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Sustainable governance of scarce metals: The case of lithium

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HIGHLIGHTS

- Lithium is a geochemically scare metal, but demand is forecast to increase in future
- We explore sustainable lithium governance implications for Australia and Switzerland
- One governance mechanism is the 'servicization' of the lithium value chain
- We explore one actual, and two hypothetical lithium service business models
- 'Servicizing' a commodity would require fundamental innovations in minerals policy

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ABSTRACT

Minerals and metals are finite resources, and recent evidence suggests that for many, primary production is becoming more difficult and more expensive. Yet these resources are fundamentally important for society—they support many critical services like infrastructure, telecommunications and energy generation. A continued reliance on minerals and metals as service providers in modern society requires dedicated and concerted governance in relation to production, use, reuse and recycling. Lithium provides a good example to explore possible sustainable governance strategies. Lithium is a geochemically scarce metal (being found in a wide range of natural systems, but in low concentrations that are difficult to extract), yet recent studies suggest increasing future demand, particularly to supply the lithium in lithium-ion batteries, which are used in a wide variety of modern personal and commercial technologies. This paper explores interventions for sustainable governance and handling of lithium for two different supply and demand contexts: Australia as a net lithium producer and Switzerland as a net lithium consumer. It focuses particularly on possible nation-specific issues for sustainable governance in these two countries' contexts, and links these to the global lithium supply chain and demand scenarios. The article concludes that innovative business models, like 'servicizing' the lithium value chain, would hold sustainable governance advantages for both producer and consumer countries.

1. Introduction

Today's global society is dependent on minerals and metals. These resources provide important services for people, communities, businesses and nations. People have come to expect that these resources will be available when society requires them. However, by their very nature minerals and metals are finite resources, and recent evidence suggests that for many, primary production is becoming more difficult and more expensive (Giurco et al., 2010; Mudd and Ward, 2008; Prior et al., 2012).

A continued reliance on minerals and metals as service providers in our society requires dedicated and concerted governance in relation to production, manufacturing, use, and recovery (Cooper and Giurco, 2011). However, governance measures must reflect the services these resources supply to society, and consequently, how these resources are ultimately valued (socially, technically or economically) by society. The services these resources provide, and therefore the value that is attributed to them, differs between 'resource producing' and 'resource consuming' countries, and is explored more fully in this article.

Lithium provides a good case study to compare governance strategies between a net raw materials producing and a net consuming country for several reasons. Firstly, lithium is a geochemically scarce metal, being found in concentrations on average lower than 0.01% by weight in the Earth's crust (Garrett, 2004; Skinner, 1976; Wäger et al., 2010).

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Secondly, demand for lithium is projected to increase over the coming century (Angerer et al., 2009; Carles, 2010; Mohr et al., 2012; Rydh and Svärd, 2003) as a key component in batteries to support future mobility options. Finally, increasing demand of a scarce metal will encourage greater production rates, possibly with growing environmental and social consequences at the mine site, as has been demonstrated in the production of other mineral commodities (Giurco et al., 2010; Mudd, 2010; Mudd and Ward, 2008).

Based on a framework proposed by Wäger et al. (2012), this paper explores interventions for sustainable governance and handling of lithium for two different supply and demand contexts: Australia as a net lithium primary producer and Switzerland as a net lithium consumer. In particular, it examines possible nation-specific issues and interventions for sustainable governance in these two countries' contexts.

2. The role of lithium for future technologies

2.1. Technologies requiring lithium

Lithium is used in a range of technologies, principally because of it is light, electrochemically active, and has a low thermal expansion coefficient (Ebensperger et al., 2005). Lithium is the lightest solid metal with the highest electrochemical potential, and therefore has a high gravimetric and volumetric energy and power density. Accordingly, it is expected that lithium-based battery chemistries will dominate the electric vehicle market in the near-term and probably long-term future, which makes lithium indispensable in the scale-up of electric vehicles (Wadia et al., 2011), for example. The various contemporary uses of lithium are provided in Fig. 1.

2.2. The future demand for lithium

Scenarios for the future demand of lithium from emerging technologies have been addressed in various studies, and although uncertainties exist, the studies cited provide a useful context in which to discuss future lithium demand. For example, McNulty and Khaykin (2009) have projected lithium demand and production to 2020. They estimate demand steadily growing to 37.7 kt Li/y by 2020 with an average growth rate of 7.4% between 2008 and 2020, and project supply to reach only 27 kt Li/y in 2020 from 21 kt Li/y in 2008 with an average growth rate of 2.1% between 2008 and 2020.

Angerer et al. (2009) calculated two projections of lithium demand by assuming a 50% and 85% penetration of electric vehicles[1] by 2050. The authors used a systems dynamics model to calculate demand and recycling rates. The two scenarios show demand reaching 177 and 590 kt Li/y in 2050, with cumulative production rising from 3.6 to 9.0 Mt Li between 2008 and 2050. By 2050, Angerer and colleagues estimate that lithium recycling will reach 50 and 180 kt Li/y for the 50% and 85% penetration scenarios. As such, by 2050 primary lithium production will need to reach between 127 and 410 kt Li/y.

Carles (2010), modelled lithium supply, consumption and recycling using a stocks and flows model for the world by source (brines, ores, recycling and sea water) to 2200. The model is consumption driven and was used to investigate a number of supply scenarios that would influence the flows of lithium from the four lithium sources. Carles' model indicates that non-seawater primary lithium production would reach a level of 0.61–1.40 Mt Li/y between 2050 and 2090 to then collapse, being replaced by lithium from seawater. Further, recycling is projected to plateau at 1.04 Mt Li/y between 2100 and 2200 and annual consumption is anticipated to plateau at 1.7 Mt Li/y between 2110 and 2200.

[1] They considered Battery Electric Vehicles (BEV - driven solely by battery), Hybrid Electric Vehicles (HEV - both battery and combustion engine) and the Plug-in Hybrid Electric Vehicle (PHEV - the same as the HEV, but with a plug-in capacity for charging the battery).

In another study, Mohr et al. (2012) modelled worldwide demand and supply of lithium to the year 2050. Building upon the work of Angerer et al. (2009), they assumed that most future demand for lithium would be driven by the production of lithium batteries for electric vehicles (with 0.15 kg of Li/kWh and a battery capacity of 20 kWh). Mohr et al. (2012) predict that lithium demand will increase to 400 kt/yr by 2050, and to 857 kt/yr by 2200. Under a 'best estimate', representing the most plausible supply of lithium, the authors demonstrate that lithium supply could not ensure a 100% penetration of electric vehicles on the market.

3. The global lithium supply chain

3.1. Lithium supply from primary production

Lithium is currently sourced in two ways: from hardrock, and more recently from the evaporation of salt brines. Lithium from rock sources is primarily produced from spodumene, a lithium/aluminium/silicate mineral (Garrett, 2004). Salt brine sources include salt lakes, which are currently the main source of lithium, and geothermal brines and salt brines associated with oil deposits (as potential future options). Chile (along with Argentina, USA and China) is producing lithium carbonate (Li_2CO_3) from salt brines, while Australia (along with China, Canada, USA, Zimbabwe) mines spodumene and produces a concentrate containing lithium oxide (Li_2O) (USGS, 2011).

Lithium oxide concentrates can be used directly in the glass and ceramics industries, and lithium carbonate constitutes the main feed material for all other industrial processes, including battery manufacture (Ebensperger et al., 2005; Yaksic and Tilton, 2009). Also, lithium carbonate is often the source material for other industrial lithium compounds, such as lithium hydroxide, lithium chloride, lithium metal and butyl lithium. Although these production methodologies and products suggest that the global lithium supply chain is divided into two distinct pathways, they are strongly interlinked. For example, Australia exports lithium oxide containing ore concentrates to China, where this concentrate is further processed into lithium carbonate (Ebensperger et al., 2005; USGS, 2011).

The environmental impacts of the primary production of lithium carbonate depend on the production method, with wastewater being a particularly important issue for two reasons: first, lithium processing is water intensive and significant volumes of wastewater are generated; secondly, most lithium deposits are located in regions where access to fresh water is an important issue (Mohr et al., 2012). Both production methodologies must address post-operation environmental (and social) rehabilitation issues. Compared to the production from rocks, the production of lithium carbonate from brines benefits from the 'free of charge' energy input of the sun to concentrates the brine through evaporation. However, further processing using this method is still energy and material intensive. From a life cycle perspective, the environmental impacts of lithium carbonate production from brine are slightly lower than for production from ore concentrates (Stamp et al., 2012).

3.2. Supply of lithium from secondary production

Supply of lithium from secondary production is still very limited (less than 1% according to Graedel et al., 2011) since lithium's comparatively low price has not stimulated recycling efforts, which must source lithium from often dispersive applications (*e.g.* glass and ceramics, lubricating greases). According to Luidold and Antrekowitsch (2010), from the different applications listed in Fig. 1, only primary and secondary batteries are appropriate as secondary lithium sources. Even so, current recycling of lithium battery systems is mainly targeted towards the recovery of cobalt, copper and nickel. Industrial scale recovery of lithium is currently undertaken using the 'Toxco process' (Toxco Corporation, USA) (Luidold and Antrekowitsch, 2010; Vadenbo, 2009) and in the 'Batrec process' (see for example, Bernardes et al., 2004;