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Modeling the potential impact of lithium recycling from EV batteries on lithium demand: A dynamic MFA approach

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ABSTRACT

Electric mobility is a key element in the transition to a more sustainable transport system. Already today Li-ion batteries (LIB) are used in many stationary and mobile applications. If electric vehicles (EV) based on LIB reach a strong market penetration the recycling of lithium from growing numbers of automotive batteries will be decisive for future availability of this resource. However, the amount that EV battery recycling can contribute to lithium availability is unclear since the ability of secondary lithium to be reused in batteries is uncertain. Here we assess the trend in demand for lithium and the possible effects of automotive battery recycling by applying dynamic material flow analysis to the global lithium cycle. We found that lithium recovery from EV battery recycling could result in a significant oversupply of secondary material if its quality is not high enough to allow for reprocessing in battery production. In this case the application of secondary lithium would be limited to other use sectors and thus also restrict the possible savings of this resource. If secondary lithium only substitutes a relatively small quantity of virgin material whereas total lithium demand keeps rising, the production of primary raw materials will have to increase strongly.

The findings of our work reveal the challenge that might result from a quality problem of recycled battery materials and thereby emphasize the importance of developing cost-effective recycling technologies with efficient material recovery processes for traction batteries as well as the timely development of a functioning recycling infrastructure.

1. Introduction

Electric vehicles (EV) can be an alternative to cars using fossil fuel and can play an important role in a more sustainable development of the transport sector. In scenarios featuring increasing electric mobility, the use of traction batteries such as lithium-ion batteries (LIB) is expected to grow significantly, raising the demand for the component materials (Simon et al., 2015; Weil and Ziemann, 2014; Navigant, 2013; Buchert et al., 2011).

As a contribution to the ongoing discussion of future lithium availability, several studies have analyzed the impact of EV penetration on lithium demand and compared it with data on lithium reserves and resources (Pehlken et al., 2017; Weil and Ziemann, 2014; Vikström et al., 2013; Mohr et al., 2012; Kushnir and Sandén, 2012; Gruber et al., 2011; Gaines and Nelson, 2010; IEA, 2009; Yaksic and Tilton, 2009; Angerer et al., 2009; Roskill, 2013; Weil et al., 2009; Tahil, 2008). The majority of these studies have determined there is sufficient lithium to meet the possible future demand for EV in the coming decades. However, some of these analyses also detected a potential premature depletion of current lithium reserves (Pehlken et al., 2017; Weil and Ziemann, 2014, Gruber et al., 2011; IEA, 2009; Tahil, 2008). Specifically, there is a considerable risk of a shortage due to the concentration of lithium deposits in certain regions and countries characterized by political instability such as Bolivia and China (DERA, 2014; Worldbank, 2011). Due to the risk of supply chain disruptions, the status of a significant part of the lithium reserves can be classified as critical (cf. Fig. 1, see also Oliveira et al., 2015; Weil and Ziemann, 2014; Grosjean et al., 2012).

Recycling is an important measure to mitigate potential supply risks and also to reduce the demand for primary raw materials (Hagelüken,

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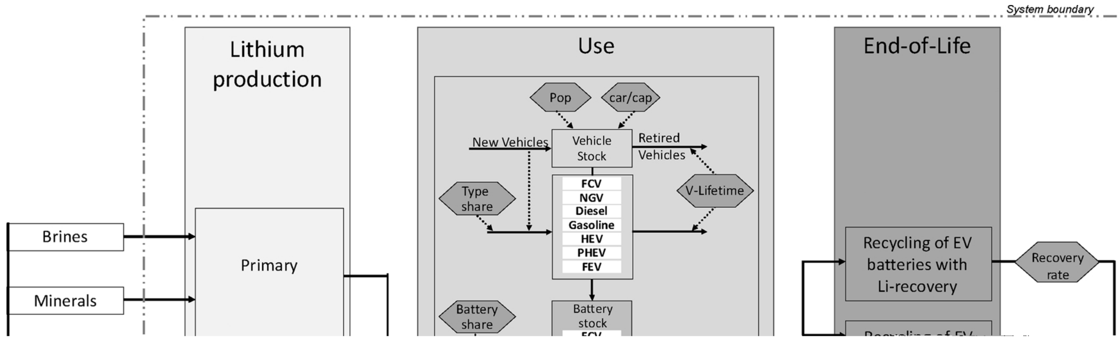

Fig. 1. Dynamic model with lithium flows.

2014; UNEP, 2013; Buchert et al., 2011). Recycling is usually considered to be beneficial for the economy and the environment because it reduces primary production, energy consumption, and the associated environmental impact (Zeng et al., 2014; Hagelüken, 2014; UNEP, 2013; Li et al., 2013). In addition, domestic recycling can reduce the quantity of imported materials (Gaines, 2014; Richa et al., 2014) and thus the vulnerability of supply chains. Therefore, the majority of the above-mentioned studies emphasize the relevance of battery recycling for future lithium supply security and include recycled material as an important additional future source of lithium that could significantly decrease the need for primary raw materials (Idjis et al., 2013; Mohr et al., 2012; Kushnir and Sandén, 2012; Gruber et al., 2011; Gaines and Nelson, 2010; IEA, 2009; Yaksic and Tilton, 2009; Angerer et al., 2009).

However, the recycling of batteries does not directly imply the recycling of lithium from spent batteries (Gardener, 2017; McCormick, 2016; Kushnir, 2015). The European Union already defined legal requirements for recycling of batteries, where collection rates of at least 45% should be reached by 26 September 2016 (Richtlinie, 2013/56/EU). Since the number of end-of-life (EOL) batteries from EVs is expected to rise significantly over the coming decades (Gaines, 2014; Richa et al., 2014; Georgi-Maschler et al., 2012), companies such as Toxco (Thompson, 2011), Umicore (Tytgat et al., 2008), and Accurec (Weyhe, 2010) have developed recycling processes for batteries, including LIB. These technologies are focused, however, on the recovery of more valuable materials such as cobalt and nickel (Heelan et al., 2016; Kushnir, 2015; Sonoc et al., 2015). Even though these processes can be applied to batteries from consumer electronics, recycling technology for lithium-based traction batteries is still the subject of ongoing research (e.g., Zeng et al., 2014; Li et al., 2013; Georgi-Maschler et al., 2012; Kwade et al., 2013; Buchert et al., 2011). This research has led to the development of recycling processes, including lithium recovery, on a laboratory scale, but the reuse of recycled lithium in the manufacture of new EV batteries has only been partly successful (Kwade et al., 2013).

Today, almost no lithium is recovered because it is not economical, and this resource remains instead in the slag that is used in the construction sector as a cement additive (McCormick, 2016; Kushnir, 2015; Sonoc et al., 2015; Tytgat, 2013 pers. comm.; Dewulf et al., 2010). This means, based on our current knowledge, that the economics of lithium recovery is dependent on the costs for producing lithium from primary sources. The cost of recovering lithium (in the form of Li_2CO_3) from the slag using the currently available recycling processes is estimated to be in the same range as that of producing battery-grade lithium carbonate (Li_2CO_3) from pegmatite minerals such as spodumene (Tytgat, 2013 pers. comm.). Specifically, the variable[1] cost of extracting Li_2CO_3 from spodumene can be estimated at 3.1 US$ per kg Li_2CO_3 (Hykawy and Thomas, 2009) and are thus actually higher than the cost of the current procedure for extracting Li_2CO_3 from brine deposits corresponding to 1.2 US$/kg (Muhl, 2014; Yaksic and Tilton, 2009; Hykawy and Thomas, 2009). To achieve lower recycling costs, the whole recycling chain must become more efficient, and more cost-efficient recycling technologies must be developed. Furthermore, subsidies could also be an important factor for increasing recycling whose potential role will be investigated further.

An additional challenge is posed by the quality of Li_2CO_3 recovered from EV batteries: the secondary Li_2CO_3 needs to be of high enough quality to find a market for its original purpose, or it has to find an alternative market (Gaines, 2014). Even if there is still relatively little information about the application of recovered Li_2CO_3 in battery manufacture some research results showed that performance and durability of batteries produced from recycled active materials did not reach the same quality level as if they were produced from virgin materials (Kwade et al., 2013). In this case, the recirculation of secondary Li_2CO_3 may be limited to use in other sectors such as in ceramics, glass, and alloys (not for rechargeable batteries). But here a problem could be arising, because the demand for lithium in these sectors is very likely to grow at a slower rate than that for EV batteries. It has to be stated, that the stationary applications of LIB are not considered in this work, but would further deepen the mentioned problem.

The effects of the quantities and qualities of Li_2CO_3 recovered from EV batteries on the overall recycling system have not been investigated so far.

Our study analyses the impact of a rising demand for lithium-based traction batteries in electric mobility on the potential for lithium recovery from EOL-EV batteries and the options for as well as the limitations of using secondary lithium for EV batteries and other lithium products. The following questions are addressed. (1) What impact does

[1] Variable costs do not include the amortization of capital cost of the mine and plant construction that would additionally amount to $ 3.333 per ton of Li_2CO_3.