CIRCULAR IMPACTS

Circular economy perspectives for future end-of-life EV batteries

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Introduction

Circular economy and EV batteries:

- Battery-powered EVs is among the key technologies for decarbonising road transport
- Lithium-ion batteries is the most common type of batteries used in these vehicles
- The manufacturing of these batteries requires several materials with significant economic importance

Introduction

- There are various estimates about EV sales and the majority projects a large increase in the coming 10 to 20 years
- Such a large increase will also drive an increase in the demand for lithium-ion batteries
- There is a key question about what will happen to this large number of batteries when they reach their end of life
- This question is particularly important for Europe which is currently lacking a strong batter cell manufacturing base

Introduction

- This study aims to provide evidence about the impacts of managing the large number of lithium-ion batteries for EVs
- There is a focus on the potential benefits for the EU economy
- The analysis is based on the comparison of two different hypothetical scenarios
- Information has been collected through a literature review and interviews with experts from the battery value chain

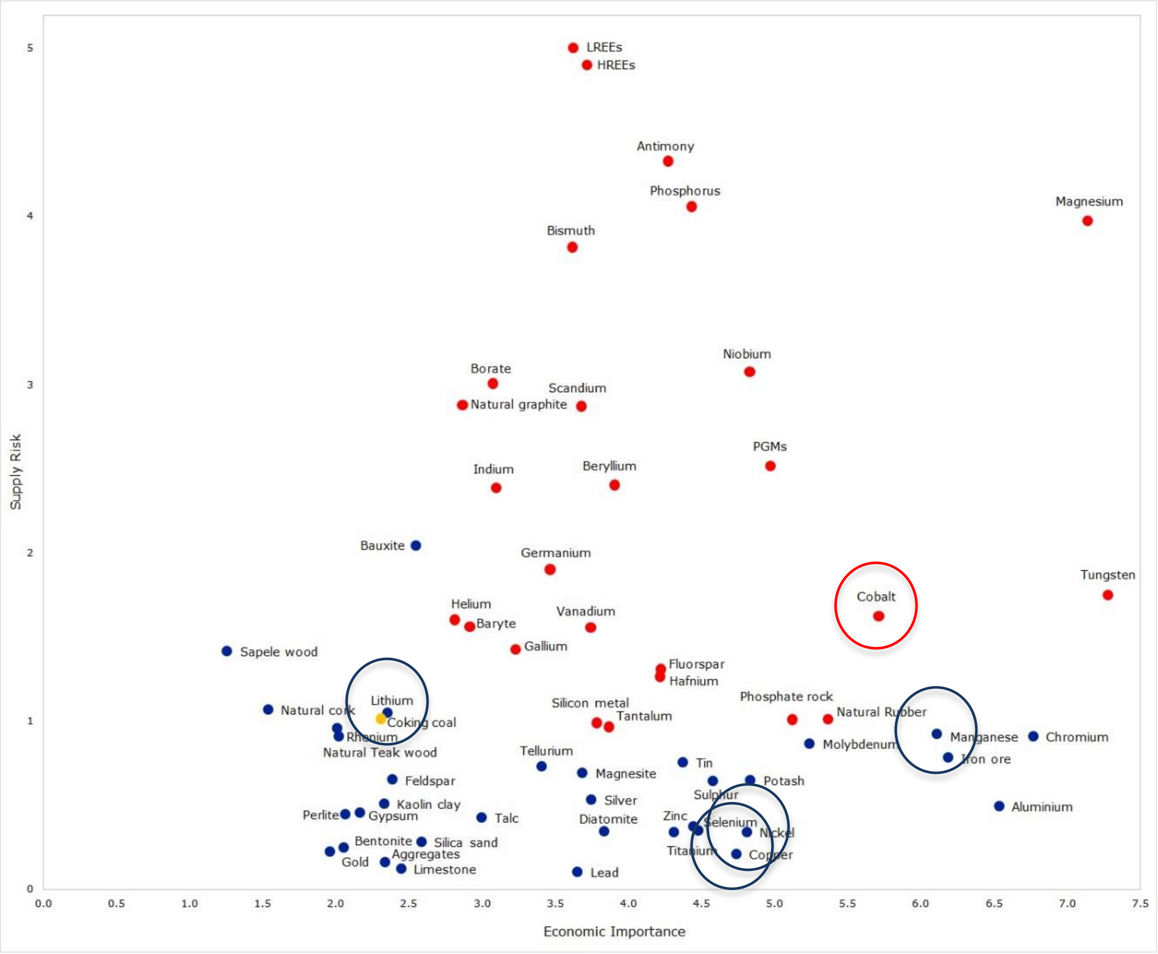
Defining the baseline

Context – critical raw materials

- JRC definition of a CRM is having a high economic importance and is vulnerable to supply disruptions.
- European Commission consider:
  - 27 critical raw materials
  - 61 candidate raw materials
- The materials used in lithium-ion batteries include lithium, cobalt, nickel, copper and manganese

Defining the baseline

Critical raw materials graph



Source: European Commission (2017)

Defining the baseline

Key figures for the demand and price of EV batteries

		Source
Global EV sales in 2016 (actual)	750,000	IEA (2017)
EV sales in Europe 2015 (actual)	145,000	Transport & Environment, (2016)
EVs on the road in Europe 2015 (actual)	250,000	Transport & Environment, (2016)
Global EV sales in 2017 (actual)	1 million	Bloomberg (2017a)
Global EV sales in 2030 (forecast)	24.4 million	Bloomberg (2017a)
EV sales in Europe in 2030 (forecast)	5 million	Bloomberg (2017b)
EV sales in Europe in 2040 (forecast)	10 million	Bloomberg (2017b)
Global lithium-ion battery demand for EVs in 2016 (actual)	21 GWh	Bloomberg (2017b)
Global lithium-ion battery demand for EVs in 2030 (forecast)	1,300 GWh	Bloomberg (2017b)
European lithium-ion battery demand for EVs in 2030 (forecast)	200 GWh	Combined Bloomberg (2017b) with an average battery size of 40kWh
Price of EV batteries in 2015 (actual)	$320-460/kWh	Bloomberg (2017c)
Price of EV batteries in 2030 (forecast)	$50-80/kWh	Berckmans et al. (2017)
Price of EV batteries in 2030 (suggested target)	€75/kWh	European Commission (2016)

Defining the baseline

Automotive lithium-ion battery value chain

	Raw and processed materials	Cell component manufacturing	Cell manufacturing	Battery pack manufacturing	Electric vehicle manufacturing	Recycling
Most Relevant Statistics	51 %	43 %	88 %	40 %	31 %	50 %
	Democratic Republic of Congo's share of global cobalt production [4] - a critical material for Li-ion technology	Cathode revenue as share of cell components market [5]	Asian share of Li-ion cell manufacturing market [6]	Share of pack assembly cost over the total battery pack cost [7]	Automotive share of Li-ion cell market in volume (MWh) [8]	Recycling efficiency for Li-ion batteries set in the Battery Directive [9]
Revenues	EU Mining and quarrying industry revenues: B$ 19 [1] EU Chemical industry Revenues: B$ 28 [1]	Global Li-ion cell components Industry revenues: B$ 7 [5]	Global Li-ion cell manufacturing revenues: B$ 16.7 [5]	Global automotive battery pack manufacturing revenues: B$ 22 [5]	EU Automotive industry Revenues: B$ 900 [10]. 20% of worldwide [11]	EU Waste collection & Recycling Industry Revenues: B$ 150 [10]. 75% of worldwide [12]

Source: JRC, 2017

Defining the baseline

Key materials and impacts

- Cobalt
  - Production 0.124 million tons in 2014 (51% from DRC)
  - Expected to need 128% of the amount of mined cobalt in 2013 for the lithium-ion battery market in 2035.
  - Around 5-10kg is used in an EV battery
  - Price in 2017 $61,000 / tonne (doubled since 2012/2013)

- Lithium
  - Global lithium demand for EV batteries was 300 tonnes in 2013
  - The global lithium demand for EV batteries is expected to increase to 7,000 tonnes in 2030 (JRC, 2013)
  - Price of lithium in 2002 $1,600 / tonne
  - Price of lithium in 2017 $9,100 / tonne (Metalery, 2017)

Defining the baseline

Recycling and investment opportunities

In the **Battery Directive (2006/66/EC)**

Collection rate ‘industrial batteries’:

“The disposal of industrial and automotive batteries and accumulators in landfill sites or by incineration should be prohibited.”

Recycling efficiency of ‘other batteries’ is 50% of the weight.

→ Incentive to recover materials with the highest value up to 50% of the weight of the battery, while lithium and other elements are often discarded.

Defining the baseline

Investment opportunities

A key sector where value is created through jobs and materials is the recycling sector and Europe has an advantage being among the market leaders, particularly for the recycling of lithium-ion batteries. (JRC, 2017)

Defining the scenarios

	Scenario 1*	Scenario 2*
Collection rate within the EU	60%	85%
Lithium recycling efficiency rate	57%	94%
Cobalt recycling efficiency rate	94%	99%

* Show the macro-economic and environmental impacts of increasing collection and recycling rates

- **Collection rates**: taken from European Commission’s (2016) SET-Plan Action no.7 – Declaration of Intent "*Become competitive in the global battery sector to drive e-mobility forward*“

- **Recycling rates**: taken from two processes in the JRC (2017) report *“Lithium ion battery value chain and related opportunities for Europe”*

Scenario analysis

Key assumptions based on a literature review and interviews with experts

Assumption		Source
Lifetime of EV batteries	10 years	Tesla and Nissan warrant their batteries against malfunction and defect for 8 years. Gaines (2014) also states an average 10 year lifetime of batteries in EV cars.
Length of second-life	5 years	Bundesverband Erneuerbare Energie e.V. (BEE) (2016) state the lifetime of EV batteries is on average 15 years.
Percentage of batteries used for second-life	80%	Bundesverband Erneuerbare Energie e.V. (BEE) (2016)
Average weight of an EV battery	250 kg	Battery University, 2017
Average weight of cobalt in an EV battery	6.8 kg	The Washington Post, 2016
Average weight of lithium in an EV battery	0.07 kg	Research Gate Q&A, 2016
Price of cobalt in 2030	61,000 $/tonne	Based on 2017 prices from The London Metal Exchange (2017)
Price of lithium in 2030	9,100 $/tonne	Based on 2017 price from Metalary (2017)
Investment	25 m€ per 7,000 tonne capacity plant	Based on figures from Umicore's plant in Hoboken.
Employment	0.059 jobs per metric tonne or waste EVs	Employment rates from the EPA

Scenario analysis

Results

- **Number of batteries at their end-of-life in 2030:** 316,000
- **Capacity of those batteries:** 12,640 GWh

	Scenario 1	Scenario 2
Value of recovered cobalt	73.9 (million €)	110.3 (million €)
Value of recovered lithium	2.8 (million €)	6.6 (million €)
Investment in recycling infrastructure required	68.9 (million €)	84.9 (million €)
Employment	2,799	3,965

Next steps

- Incorporate comments from stakeholders
- Collect missing data, including:
  - Recycling costs
  - Employment rates per collection, dismantling and recycling – additional employment with higher recycling efficiencies?
  - Environmental impacts including CO2 emissions
  - Social impacts
- Generate results for 2040 (?)
- Develop conclusions and policy recommendations

- DISCUSSION -