent developments provide hope for the future of rare elements and their relationship to green technology in the United States. Due to the influence of private industry and government investments, technologies are being designed in a way that decreases their reliance on rare elements. Additionally, improvements in recycling technology, the discovery of new rare element deposits, and the reopening of old mines all open the future possibility of decreasing the United States' reliance on the countries that currently dominate the markets for rare elements. These advancements provide hope for a brighter future for green technology and clean energy, both in the United States and globally.