Batteries
and the
Circular Economy

Presentation to ELI-ABA Conference

The Circular Economy:

Regulatory and Commercial Law Implications

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Circular Economy

"A Circular Economy is an economy which balances economic development with environmental and resources protection. It puts emphasis on the most efficient use and recycling of resources, and environmental protection. A Circular Economy features low consumption of energy, low emission of pollutants and high efficiency."

United Nations Environmental Program - 2006

Five major technological innovations are serving the growing worldwide population and rising middle class.

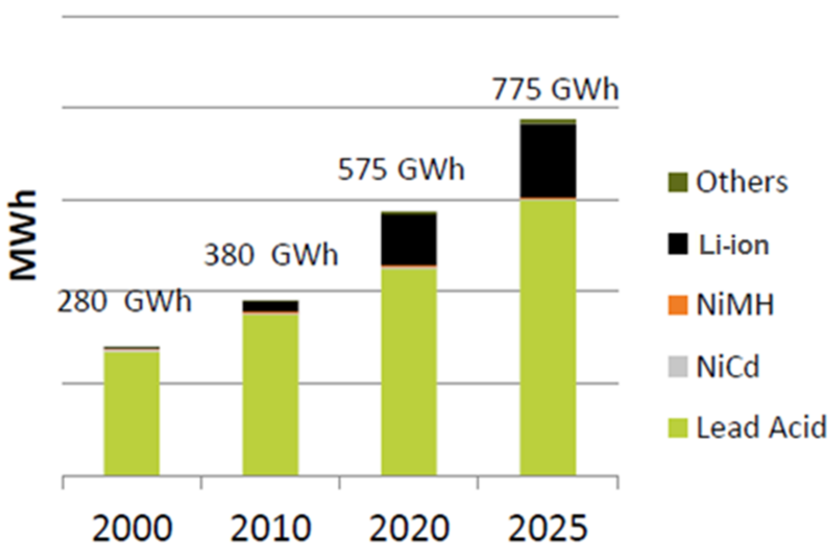
Internet | **Internet of things** | **Advanced materials** | **Renewables** | **Energy storage**

Each is important. All are interlinked.

Let's focus on rechargeable batteries as *enablers.*

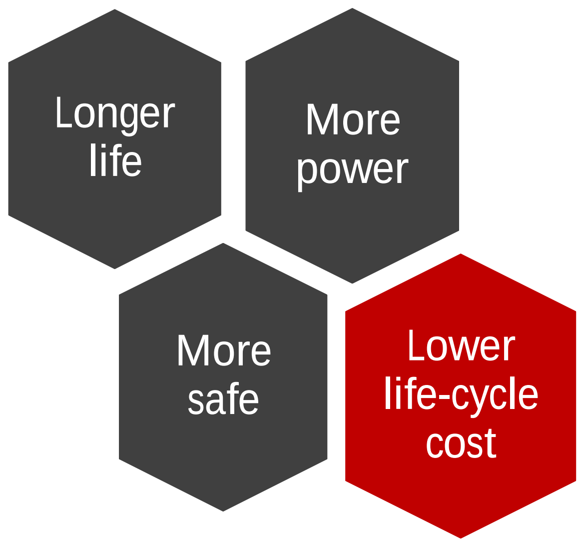
Rechargeable batteries are needed more than ever for the growing worldwide population.

Worldwide Rechargeable Battery Sales
Estimated Projection



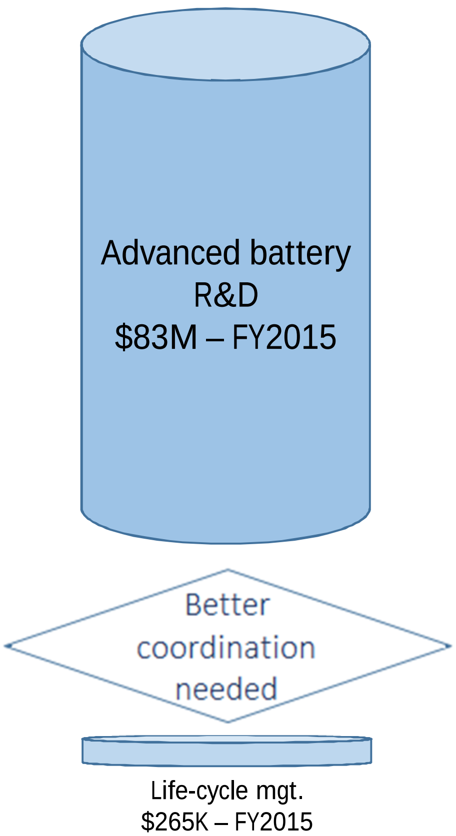
Source: Avicenne

Batteries face several challenges



Each challenge is important, but life-cycle cost has been receiving inconsistent attention by government and industry.

U.S. government battery R&D programs are *not* as coordinated as they should be…



Goal – Advanced batteries must have a "closed-loop" life cycle.

- End-of-life management must be rolled into the retail price of batteries.
- The closed-loop process should be profitable without government subsidies.

Objective – Make advanced battery R&D supportive of the circular economy.

- Life-cycle management must be included in battery design.

Strategy – Public-Private Partnership must consider entire closed-loop process.

- Lessons learned from batteries with established life-cycle management should be shared with other chemistries.

Why recycling?

- ✓Reduces life-cycle costs by saving energy and cutting pollution
- ✓Reduces the need for mining
- ✓Protects natural resources
- ✓Reduces the need for landfills
- ✓Facilitates efficient use of critical materials
- ✓Reduces legal risk for producers/customers
- ✓Reduces material imports
- ✓Generates income

Recyclers take feedstock from “mines” like this…

…and produce materials for new batteries.

The economics of a battery recycling model in a circular economic structure:

- The closed loop:
  - Batteries are produced, sold, used and collected at their end-of-life.
  - Recyclers separate and reprocess materials (metal, acids, containers, etc.).
  - Separated materials are recycled and sold to battery producers.
  - Prices charged for recycled materials produced in this closed loop are competitive with primary (or “virgin”) materials.
  - The cost of recycling is rolled into the retail battery price.
- How recyclers make profits:
  - Recyclers make a profit when the price of the finished product sold to battery producers is higher than the price recyclers pay for batteries at their end-of-life (scrap).
  - Sufficient production volume generates revenue to support the enterprise.

Can batteries meet the circular challenge? Does a model already exist?

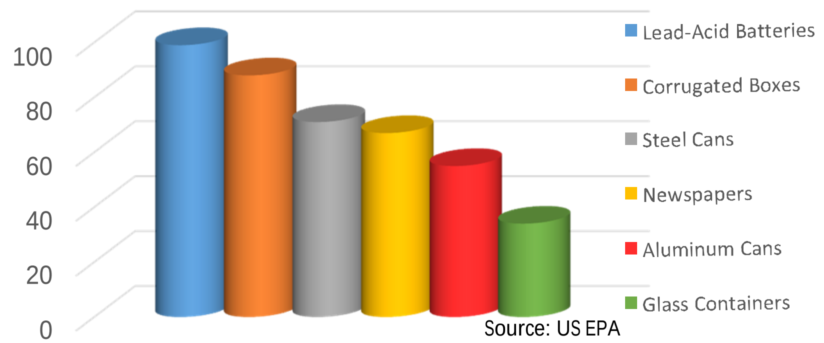
With one important exception, most rechargeable batteries are not recycled profitably because the prices that manufacturers pay for virgin materials is lower than the price of recycled materials.

The exception is lead-acid batteries, which are 99% recycled because the price of recycled materials is competitive with virgin materials.

No other battery chemistry is yet able to equal lead-acid's closed loop recycling process and profitability.

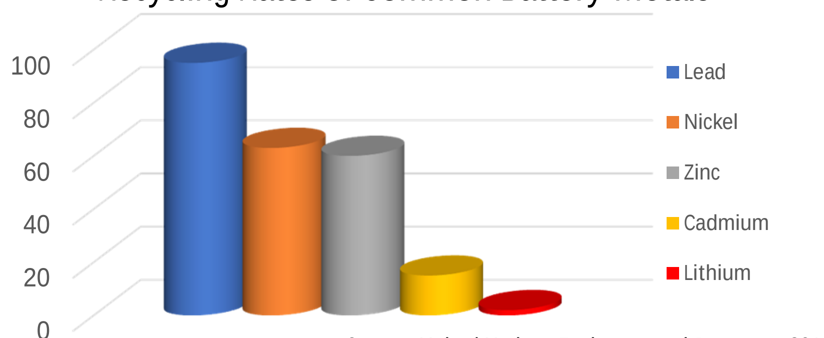
Lead-acid's circular business structure is a model for other battery chemistries.

Recycling Rates of Major Consumer Goods



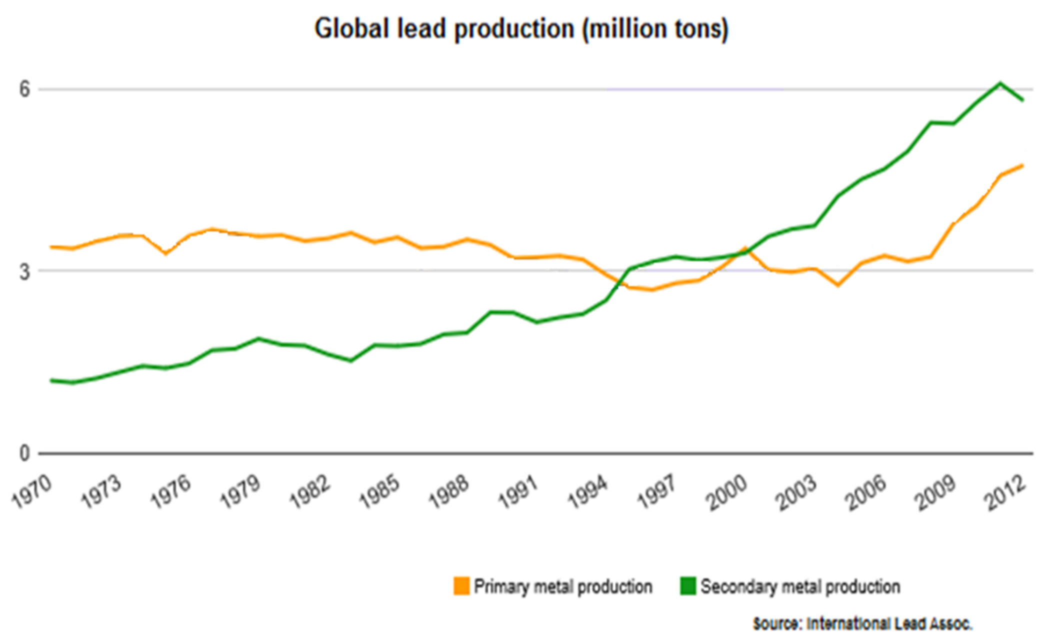
Source: US EPA

Recycling Rates of Common Battery Metals



Source: United Nations Environmental Program - 2011

What recycling has meant in the lead industry.

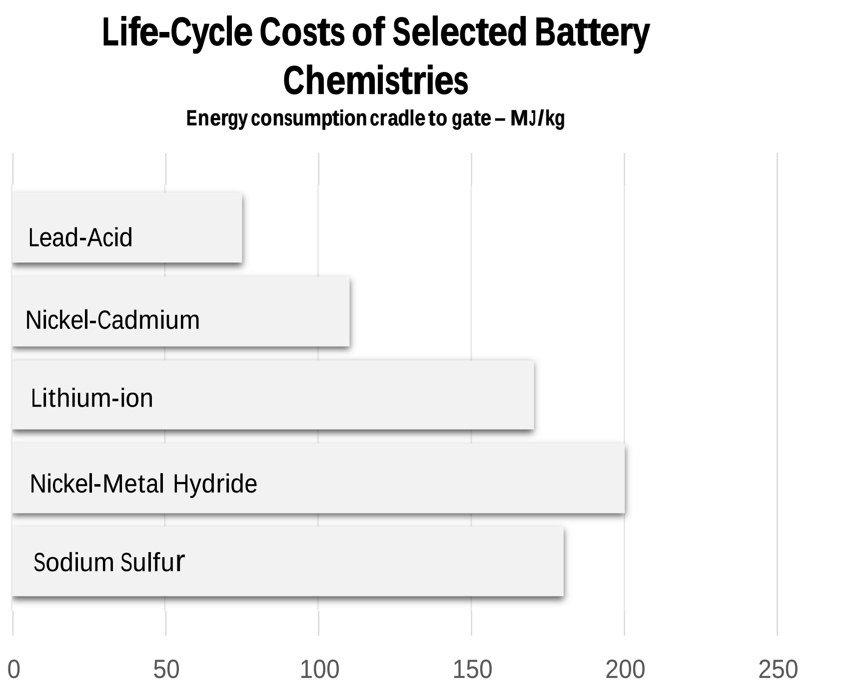


For nearly 50 years, technological improvements have allowed dramatic growth in the lead secondary (recycling) industry's production to keep pace with the production of lead from primary (virgin) resources.

Some lead production from primary resources remains necessary to meet rising overall demand.

Recycling creates a second source of supply that helps stabilize the commodity price of lead.

The life-cycle cost of rechargeable batteries is far more important than one might think.



Source: Argonne National Laboratory

Why is a lead-acid battery's life-cycle cost so low?

- One of the key reasons is recycling!
- Less energy is required to produce recycled lead than "virgin" lead.
- Less SO_2/CO_2 is emitted.

Other chemistries need to incorporate full life-cycle "externalities" management into their manufacturing processes and ultimate product cost.

A tale of three major rechargeable battery chemistries.

Lead-acid	Lithium-ion	Nickel Metal Hydride
Lead-acid batteries are based on a design that has stood the test of time for more than 150 years. Lead plates and sulfuric acid are the battery's primary elements. Despite its relatively low energy-to-weight ratio, lead conveys high surge currents in a stable, cost-effective manner. The thickness of lead plates can be adjusted for high or low surge requirements. The quality and price of recycled lead are competitive with "virgin" lead.	Lithium-ion (Li-ion) batteries are far more complex than lead-acid batteries. Li-ion batteries are made from metal oxides and/or phosphates with combinations of manganese, cobalt, nickel, iron, titanium, etc. Carbon based materials are for anodes or electrolyte. While these elements are relatively inexpensive, it is the engineering required to design the batteries that accounts for their high cost. Cost-effective recycling has not been factored into Li-ion design.	Nickel Metal Hydride (NiMH) batteries are comprised mostly of nickel. However, the use of lanthanides (rare earths) and other "specialty" elements adds complexity to the design. The reprocessing of these elements back into commercially usable metals is very difficult and expensive. Because much of the battery grade quality of nickel is lost in the recovery process, most recovered nickel is used in secondary stainless steel operations.

How major battery chemistries compare on circular end-of-life paradigm.

	Lead-acid	Lithium-ion	Nickel Metal Hydride
Standard chemistry design	Yes	No	Yes
Battery design compatible with recycling	Yes	No	No
Recycled materials used in new batteries	Yes	No	No
Recycling cost rolled into retail battery price	Yes	No	No
Battery end-of-life management rate*	99%	<15%	<60%
Notes:	Most recycled lead is used in new lead-acid batteries.	Some cobalt recycled. Other materials “downcycled,” i.e, road slag.	Most nickel “downcycled” for use in stainless steel production.

*Source: US EPA, USGS

Recycling solutions for lithium-ion and other advanced batteries are emerging…

Pyrometallurgy:

Batteries fed into a smelter and melted to recover metals.

Hydrometallurgy:

Battery elements float or sink in water, with chemicals added to aid separation.

Direct recycling:

Low-temperature, low-emission process in early development stage.

However, these options remain economically challenging. Integrating recycling into battery design will help make them more viable.

Recycling – what it is and what it isn't.

We need to understand what recycling is:

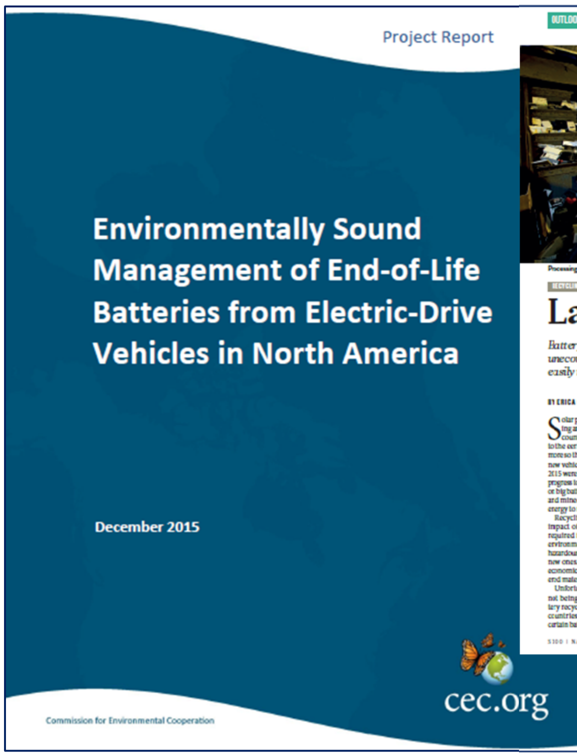
- Recycling is the processing of used materials into reusable materials to reduce consumption of "virgin" materials.
- Recycled materials must be competitive (price and function) with primary "virgin"materials.

We need to understand what recycling is *not*:

- Downcycling, in which materials are reprocessed for use in lower grade functions, i.e. road slag.
- Repurposing, in which products are shifted to less demanding functions.

Downcycling and repurposing are useful components of a circular economy, but they are not synonymous with recycling.

Literature on the need for end-of-life management continues to grow.



OUTLOOK BATTERIES

RECYCLING

Lazarus batteries

Battery recycling can be hard, energy intensive and uneconomic. But soon, dead power cells could be more easily resurrected.

Sustainable Materials and Technologies

The future of automotive lithium-ion battery recycling: Charting a sustainable course

Linda Gaines [1]

ROADMAP FOR THE LIFE-CYCLE OF ADVANCED BATTERY CHEMISTRIES

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Keywords: Circular Economy, Recycling, Batteries

Abstract

Energy storage and recycling are among the most important strategies identified by governments and non-governmental organizations to confront the challenges of developing a more "circular" economy. The need for more efficient batteries to help the energy storage industry meet the changing needs of a growing world population is presenting new opportunities for metals used in making batteries. For the use of these metals to be compatible with the needs of a circular economy, recycling is key to the efficient utilization and conservation of natural resources. Some materials used in the battery industry have been adapted to the needs of a circular economy more successfully than others. Lead is the most recycled of all metals, with a battery recycling rate of 99%. The lessons learned from the utilization of a highly-recycled metal such as lead must be considered a model for the development of batteries made with other metals.

Introduction

Between now and 2050, the world's population is expected to grow from 7.7 billion to 9.5 billion. Population in urban areas will increase from 4.2 billion to 6.3 billion. In addition, the world's middle class will grow from the current 23 per cent to 52 per cent. The demand for energy to serve the expanding agricultural, manufacturing, communications, and transportation needs of this growing population will grow exponentially. This, in turn, will increase demand for natural resources, with consequent risk to air, water and land.

Five major technological innovations are in the forefront of serving this growing need: the internet, the internet-of-things, advanced materials, renewable energy resources, and energy storage.

Energy storage is particularly important not only because of its facilitating role in the internet and renewable energy, but because of its requirement for greater use of natural resources mined from the earth. To minimize the impact of the growing burden on natural resources, recycling is one of the most important life-cycle strategies identified by governments and non-governmental

September, 2015 1

For the circular economy to work, we need a “race to the top,” not a “race to the bottom”.

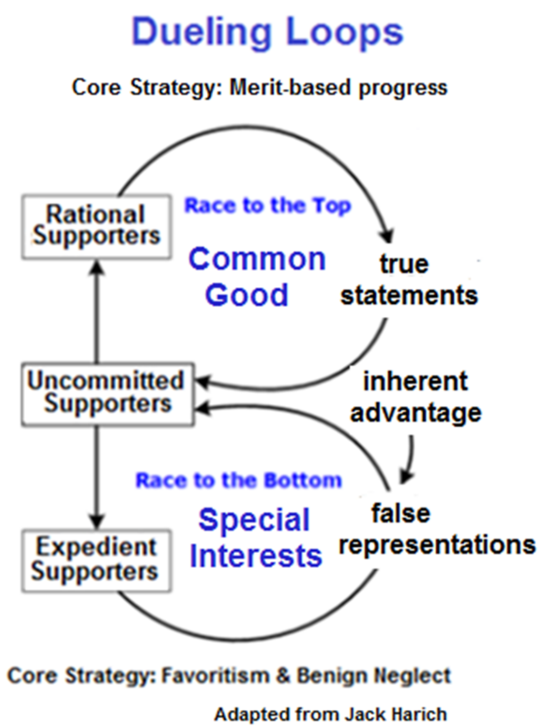
US environmental protection and safety regulations for lead-acid battery recyclers are among the world’s most stringent. This should encourage a “race to the top”. But, many other countries are not keeping pace with U.S. standards. One example is lead ambient air emission standards:

- 0.15 µg/m3 – US EPA standard
- 0.5 µg/m3 – European Union standard
- 1.0 µg/m3 – China standard
- 1.5 µg/m3 – Mexico standard

US battery recyclers pay more to comply with regulations, which undermines their ability to pay for scrap.

Recyclers in poorly regulated countries can pay more for scrap because they have lower regulatory overhead. This encourages some recyclers to “race to the bottom” by taking advantage of inferior regulations in other countries.

This is an important issue not only for batteries, but all electronic waste.



Conclusion…

- For the rechargeable battery industry to succeed in an increasingly circular economy, the life-cycle standards of lead-acid batteries must extend to other battery chemistries.
- These standards, however, must be equitably applied internationally to guard against a “race to the bottom” that emerges when the high standards of one country are undermined by inferior standards of another.
- A public-private partnership among government, industry, consumers and environmentalists is needed to establish sound, life-cycle standards, including “scorecards”, to assure consumers that products meet the highest standards.

About RSR Technologies

- Headquartered in Dallas, Texas, RSR Technologies provides research expertise to the metals industry and is part of Eco-Bat Technologies.
- Eco-Bat is the world's largest producer of lead
    - (840,000 tons/p.a.)
- 29 facilities located in Austria, France, Germany, Italy, South Africa, United Kingdom and United States.
- 13 lead smelters, nine in Europe, three in U.S. and one in South Africa.
- More than 3,500 skilled employees.
- 80% of the lead production is recycled lead.

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