The Dirty Effects of Clean Energy Technology: Supportive Regulations to Promote Recycling of Lithium Ion Vehicle Batteries

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I. BACKGROUND

The advent of "green" vehicles in the United States has been a major part of the federal government's effort to reduce oil consumption and air pollution.[1] With almost 100,000 electric vehicles ("EVs") sold in 2013, the United States had the biggest increase of EV sales in the world, almost matching global EV sales in 2012.[2] Second to Japan, the United States had the highest percentage (thirty-nine percent) of sales of non-plug-in hybrid electric vehicles ("HEVs") throughout the world.[3] The development of these vehicles depends on advancements in battery technology, and therefore Congress has funded public and private sector research over several decades on a variety of new types of batteries.[4] However, there is no federal recycling legislation in place to combat the issues associated with the production and disposal of these new generation vehicle batteries.[5]

Traditionally, electric vehicles have been powered by lead-acid, nickel-metal hydride ("NiMH"), or sodium-nickel-chloride ("ZEBRA") batteries.[6] However, electric cars today typically use lithium ion ("Li-ion") batteries because of the favorable material characteristics of lithium.[7] For instance, lithium is the lightest of all metals and offers the greatest electrochemical potential, which results in a high power-to-weight-ratio and high energy efficiency.[8] Additionally, Li-ion batteries provide higher resistance to

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[1] *Vice President Biden Announces Plan to Put One Million Advanced Technology Vehicles on the Road by 2015*, THE WHITE HOUSE STATEMENTS AND RELEASES (Jan. 26, 2011), https://www.whitehouse.gov/the-press-office/2011/01/26/vice-president-biden-announces-plan-put-one-million-advanced-technology.

[2] INT'L ENERGY AGENCY PUBL'NS, TRACKING CLEAN ENERGY PROGRESS 2014, at 42 (2014), http://www.iea.org/publications/freepublications/publication/Tracking_clean_energy_progress_2014.pdf (stating global EV sales in 2012 amounted to 115,000).

[3] *Id.*

[4] American Recovery and Reinvestment Act of 2009 (ARRA), Pub. L. No. 111-5, 123 Stat. 115 (2009); BILL CANIS, CONG. RESEARCH SERV., R41709, BATTERY MANUFACTURING FOR HYBRID AND ELECTRIC VEHICLES: POLICY ISSUES 1 (2013), http://fas.org/sgp/crs/misc/R41709.pdf; *see Funding-Financing*, ENERGY.GOV (Mar. 29, 2015), http://energy.gov/public-services/funding-financing.

[5] Linda Gaines, *Lithium-Ion Battery Issues*, U.S. DEP'T OF ENERGY 17 (Sept. 26-27, 2011), http://www.transportation.anl.gov/pdfs/B/814.PDF [hereinafter *Lithium-Ion Battery Issues*].

[6] Dominic A. Notter et al., *Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles*, 44 ENVTL. SCI. & TECH. 6550, 6550 (2010); *Batteries for Hybrid and Plug-In Electric Vehicles*, U.S. DEP'T OF ENERGY (Mar. 22, 2015), http://www.afdc.energy.gov/vehicles/electric_batteries.html.

[7] Notter et al., *supra* note 6, at 6550; *see Batteries for Hybrid and Plug-In Electric Vehicles*, *supra* note 6.

[8] Notter et al., *supra* note 6, at 6550; *see Batteries for Hybrid and Plug-In Electric Vehicles*, *supra* note 6.

charging failure because of their no memory effect, and therefore these batteries require much less maintenance than other battery chemistries.[9]

Lithium is used for a number of different industrial purposes, and one of the most valuable uses of lithium is as a component of high energy-density rechargeable Li-ion batteries.[10] With the proliferation of electric vehicles powered by Li-ion batteries, lithium demand is inevitably increasing. Since lithium batteries first entered the market in 1993, about 45,000 tons of lithium has been incorporated into these batteries worldwide.[11] It is expected that batteries will account for forty percent of total lithium consumption in 2020.[12] Just a few years ago, the United States produced less than two percent of the world's advanced batteries.[13] However, Tesla Motors broke ground on the Tesla Gigafactory in June 2014, outside Sparks, Nevada, and by 2020, the Gigafactory will produce more lithium-ion batteries annually than were produced worldwide in 2013.[14]

The main lithium reserves are located in the so-called "Lithium Triangle," composed of Bolivia, Argentina, and Chile. Currently, Chile holds approximately seventy-six percent of the world's accessible lithium reserves, followed by Argentina which holds approximately eight percent.[15] Lithium, like other rare earth materials, is extracted from the ground and then processed in a way that demands energy and can release toxic wastes.[16] In regions that lack proper regulations, mineral extraction can extend risks beyond just the workers directly involved, and surrounding communities may be exposed to toxic substances through air and groundwater contamination.[17]

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[9] Notter et al., *supra* note 6, at 6550.

[10] *See* Thomas G. Goonan, *Lithium Use in Batteries*, at 3 (U.S. Geological Survey Circular 1371, 2012), http://pubs.usgs.gov/circ/1371/pdf/circ1371_508.pdf.

[11] *Id.* at 9.

[12] *Id.* at 5.

[13] THE WHITE HOUSE STATEMENTS, *supra* note 1.

[14] *Tesla Gigafactory*, TESLA MOTORS (Feb. 26, 2014), https://www.teslamotors.com/gigafactory. With a planned production rate of 500,000 vehicles per year in the latter half of this decade, Testla alone will require today's entire worldwide production of lithium-ion batteries. *Id.* The Tesla Gigafactory is necessary to allow Tesla to supply enough batteries to support the company's projected vehicle demand. *Id.*

[15] U.S. Dep't of Energy, Critical Materials Strategy 28 tbl. 3-1 (2010), http://energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf.

[16] Ozzie Zehner, *Unclean at Any Speed: Electric Cars Don't Solve the Automobile's Environmental Problems*, IEEE SPECTRUM (June 30, 2013, 14:00 GMT), http://spectrum.ieee.org/energy/renewables/unclean-at-any-speed.

[17] *Id.*

Mining operations significantly impact communities living in arid territories where the access to water is key for the local flora and fauna, as well as their livelihood.[18] In Chile, lithium is extracted from deposits in salt flats, which are located in arid territories.[19] Mining lithium in these dry and barren areas consumes, pollutes and diverts scare water supply away from the local communities.[20] Unsurprisingly, the widespread mining operations in place for the purposes of lithium extraction have caused water-related conflicts with different communities throughout Northern Chile.[21]

The discovery of potential environmental, geo-political, and human health concerns from the production and disposal of millions of Li-ion batteries each year demands stronger government policies to encourage recovery, recycling and reuse of Li-ion battery materials. The increasing demand for lithium will potentially shift the resource curse experienced by oil-rich countries to lithium-rich countries in South America, such as Chile, Argentina, and Bolivia.[22] Part II of this Comment provides an overview of the negative impacts associated with the mining, production, and disposal of Li-ion batteries. It examines the environmental and human health effects of mining lithium on surrounding communities, and brings to light the future threat of lithium depletion. Part III discusses the challenges associated with recycling Li-ion batteries, and how the impediments to recover Li-ion battery materials makes mining the materials more profitable than recovering them. Moreover, Part III addresses how the unknown potential of a future market for recycling Li-ion battery materials discourages investment in the industry.

Part IV illustrates the achievements of Tesla Motors and Umicore's battery recycling plant in Europe to develop a battery recycling process that is both profitable and environmentally conscious. Part IV then explores extended producer responsibility ("EPR") legislation in the European Union as a potential model for United States regulations to promote Li-ion battery recycling. Part V illustrates an absence of supportive regulations in the United States to abate our dependence on foreign nations for natural

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[18] *See* ANTONIO BELMAR ET AL., *Conflicts Over Water in Chile: Between Human Rights and Market Rules*, CHILE SUSTENABLE (Sept. 2010), http://www.canadians.org/sites/default/files/publications/ChileWaterReport%20-final%20March%202011.pdf.

[19] *See* Critical Materials Strategy, *supra* note 15, at 17.

[20] *See* BELMAR, *supra* note 18, at 37.

[21] *See id.*

[22] *See* Andrew W. Eichner, *More Precious Than Gold: Limited Access to Rare Elements and Implications for Clean Energy in the United States*, U. ILL. J.L. TECH. & POL'Y 257, 265 (2012) (demonstrating the implications of foreign control over rare earth materials and the difficulties that the United States may face by relying on external sources to meet its internal demand); *see also* 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?_r=0.

resources that are being depleted. Finally, Part V argues that supportive regulations can make a profitable and environmentally sound recycling process achievable.

II. THE NEED FOR RECYCLING LITHIUM VEHICLE BATTERIES

Demand from consumer electronics, geo-political relationships, environmental impacts of mining, and new modes of mobility solutions are among the diverse factors expected to impact lithium supply and its price in the future. Traditionally, common uses of lithium include ceramics, glass, batteries, and lubricating greases.[23] With the ubiquitous presence of electronic devices, along with the introduction of electronic vehicles, the demand for lithium-containing batteries already requires twenty-three percent of the global lithium production.[24]

With few Li-ion powered vehicles on the road today, it may appear that this situation is years away. However, evidence shows that demand for lithium from the electric vehicle battery market could cause a lithium shortage in the near future.[25] A report by the Mineta National Transit Research Consortium estimates that by 2035 there will be somewhere between 1.3 million and 6.7 million worn-out EV hybrid and plug-in vehicle batteries in the United States.[26] This volume of spent EV batteries justifies the need to set up effective recycling programs.

The accessibility of lithium depends upon the feasibility of extracting the material. South America holds seventy-five percent of the known global lithium reserve base.[27] Recently, vast deposits of lithium were discovered in Bolivia and Afghanistan; however, it is not yet clear how the element

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[23] Minerals Information Team, U.S. Geological Survey, Mineral Commodity Summaries 92 (2010), http://minerals.usgs.gov/minerals/pubs/mcs/2010/mcs2010.pdf.

[24] *Id.* at 92, 93 ("Batteries, especially rechargeable batteries, are the market for lithium compounds with the largest growth potential.").

[25] Linda Gaines, Ph.D. & Paul Nelson, Ph.D., *Lithium-Ion Batteries: Possible Material Demand Issues*, CTR. FOR TRANSP. RES. AT ARGONNE NAT'L LAB. 8 (2009), http://www.transportation.anl.gov/pdfs/B/583.PDF [hereinafter *Lithium-Ion Batteries*] (noting that demand was estimated for U.S. vehicle use only, and that world demand, including that for all other battery applications, must eventually be included as well).

[26] *See* CHARLES R. STANDRIDGE & LINDSAY CORNEAL, *Remanufacturing, Repurposing, and Recycling of Post-Vehicle-Application Lithium-Ion Batteries*, MINETA NATIONAL TRANSIT RESEARCH CONSORTIUM, REP. 12-20, 1 (2014), http://transweb.sjsu.edu/PDFs/research/1137-post-vehicle-Li-Ion-recycling.pdf.

[27] Critical Materials Strategy, *supra* note 15, at 28.

will be extracted.[28] Different methods of extraction are required depending on the composition of the lithium deposits.[29] For instance, the mining companies in Chile and Argentina perform an evaporation method to extract lithium by drilling through dried-up lake beds and exposing lithium-laced saltwater beneath.[30] Because this method of extraction is the least expensive, Chile and Argentina are the largest suppliers of lithium in the world.[31]

There are also lithium deposits in Nevada, but most of the lithium used in the United States is imported because the extraction process is more costly than the evaporation method done in Chile and Argentina.[32] According to researcher Linda Gaines, a systems analyst at Argonne National Laboratory, effective recycling of certain types of Li-ion batteries could significantly decrease the amount of virgin lithium needed to manufacture the batteries.[33] With a successful recycling program in the United States, along with the lithium deposits in Nevada, the United States could potentially reduce its dependence on foreign supply.[34]

Due to harmful mining impacts, the increasing demand for lithium is progressively affecting communities where destructive extraction takes place by jeopardizing their access to water.[35] For example, the indigenous community of Quillagua, located in Northern Chile, is facing a socio-environmental conflict with mining companies CODELCO Norte (Chuquicamata) and Soquimich ("SQM") due to the drying and contamination of the Loa River, caused by both companies.[36] SQM is the main producer of lithium in Chile, which was the mining company responsible for drying up the Loa River.[37]

The mining impacts have permanently destroyed productive activities, such as farming of shrimp, alfalfa, and livestock in the Quillagua Oasis area, causing a massive migration of people.[38] In 1940, four hundred families lived in the town of Quillagua and had access to six hundred and sixty liters of water per second.[39] Today, less than one hundred families live in

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[28] *See* Risen, *supra* note 22; *see* Brian Palmer, *Troves of Lithium, Valuable for Batteries, Boost Mood in Bolivia and Afghanistan*, WASH. POST, Aug. 31, 2010, http://www.washingtonpost.com/wpdyn/content/article/2010/08/30/AR2010083003937.html.

[29] *See* Palmer, *supra* note 28.

[30] *Id.*

[31] *Id.*

[32] *See* Critical Materials Strategy, *supra* note 15, at 34.

[33] *See* Gaines, *Lithium-Ion Batteries*, *supra* note 25, at 9.

[34] *Id.*

[35] *See* BELMAR, *supra* 18, at 37.

[36] *Id.* at 37.

[37] *Id.* at 38.

[38] *Id*.

[39] *Id*.

Quillagua, and the availability of water is of only ninety liters per second.[40] Due to the failures of Chilean authorities to remedy the social, economic, and environmental costs caused by the mining impacts on the Loa River, the town of Quillagua is on the verge of disappearing.[41]

Government instability in these regions can significantly affect the supply of lithium and, in turn, impact battery prices and vehicle costs. According to William Tahil, research director with Meridian International Research, the last and biggest untapped reserve of lithium in the world is in the Salar de Uyuni salt flats of Bolivia.[42] Bolivia has made numerous attempts over the years to exploit these lithium resources, but they have all failed for political reasons.[43] The present political situation in Bolivia is acting as a strong disincentive for western mining companies to operate in the country because the historical exploitation of mineral resources by foreign firms is considered an insufficient benefit to Bolivian society.[44]

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.[45] China, being the world's largest consumer of lithium, poses a significant threat to the growing competition for this resource.[46] While China's domestic lithium resources are being rapidly depleted, efforts to secure lithium supply in South America are transpiring.[47] On August 5, 2014, International Lithium Corp. ("ILC"), a Canadian exploration company, announced that it signed a joint venture agreement with Gangfeng Lithium Co. ("Gangfeng"), a leading China based lithium manufacturer, pertaining to the Mariana Lithium Brine project in Salta Province, Argentina.[48] The Mariana Project allowed ILC to acquire one hundred percent of the mineral rights of several contiguous mining claims

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[40] *Id*.

[41] *Id.*

[42] *See* William Tahil, *The Trouble with Lithium: Implications of Future PHEV Production for Lithium Demand*, MERIDIAN INT'L RES., at 6 (Jan. 2007), http://www.reveo.com/us/reveofiles/reveofiles/Acrobat%20Document-lithium.pdf.

[43] *Id.*

[44] *Id.*

[45] Eichner, *supra* note 22, at 260.

[46] *See* Xianlai Zeng & Jinhui Li, *Implications for the Carrying Capacity of Lithium Reserve in China*, RESOURCES, CONSERVATION, AND RECYCLING, at 58 (Nov. 2013).

[47] *Id.*

[48] *See International Lithium Corp. Completes Payments On Mariana Lithium Brine Project in Argentina*, ACCESSWIRE (Aug. 5, 2014), http://www.accesswire.com/viewarticle.aspx?id=418719.

that cover an expansive one hundred and sixty square kilometers.[49] Under the terms of the agreement, Gangfeng now holds an eighty percent interest in the Mariana Project.[50]

"[A] world dependent on lithium for its vehicles could soon face even tighter resource constraints than we face today with oil."[51] For instance, lithium is also consumed for a number of other purposes like construction, portable computers, cameras, mobile phones, ceramics and glass, and many other devices.[52] To date, automotive industry consumption has been fairly insignificant.[53] Currently, batteries account for about one quarter of lithium consumption; however, they are expected to account for about forty percent by 2020.[54] In 2007, Tahil expressed concern that if the sixty million cars that are produced worldwide each year were totally replaced with plug-in hybrids, demand for lithium carbonate would be 420,000 tons annually, which is nearly five times the current lithium carbonate production.[55]

It is safe to predict that lithium will play a significant role in our future mobility. Lithium is already a key part of our everyday lives, and as batteries become increasingly important in a new global energy picture, demand for lithium will continue to soar.[56] There is no substitute for lithium used in advanced vehicle batteries, and the known reserves are concentrated in just a few countries.[57] A sophisticated recycling infrastructure is crucial to secure the mid- and long-term supply of the required raw materials.[58] At present, the development of technology and strategies for recycling pales in comparison to the development and production of advanced vehicle batteries.

III. THE CHALLENGES ASSOCIATED WITH RECYCLING LITHIUM VEHICLE BATTERIES

While lithium is one hundred percent recyclable, unfavorable economics provide little support for recycling Li-ion batteries. One major reason for this is that certain battery chemistries are more conducive to recycling

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[49] *Id.*

[50] *Id.*

[51] Tahil, *supra* note 42, at 1.

[52] U.S. Geological Survey, *supra* note 23, at 93.

[53] *Id.* at 92–93.

[54] *Id.*

[55] Tahil, *supra* note 42, at 12.

[56] *See* Luis Oliveira et al., Key Issues of Lithium-ion Batteries—From Resource Depletion to Environmental Performance Indicators, 108 J. Cleaner Prod. 354, 355 (2015), https://pdfs.semanticscholar.org/e0a7/4ad9e1cb8b11ff9d1a0510009351c658585c.pdf.

[57] *See id.*

[58] *See id.*

than in others.[59] For instance, hybrid vehicles that are powered by nickel-metal hydride batteries are exceptionally valuable to recycle because nickel, even when recovered, will sell at a high price.[60] By contrast, Li-ion batteries contain complex chemistries that make the recycling process complicated and too costly when taken into account the low yield of precious metals that can be recovered.[61] Many of the materials used in Li-ion batteries have low market value, and in turn, the recovered raw material hardly pays for the labor involved in the recycling process, which includes collection, transport, sorting between battery chemistries, shredding, neutralizing hazardous substances, smelting, and purifying the recovered metals.[62]

The recycling industry for advanced vehicle batteries is trivial compared to the massive battery manufacturing industry.[63] To this day only lead-acid batteries, which are used in traditional gas-powered vehicles, can be recycled profitably.[64] Batteries are designed for effective performance and long life span at a low price.[65] Manufacturers do not consider the recyclability of the batteries during the design stage, and they invest little thought into simplifying the recovery of precious metals from batteries at their end-life.[66] Because Li-ion battery construction is so new and rapidly developing, there is no standard chemistry and the technology is still changing.[67] Consequently, the advanced lithium batteries in most EVs and plug-in cars today are more difficult to recycle, in part because automakers use various chemistries, and the several chemical components have different

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[59] Gaines, *Lithium-Ion Batteries*, *supra* note 25, at 1.

[60] *Id.*

[61] *Id.*

[62] Linda Gaines, *The Future of Automotive Lithium-ion Battery Recycling: Charting a Sustainable Course*, SUSTAINABLE MATERIALS AND TECHNOLOGIES, at 2, 5–6 (Dec. 2014), http://www.sciencedirect.com/science/article/pii/S2214993714000037# [hereinafter *The Future of Automotive Lithium-ion Battery Recycling*].

[63] *See* Klaus Bellmann & Anshuman Khare, *Economic Issues in Recycling End-of-Life Vehicles*, TECHNOVATION 677, 678, Dec. 2000, http://www.sciencedirect.com/science/article/pii/S0166497200000122.

[64] Gaines, *The Future of Automotive Lithium-ion Battery Recycling*, *supra* note 62, at 2.

[65] Bellmann & Khare, *supra* note 63, at 681.

[66] *Id.*

[67] Linda Gaines, *A Look Through the Crystal Ball at the Future of Automobile Battery Recycling*, CTR. FOR TRANSP. RESEARCH AT ARGONNE NAT'L LAB., at 2, 9 (Mar. 13, 2014), http://www.transportation.anl.gov/pdfs/B/964.pdf.

recycling values.[68] Standardization of batteries, materials, and cell design would make recycling easier and more cost-effective.[69]

Recycling industries generally emerge due to consumer or regulatory pressure and usually do not benefit from favorable economics.[70] Currently, in most of the United States, entering the recycling market is dissuaded because the value of salvageable materials is not sufficient to cover the costs associated with recycling.[71] Pending a guaranteed supply of recyclables and a market for goods made with recycled materials, investors will not risk funds to use the recycled material.[72] Additionally, future Li-ion battery chemistries that are being developed, such as phosphate or manganese-based chemistries, include little or no valuable metals like cobalt or nickel.[73] Thus, there is an overall negative value in recycling the cheaper materials contained in Li-ion batteries when the cost of their recovery is exceptionally high.[74]

The most efficient way to reduce the negative impacts of a product is to reduce waste at the initial design stage. The design phase of a product determines about seventy percent of the final cost of the product and is the stage that has the most impact on the product's functionality and environmental impact.[75] An important notion to keep in mind is that recycling is not always good for the environment—especially when large amounts of energy are required to collect and process the materials to be recycled.[76] Traditionally, recyclability is not considered when designing a product; however, changes in product design would greatly improve product recycling.[77] As mentioned previously, disassembly for recycling is a difficult and labor-intensive process.[78] Labor costs could be reduced, however, through design modifications that would make it easier to remove valuable materials.

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[68] *Id.* at 9

[69] *Id.* at 14.

[70] Bellmann & Khare, *supra* note 63, at 689.

[71] Heather L. Drayton, *Economics of Electronic Waste Disposal Regulations*, 36 HOFSTRA L. REV. 149, 156 (2007).

[72] *Id.*

[73] *See* Xue Wang, et al., *Economic and Environmental Characterization of an Evolving Li-ion Battery Waste Stream*, 135 J. ENVTL. MGMT. 126, 127 (2014).

[74] *Id.*; *see also* Bellmann & Khare, *supra* note 63, at 681 (demonstrating how the cost of recycling serves as a major impediment to the emergence of recycling industries).

[75] Jack Jeswiet & Michael Hauschild, *EcoDesign and Future Environmental Impacts*, 26 MATERIALS & DESIGN 629, 629 (2005).

[76] *See id.* at 632.

[77] *See id.*

[78] Drayton, *supra* note 71, at 157.

IV. THE BATTERY RECYCLING PROCESS CAN BE BOTH PROFITABLE AND ENVIRONMENTALLY CONSCIOUS

The efforts made by Tesla Motors in conjunction with Umicore's battery recycling plant provide a noteworthy example of a partnership dedicated to developing a battery recycling process that is both profitable and environmentally sound. An examination of the recycling process will demonstrate the methods that Umicore developed and what pressures encouraged Umicore to create an environmentally innovative recycling system. Additionally, a discussion of the End-of Life Vehicles Directive ("ELV Directive") shows how the European Union's EPR legislation encourages effective recycling, reuse, and recovery of vehicles, including their components and materials, at their end of life.[79]

A. Tesla Motors and Umicore's Closed-Loop Battery Recycling System

Umicore—a global materials technology and recycling group based in Europe—developed a recycling process for the new generation of rechargeable batteries and is currently a leader in this sector.[80] In 2011, Umicore built an industrial scale recycling facility for spent vehicle batteries in Belgium to increase capacity and to further improve the recycling process.[81] The venture enables Umicore to prepare for the expected growth in end-of-life Li-ion, lithium-polymer and NiMH rechargeable battery availability.[82]

Recently, Tesla Motors ("Tesla") has been working with Umicore to develop a closed loop recycling system that is both profitable and environmentally friendly.[83] The Umicore battery recycling process creates "products" and "byproducts," rather than following a mechanical separation process.[84] The "product" created by this process is a material comprised of metals and nonmetals.[85] The factory uses the cobalt from the batteries (the highest value material in most batteries) to make up a material called "LCO" (lithium cobalt oxide), which can then be resold to battery manufacturers.[86] Umicore,

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[79] Council Directive 2000/53, 2000 O.J. (L 269) 34 (EC) [hereinafter ELV Directive].

[80] UMICORE BATTERY RECYCLING, http://www.batteryrecycling.umicore.com/UBR/ (last visited Feb. 18, 2015).

[81] *Id.*

[82] *Id.*

[83] Kurt Kelty, *Tesla's Closed Loop Battery Recycling Program*, TESLA BLOG (Jan. 26, 2011), http://www.teslamotors.com/blog/teslas-closed-loop-battery-recycling-program.

[84] *Id.*

[85] *Id.*

[86] *Id.*

being one of the largest suppliers of LCO to battery manufacturers, provides Tesla with a high margin of return from the recycled material, and simultaneously releases less CO2 emissions compared to other recycling processes.[87]

The "byproduct" from this process is an environment-friendly slag where the lithium from EV batteries ends up.[88] This "byproduct" containing lithium is used for a variety of different applications, one being construction material, such as cement.[89] By replacing raw materials with secondary raw materials, i.e., the "byproduct," and avoiding thermal processing, this process significantly reduces the CO2 emissions and non-renewable resource consumption produced by typical cement manufacturing.[90] By using the "byproduct" that Umicore creates when recycling Li-ion batteries, the construction industry is able to use this secondary raw material as a more environmentally conscious alternative.[91]

Additionally, in an effort to reuse every possible part of the recycling process, the Umicore facility sells the electricity created from an on-site natural gas generation plant to a copper mine next door, which uses the heat in its smelters.[92] The Umicore battery recycling process is able to save at least seventy percent on CO2 emissions at the recovery and refining stages of valuable materials.[93] Tesla acknowledges that working with Umicore has allowed their company to completely recycle Tesla's Roadster battery packs profitably, without the necessity of any special financial incentives to promote recycling.[94] Tesla also claims that the type of battery chemistry used in the Roadster is a significant factor to the battery's conduciveness to be recycled efficiently "[a]s opposed to the lithium manganese or lithium iron phosphate chemistries used in [EVs] just hitting the road now[.]"[95]

There is a major difference in progress between the United States and Europe with respect to advanced battery recycling. A possible explanation for this disparity in progress is the existing body of law promulgated by the European Union that promotes efficient recycling processes. For instance, the Batteries Directive 2006/66/EC lists detailed rules on calculating recycling efficiencies of the recycling processes of waste batteries and accumulators.[96] The Directive sets out minimum recycling efficiencies by

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87. *Id.*
88. *Id.*
89. *Id.*
90. *Id.*
91. *Id.*
92. *Id.*
93. *Id.*
94. *Id.*
95. *Id.*
96. Council Directive 06/66, art. 2, 15, 2006 O.J. (L 266) 26, 9 (EC) [hereinafter Batteries Directive].

developing a standard method for calculation of the efficiency of the battery recycling process.[97] Umicore, as well as other recycling plants throughout Europe, must comply with the Directive's efficiency guidelines by developing recycling processes that meet the minimum recycling efficiency levels.[98]

B. Producer Responsibility and the European Union's Approach to Environmental Regulations

As mentioned previously, the battery chemistry in some vehicles are more suitable and conducive for recycling as compared to others.[99] Since manufactures and companies do not follow products after they are sold, it is not surprising that little consideration of the product's impact at its end-life goes into the product's design.[100] In theory, an efficient recycling market would provide incentives in order to encourage manufacturers to think about products at their end-life because the higher value would convert into a higher selling price.[101] However, for durable goods that last for years, such as computers, electric appliances, and vehicles, and for consumers who will not take into consideration the value of the discarded product, the manufacturer will not be able to charge much more for these products, even if they will have great value at the end of their lives.[102] As a solution to this problem, forcing the manufacturer to be responsible for reuse, recycling, or disposal of a discarded product will create a direct incentive to think about the end of the product's life during disposal.[103]

Product stewardship ("PS") and extended producer responsibility ("EPR") are policy approaches applied around the world with the purpose of requiring or encouraging manufacturers to reduce the negative environmental and societal impacts of their products throughout the products' life cycle.[104] According to the OECD definition, extended producer responsibility is "an environmental policy approach in which a producer's responsibility

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[97] *Id.* at Annex III.

[98] *Id.* at arts. 12, 19, 26, Annex III.

[99] Gaines, *Lithium-Ion Battery Issues*, *supra* note 5.

[100] Bellmann & Khare, *supra* note 63, at 689.

[101] *Id.*

[102] *Id.*

[103] *Id.*

[104] *See* Jennifer Nash & Christopher Bosso, *Extended Producer Responsibility in the United States: Full Speed Ahead?* (Harvard Kennedy Sch. Mossavar-Rahmani Ctr. for Bus. & Gov't Assoc. Working Paper Series, Paper No. 10, 2013), http://www.hks. harvard.edu/ content/download/70790/1255970/version/1/file/RPP_2013_04_Nash_Bosso.pdf.

for a product is extended to the post-consumer stage of a product's life cycle."[105] The key function of EPR allocates long-term environmental responsibility to manufacturers for their products in an attempt to internalize costs and transform the so-called "cradle-to-grave" production and distribution chain into a "cradle-to-cradle" system that encourages recycling and reuse through improved product design.[106]

In practice, EPR is commonly implemented through product take-back legislation.[107] Essentially, this type of legislation compels manufacturers to take back their products after consumer use or to make arrangements, including paying a fee, with an organization that will collect and recycle the products.[108] Product take-back legislation enables the achievement of a central EPR objective—to improve product design by making producers responsible for long-term environmental management of their products.[109] The underlying notion behind EPR, and particularly product take-back laws, is that manufacturers *should* be forced to internalize the disposal costs and the environmental externalities associated with their products.[110]

States throughout the United States have implemented EPR schemes for various environmental regulations, however, federal lawmakers have not embraced EPR policies at the national level.[111] By contrast, the EU has enacted a robust amount of product-oriented legislation based on the principle of EPR.[112] In 2000, the EU enacted the End-of-Life Vehicles Directive ("ELV Directive") to encourage recycling, reuse, and recovery of vehicles, including their components and materials, at their end of life.[113] The primary goals of the ELV Directive are to make vehicle dismantling and recycling more environmentally friendly, to set clear quantified targets for reuse, recycling and recovery of vehicles and their components, and to encourage producers to manufacture new vehicles with a view towards recyclability.[114] The ELV Directive required automakers to reuse or recycle eighty-five percent of the vehicle's weight by 2006, a target that increases to ninety-five percent by 2015.

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[105] THE ORG. FOR ECON. CO-OPERATION AND DEV. (OECD), EXTENDED PRODUCER RESPONSIBILITY: A GUIDANCE MANUAL FOR GOVERNMENTS 9 (2001).

[106] Noah Sachs, *Planning the Funeral at the Birth: Extended Producer Responsibility in the European Union and the United States*, 30 HARV. ENVTL. L. REV. 51, 52–53 (2006).

[107] *Id.* at 53.

[108] *Id.*

[109] *Id.*

[110] *Id.*

[111] *Id.*

[112] *Id.*

[113] *See generally* ELV Directive, *supra* note 79.

[114] Directorate General for Internal Policies on End of Life Vehicles: Legal Aspects, National Practices and Recommendations for Future Successful Approach, at 8 (Oct. 2010), http://ec.europa.eu/environment/waste/pdf/study/elv.pdf.

Under the ELV Directive, manufacturers play a critical role in the responsibility of end-of-life vehicle management and must meet specific requirements set forth in the ELV Directive. These provisions require manufacturers to: (1) limit the use of hazardous substances in vehicles and to integrate an increasing quantity of recycled material in vehicles and other products, (2) set up systems for the collection of all end-of-life vehicles, (3) use component and material coding standards, to provide dismantling information for each type of new vehicle put on the market, and make available appropriate information concerning dismantling, storage and testing of components which can be reused, and (4) make information accessible to the prospective buyers of vehicles, including information on the design of the vehicles/components, environmentally sound treatment of vehicles or the progress achieved with regard to recovery and recycling.[115]

The success of the ELV Directive on end-of-life vehicle management is tentative, and evidence suggests that there is still room for improvement in the recycling and recovery of ELV materials.[116] A European Parliament policy report evaluating the progress of end-of-life vehicle management in Europe shows that considerable amounts of ELV materials are still disposed of, and that not all Member States have achieved the recycling and recovery targets.[117] Moreover, the study assessed evidence suggesting that the reported recycling and recovery rates are overestimated.[118] One explanation for this is that the classification of technically identical treatment operations as “recycling”, “recovery”, or “disposal” differs between Member States due to different national interpretations.[119] To remedy this problem, the report suggests that the European Commission establish binding rules for the classification of treatment operations for recycling, recovery, and disposal, and for data gathering and calculation methodology.[120] While the long-term success of the ELV Directive is uncertain, Europe’s EPR legislation serves as an ambitious example of supportive policy initiatives to combat material scarcity.

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[115] *Id.* at 67.
[116] *Id.* at 12.
[117] *Id.* at 14.
[118] *Id.*
[119] *Id.* at 59.
[120] *Id.* at 14.

V. SUPPORTIVE REGULATIONS CAN MAKE A PROFITABLE AND ENVIRONMENTALLY-FRIENDLY RECYCLING PROCESS ACHIEVABLE

Some progressive politicians have advocated for early efforts to improve recycling technology in the United States. In June 2011, Congress considered H.R. 2284, proposing the Responsible Electronics Recycling Act.[121] H.R. 2284 would have required 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.[122] This bill was introduced but not subsequently enacted.[123]

In 2009, the U.S. Department of Energy ("DOE") granted $9.5 million to Retriev Technologies (formerly Toxco), a company in California that recycles lead-acid and nickel-metal hydride batteries, to build the first U.S. recycling facility for lithium-ion vehicle batteries.[124] However, this seems like pocket change compared to the DOE's $2.4 billion award to companies developing batteries and systems for electric vehicles.[125] The significant discrepancy between these grants demonstrates how the United States government prioritizes the mass production of green vehicles over the recovery of important battery materials at their end-life.

The demand for battery recycling will inevitably increase as more green vehicles hit the road. The United States automotive industry faced this same situation only two decades ago when lead-acid batteries used in gasoline-powered vehicles phased out. In 1996, Congress passed the Mercury-Containing and Rechargeable Battery Act ("MCRBMA") to make it easier for rechargeable battery and product manufacturers to collect and recycle Ni-CD (nickel-cadmium) batteries and certain small sealed lead-acid batteries.[126] For these regulated batteries, the MCRBMA requires the following: (1) batteries must be easily removable from consumer products, to make it easier to recover them for recycling; (2) battery labels must include the battery chemistry, and a phrase indicating that the user must recycle or dispose of the battery properly; (3) national uniformity in collection, storage, and transport of certain batteries; and (4) the phasing out of certain mercury-containing batteries.[127]

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[121] Responsible Electronics Recycling Act, H.R. 2284, 112th Cong. (2011).

[122] *Id.* § 4.

[123] *Id.*

[124] Tyler Hamilton, *Lithium Battery Recycling Gets a Boost*, MASS. TECH. REV., Aug. 12, 2009, http://www.technologyreview.com/energy/23215/.

[125] *Id.*

[126] Mercury-Containing Battery Management Act (MCRBMA), 42 U.S.C. § 14321 (1996).

[127] *Id.* § 14322.

As a result of this legislation, recycling of lead-acid batteries is one of the most successful recycling efforts of any industry.[128] According to the U.S. Environmental Protection Agency ("EPA"), ninety-six percent of all lead-acid automotive batteries are recycled.[129] MCRBMA allows the recycling process to be profitable and simple by regulating the automotive battery design.[130] Interestingly, the primary concern that led to the enactment of the MCRBMA was the improper disposal of hazardous materials from battery waste; not the need to recycle rare earth materials.[131] In fact, existing environmental regulations, such as the Resource Conservation and Recovery Act, generally focus only on regulating the disposal of materials that are deemed hazardous to the environment, and are not designed to encompass other environmental issues, such as material scarcity.[132] Therefore, because lithium is not considered a hazardous material, regulation of its disposal is not as crucial as the regulation of a toxic material, such as lead. However, a material's hazardous characteristics should not be the only criteria considered for the regulation of its disposal.

Lithium is a limited natural resource that is completely recyclable, and allowing the material to be dumped in a landfill or incinerated is inefficient and wasteful. Since recycling Li-ion batteries has little economic value, the neglect of the federal government to regulate the disposal of non-hazardous materials encourages wasteful practices by manufactures. The impending green vehicle boom requires responsible management of lithium: efforts to improve lithium recycling processes and to establish a recycling infrastructure must be made in conjunction with the adoption of green vehicles in order to prevent a global lithium shortage.[133]

There are many ways that government policy can encourage the recycling of Li-ion batteries. First, regulating battery design is key to developing a standardized recycling industry. Manufacturers should be forced to incorporate environmental costs in their battery design. Second, information on battery chemistries should be made available in order to promote the correct and environmentally sound treatment of end-or-life batteries. Third, partnerships between battery manufacturers and recycling plants—similar to the Tesla-

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[128] Gaines, *The Future of Automotive Lithium-ion Battery Recycling*, *supra* note 62, at 2.

[129] *Batteries*, U.S. ENVTL. PROT. AGENCY [hereinafter EPA], http://www.epa.gov/wastes/conserve/materials/battery.htm (last updated Feb. 18, 2015).

[130] Gaines, *The Future of Automotive Lithium-ion Battery Recycling*, *supra* note 62, at 4.

[131] MCRBMA, *supra* note 126.

[132] *See* Resource Conservation and Recovery Act, 42 U.S.C. § 6901 [hereinafter RCRA] (governing primarily matters related to hazardous waste).

[133] *See* Hamilton, *supra* note 124.

Umicore relationship—should be encouraged by setting up systems for the collection of all end-of-life vehicle batteries. Fourth, additional federal funding must be provided for research and development on recycling vehicle batteries with the goal of recycling and repurposing valuable materials.

A. Battery Design

The design phase of a product is the stage that has the most impact on the product's functionality and environmental impact.[134] Because battery manufacturers use various chemistries, and the several chemical components have different recycling values, the advanced lithium batteries in most electric and plug-in vehicles today are difficult to recycle.[135] Regulating battery design is essential for a successful battery recycling industry, and creating financial incentives may be the best tactic to standardize battery design. Although steps have been taken by the government and private industries to improve Li-ion battery recycling technology, continued efforts to develop lithium-recycling processes and establish a recycling infrastructure should focus on improving Li-ion battery design.

Employing a federal tax on the use of virgin materials in vehicle batteries would motivate manufacturers to use recycled materials, which would in turn stimulate the need for a recycling market in order to supply manufacturers with low cost, recycled materials.[136] Likewise, manufacturers should receive subsidies when they use recycled materials in their vehicle batteries.[137] These taxes and subsidies may differentiate among virgin materials that are more or less likely to be recycled and reused. For instance, because lithium is less valuable to recover than materials such as nickel or cobalt, and therefore less likely to be recycled, larger subsidies will provide a greater incentive for manufacturers to develop efficient recovery processes for lithium. These taxes can reduce environmental harm by conserving limited resources and decreasing the emissions released when raw materials are extracted and processed.

Additionally, these vehicle battery packs are complex and have many materials that vary from one battery to another. Because the technology is still changing, it is important not to impede the battery-powered vehicle industry by imposing strict restrictions on battery design. Rather, manufacturers should pay fees based on whether their batteries can be easily disassembled for recycling purposes. This type of regulation imposes EPR goals by forcing manufacturers to consider aspects of the battery's

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[134] Jeswiet, *supra* note 75.

[135] Gaines, *The Future of Automotive Lithium-ion Battery Recycling*, *supra* note 62.

[136] Brett Godush, Note, *The Hidden Value of a Dime: How a Federal Bottle Bill Can Benefit the Country*, 25 VT. L. REV. 855, 874–75 (2001).

[137] *Id.* at 136.

end-life at the initial design stage. Like the MCRBMA and the ELV Directive, it is advantageous to apply EPR principles in order to ensure that manufacturers will design batteries that are conducive to effective recycling. Regulating battery design is a critical step in developing a profitable and environmentally conscious recycling industry.

B. Dismantling Information

The first step in the recycling process involves the dismantling of the battery system.[138] Due to their high-energy content, weight, and complex assembly, advanced vehicle batteries require comprehensive treatment so that they can be recycled in the most economical and environmental efficient way.[139] Furthermore, the wide range of battery designs makes manual dismantling the only available method at the moment.[140] With little information available on the ease of dismantling specific battery systems, many advanced vehicle batteries are extremely difficult to dismantle.[141] As a result, rare earth elements, including lithium, are lost in current recycling processes due to improper dismantling.[142]

An important provision of both the MCRBMA and the ELV Directive is the requirement of manufacturers to provide dismantling information to treatment facilities. One of the impediments to efficient recycling of EV, HEV, and PHEV batteries is technology confidentiality. Regulations should be enacted that mandate disclosure of all information required for the appropriate and environmentally sound treatment of end-of-life vehicle batteries. Manufacturers should be responsible for product labeling, such as chemistry or material lists, to enable sorting methods during the recycling process. Various labeling techniques might include the use of bar codes or RFID chips for automatic identification.[143]

Furthermore, information should be accessible to prospective buyers, including information on the environmentally sound treatment of vehicle batteries or the progress achieved with regard to recovery and recycling. Because EVs appeal to a large population of consumers who value the

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[138] Tobias Elwert, et al., *Current Developments and Challenges in the Recycling of Key Components of (Hybrid) Electric Vehicles*, 1 RECYCLING 25, 37–41 (2015).

[139] *Id.*

[140] *Id.* at 39; *see also* Gaines, *The Future of Automotive Lithium-ion Battery Recycling*, *supra* note 62, at 4.

[141] Elwert, *supra* note 138, at 39.

[142] *Id.*

[143] Gaines, *The Future of Automotive Lithium-ion Battery Recycling*, *supra* note 62, at 7.

environmental benefits from purchasing green vehicles, this information transparency will allow prospective buyers to feel confident in their investment by making an informed decision. In turn, by mandating the disclosure of this information, such as the progress achieved with recycling EV batteries, companies will be incentivized to develop methods that enhance material recycling and recovery in order to stay competitive.

C. Partnerships

Business and its activities are inextricable parts of both the problem and the solution to efficient advanced vehicle battery recycling.[144] Due to this, collaborative partnerships between public and private entities may be a paramount strategy for effective advanced vehicle battery recycling.[145] Innovative business models like the Tesla-Umicore partnership create arrangements that are as good for the company as they are for the community, and show how a recycling system can be both profitable and environmentally sound.[146] The Tesla-Umicore partnership is likely a product of the existing European laws requiring recycling plants to develop processes that meet the minimum recycling efficiency levels set out by the Batteries Directive.[147]

Both government and private sector leaders can encourage greater private sector participation in partnerships for advanced vehicle battery recycling.[148] Government can take a proactive role to engage private sector leaders and business organizations in the decision-making process to generate better policy dialogue and planning.[149] Similarly, private sector involvement in Li-ion battery recycling can be increased through better access to funding, possible tax incentives, as well as awards and public recognition.[150] Tax credits can be designed so as to reward innovation rather than just promote adoption of existing technologies.[151] Additionally, regulations that facilitate the setup of collection systems for all end-of-life batteries might serve as a platform to generate private investment and initiate partnerships; these regulations

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[144] *See generally* Alyson Warhurst, *Future Roles of Business in Society: The Expanding Boundaries of Corporate Responsibility and a Compelling Case for Partnership*, 37 FUTURES 151, 155 (2005) (discussing the roles and responsibilities of business in society to provide solutions to humanitarian crises and endemic problems facing the world).

[145] *See id.*

[146] *See id.*

[147] Batteries Directive, *supra* note 96, art. XII(2)(4).

[148] *See generally* JANE NELSON & DAVE PRESCOTT, WORLD ECONOMIC FORUM, PARTNERING FOR SUCCESS 41 (2005) [hereinafter WORLD ECONOMIC FORUM], *available at* http://www.hks.harvard.edu/m-rcbg/CSRI/publications/report_4_FINAL_GCCI_PPP-Report_200105.pdf (recommending a list of actions that government and the private sector itself could take to encourage private sector participation in partnerships for development).

[149] *See id.*

[150] *See id.*

[151] *See id.*

should ensure the development of specific recycling processes that incorporate environmentally sound techniques.

D. Additional R&D

Federally funded research and development ("R&D") is one of several means through which government policy has impacted the proliferation of green vehicles. The DOE has announced fifty-five million dollars in new funding for thirty-one projects to accelerate R&D of vehicle technologies to improve fuel efficiency and reduce costs.[152] The projects are aimed at meeting the goals of the EV Everywhere Grand Challenge, which seeks to make the US auto industry the first to produce EVs that are as affordable and convenient as today's gas vehicles by 2022.[153] As of recent, the bulk of R&D funding for EVs has been directed to the construction of the EV infrastructure with a primary goal of making EVs more affordable. With additional funding, the federal government should focus on developing an efficient recycling process for EV batteries with the goal of recycling and repurposing valuable materials.

Current projects under R&D for recycling lithium-ion batteries have delivered promising results.[154] However, a high degree of uncertainty associated with lithium-ion batteries at their end-life still remains due to a lack of experience with their remanufacturing, repurposing, and recycling.[155] Furthermore, the majority of the projects under R&D are solely based on lab-scale data rather than an industry-scale study.[156] As significant changes to batteries can be expected in the upcoming years, more R&D must be conducted[157] and additional studies to obtain in-depth information about optimization potentials of different recycling processes are needed.[158]

Additional R&D carries with it the duty to effectively disseminate project data and findings to the public. Public knowledge and increased awareness

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[152] *See Energy Department Invests More Than $55 Million to Advance Efficient Vehicle Technologies*, ENERGY.GOV (AUG. 14, 2014), http://energy.gov/articles/energy-department-invests-more-55-million-advance-efficient-vehicle-technologies.

[153] *See id.*

[154] *See, e.g.*, Elwert, *supra* note 138, at 42 (describing different recycling processes conducted by Umicore and LithoRec).

[155] Charles R. Standridge & Mehedi Hasan, *Post-Vehicle-Application Lithium-Ion Battery Remanufacturing, Repurposing and Recycling Capacity: Model and Analysis*, 8 J. INDUS. ENG'G & MGMT. 823, 824 (2015).

[156] *See* Elwert, *supra* note 138, at 42.

[157] *See id.* at 52.

[158] *See id.*

of the socio-ecological footprint of the lithium life cycle in advanced vehicle batteries can influence responsible materials management practices.[159] Dissemination of study findings will also inform the market of the potential for profit in recycling advanced vehicle batteries. Describing and publicizing projects under R&D will generate concern for recycling lithium-ion batteries and inspire innovative thinking among consumers, industries and public authorities.

VI. CONCLUSION

The proliferation of green vehicles across the globe will continue to increase, and in turn, the continued use of lithium for advanced vehicle batteries will transform this valuable material into a limited resource in the near future. In order to fully maximize the potential environmental benefits of green vehicles, there must be increased attention that focuses particularly on second-life battery use and recycling. Furthermore, the environmental and potential health impacts from lithium extraction experienced by surrounding communities need to be taken into consideration regarding resource protection and opportunities from lithium recycling. Unless the United States provides supportive regulations for the collection and recycling of advanced vehicle batteries, the existing wasteful practices will continue, and thus further contribute to extensive negative environmental and social impacts.

Supportive regulations that focus on recycling Li-ion batteries will alleviate material scarcity, lower costs of the materials, and avoid production impacts, including the reduction of energy use, emissions, and mining impacts. Governmental controls and market-based incentives are both equally essential in persuading manufacturers to design batteries that can be easily disassembled and recycled. The MCRBMA and the ELV Directive serve as models for effective regulations to promote advanced battery recycling by forcing manufacturers to take responsibility of their batteries end-life.

Solid investment in the collection and recycling infrastructure and technology for new generation vehicle batteries, along with effective regulation, will promote higher collection and recycling rates for Li-ion batteries. Building on the experience and results from EPR programs in place, it is possible to refine existing programs or create new ones that will help to prevent wasteful disposal of lithium by motivating design changes and enhancing producer responsibility throughout the products' life cycles.

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[159] *See* Pia Lindahl et al., *Strategic Sustainability Considerations in Materials Management*, 64 J. CLEANER PROD. 98, 102 (2014).