Metal Mining for Lithium-ion Battery Production of Electric Vehicles and Its Impact on Global Land Use: A Review

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Abstract. As electric vehicles are believed to be zero-emission alternative to conventional vehicles, the demand for lithium-ion batteries used to produce electric vehicles is also increasing. Although electric vehicles have the potential to improve the current world environment, the mental mining for lithium-ion battery production have the potential to cause environmental impacts. Given that many literature only discuss the possible impacts of lithium-ion battery production in a general manner, this paper conducted a “two-stage” review to first identify a targeted environmental area based on the theory of planetary boundaries, and then further collect evidences in details. Social problems related to lithium-ion batteries such as global metal mining market change and damage of protected ecosystems have been discussed. This paper also put forward several possible management methods to solve the land use change problems and the related social problems, including promoting lithium-ion battery recycling and land recovery etc.

Introduction

The transportation sector has become one of the most important pillar industry for the global industrialized countries. On the one hand, the rapid development in transportation industry has increased employment opportunities, gained large income and brought social prosperity for human beings. On the other hand, however, transportation sector also consumes huge amount of global resources and causes air pollution. About 42\% of the air pollution is generated by the exhaust gas from fuel-fired vehicles, and nearly 80\% of the city sound pollution results from the traffic [1]. Due to the fossil fuel consumption and high energy demand, the growing speed of greenhouse gas emission in global and Chinese transportation sector has become one of the fastest among all the industrial sectors.

In order to reduce the use of fossil fuels as well as the problematic vehicle emissions, the development of electric vehicles has gradually become the focus of vehicle engineers, researchers and global governments. Actually, the first battery-powered vehicle was built by Davidson in 1837 in Aberdeen [2]. However, due to the lack of mature battery technology and suitable battery materials, the traditional vehicles powered by internal combustion engines occupied the market. In 1996, the First Generation of modern electric vehicles was manufactured by General Motors and was powered by lead-acid battery. In 1999, the second Generation of electric vehicles, powered by nickel-hydrogen batteries, was also designed by General Motors and it has 1.5 times pf driving mileage per charge. In 2006, the lithium-ion battery has developed rapidly due to its safety and large energy density, and plug-in HEVs was also invented and its energy can come from electric grid instead of fossil fuels [3]. Within the following decades, countries around the world have corporate together to transform the transportation energy consumption and develop the battery industry. According to a 2018 report on electric vehicles from International Energy Agency, the global total amount of electric vehicles in 2017 is 3 million, increasing more than 50\% when compared with 2016. IEA further estimates that the total number may become 125 million in 2030 [4].

When it comes to global land use, there is no denying that the land use system is of vital importance to the entire ecosystem. Soil is the nutrient for numerous creatures and offers the basis for plants to
grow. The land system is also related to livestock production, agricultural cultivation, regional climate change and even some social aspects such as food security and people’s livelihood. According to Rockström et al., there are several key variables when studying the global land use change. Besides the variable “the percentage of global land cover converted to cropland”, “trigger of irreversible and widespread conversion of biomes to undesired states” is also emphasized, which has certain link with the metal mining for the production of electric vehicles [5].

Given the fact that the development of electric vehicles powered by lithium-ion batteries have been appointed as the focus in the 12th Five-Year Plan for science and technology development of electric vehicle in China [3], this paper typically focuses the production of lithium-ion battery vehicles. For the rest of this paper, Section 2 provides a literature review showing the existing researches about the environmental impacts of electric vehicles powered by lithium-ion batteries. Section 3 explains the “two-stage” methodology that first identifies a key environmental problem area and then further reviews specific impacts. Section 4 states the research results, and Section 5 analyses the results and also discusses the possible improvements. Finally Section 6 makes the conclusion.

**Literature Review**

Regarding the historical background of lithium-ion batteries, there are basically two generations according to several literature. The first generation of lithium-ion batteries for electric vehicles is invented in 1996, which includes lithium manganese oxide batteries (LMO) and lithium iron phosphate batteries (LFP). They have long life span with flexible self-charge, but they can carry relatively less energy [6]. The second generation of lithium-ion batteries include lithium nickel cobalt aluminum oxide batteries (NCA) from 1999 and different kinds of lithium nickel manganese cobalt oxide batteries (NMC) from 2008, which mixes nickel, manganese and cobalt with various ratios. With larger energy capacity and longer life span, the second generation of lithium-ion batteries has more market share comparing with the first generation [7].

Among the existing literature, many researches have emphasized the positive aspects of electric vehicles when discussing about their environmental impacts. Xu states that the exhaust gas of internal combustion engine vehicles accounts for 40% to 50% of the total pollution and the electric vehicles are the fundamental solution to achieve zero emission, and the environmental protection effects of electric vehicles are amazing [8]. Yang et al. concludes five major advantages of electric vehicles, namely less air pollution, reduced sound pollution caused by the engines, the ability to utilize different kinds of energy, higher energy efficiency and much simpler [9]. Song et al. compared characteristics of various kinds of batteries, including energy density, power density, working temperature, electricity maintenance, safety and recycling energy, and concluded that the lithium-ion batteries have strong advantages over the other kinds in all aspects [3].

During the development of electric vehicles, many scholars have also spotted different kinds of problems related to the batteries. Zhao et al. point out the controversy between vehicle weight and battery capacity, which leads to the demand of batteries that have high energy density and light material weight.[1]. Yu and Shi state the security problem of electric vehicles, including the combination of several sets of batteries, the function of recycled batteries and the stability during battery charging [10]. For lithium-ion batteries, Li finds that a lot of heat is generated by the continuous charging and discharging of the lithium-ion batteries during the operation of electric vehicles. If the heat cannot be dissipated in time, the temperature of the battery will rise and affect the performance of lithium-ion batteries [11]. Xue et al. have discussed the pollution caused by electricity generation for electric vehicles, emphasizing that the environmental problems such as severe air pollution, water pollution and health problems after introducing electric vehicles are not avoided and have been transferred to the electricity generation stage [12].

From the literature reviewed above, lots of people regard electric vehicles as an alternative way for traditional inter combustion engine vehicles to ease the environmental problems. The advantage of electric vehicles that no emission during the using stage are emphasized by researchers, and they are
believed to be the solution for zero emission to some degree. The problems of electric vehicles discussed by the literature focus mainly on the technical problems, security problems and the methods to increase the performance of electric vehicles. The possible environmental problems of electric vehicles are focused on the leakage of heavy metals during the production or disposal stages, and those problems are discussed in general in many cases. After reviewing lots of existing literature, this paper first chooses a specific area to which the electric vehicles have obvious impacts. Then detailed and in-depth impact analysis is given in the paper based on intensive literature.

Methodology

In order to evaluate the potential environmental problems of lithium-ion battery production for electric vehicles, this paper has conducted a “two-stage review” based on planetary boundary theory.

Planetary Boundaries

Similar to the ability of rivers to clean themselves up after the water pollution caused by surrounding animals, the ecosystem people rely on also have the capacity to take in disturbance and maintain in the original state at the same time. This resilience serves as the theoretical foundation that human being can continue the social development while dealing with environmental changes [13]. However, this resilient ability of the earth has limitation. As global environment problems become more and more severe, the earth may come to the tipping points, beyond which it may face a catastrophic change and never go back to its previous stage [5].

In order to avoid crossing the tipping points and maintain the resilience of the earth, the core theory of planetary boundaries have been put forward, which offers a safe operating space for human development. By first identifying the key processes determining the stability of the earth system and then finding indicators to measure how far human can go for each process, Rockström et al. defines nine planetary boundaries, namely climate change, ocean acidification, stratospheric ozone depletion, biogeochemical nitrogen and phosphorous cycles, global freshwater use, global land use change, biodiversity loss, chemical pollution and atmospheric aerosol loading [5].

The “Two-Stage Review”

The so-called two stages include a pre-study and the main study in this paper. The pre-study is based on the theory of planetary boundaries and to check the relationship between lithium-ion battery production for electric vehicles and each planetary boundaries. Mainly based on literature review, pre-study summarized how the lithium-ion battery production can affect the environment from these nine aspects. After comparing all the impacts, pre-study identifies the environmental area which is affected by the production of lithium-ion batteries for electric vehicles in the most significant way. The pre-study helps this research to target on a focus and enables the main study in the second stage to dig deeper into the certain environmental impacts.

After the pre-study, main study of this paper is conducted by the additional intensive literature review. Given that the land use change problem caused by electric vehicle production is mainly due to the heavy metal mining, the review focuses on different metals as the raw material of lithium-ion batteries in electric vehicles. More specifically, this paper chooses five types of heavy metals used for lithium-ion battery production, namely lithium, cobalt, nickel, manganese and iron [14]. The database and materials for the review include Google Scholar, ScienceDirect and CNKI. The keywords for the literature involve “lithium-ion battery production”, “lithium mining and land use”, “lithium-ion battery recycle” etc. As the mining activities for these heavy metals are located around the world, the geographical delimitation of this paper is not only China, but also other countries who also extract metals for lithium-ion battery production.
Results

Results of Pre-study

After considering each planetary boundary and conducting thorough literature review, the impacts of lithium-ion battery production on each planetary boundary have been summarized and compared:

(1) For Biogeochemical nitrogen and phosphorous cycle, the charging of batteries in electric vehicles requires more electricity, which will increase the NOx emissions by 27%. The total NOx emissions in all the energy systems may remain the same or even worse when the use of electric vehicles increases [15]. (2) For land use change, nickel mining affects the land systems in 25 countries, especially in Brazil. With the development of electric vehicles, the metal mining will also dramatically increase correspondingly and leads to huge land use change [16]. (3) For global freshwater use: lithium mining requires saline and freshwater, and mining activities need pollute freshwater, and the long-term impact on the freshwater system is uncertain [17]. (4) For stratospheric ozone depletion: lifecycle assessments of vehicles powered by lithium-ion batteries show that the impacts to ozone depletion are mainly from using stage, instead of mining stage [18]. (5) For biodiversity loss: the leakage of heavy metals during mining activities can contaminate rivers and lakes, therefore poisoning animals and plants. Metal mining also demands huge amount of water, which can cause harm to nearby creatures [19]. (6) For climate change: the mining activities and lithium-ion battery production require large amount of electricity which are generated by fossil fuels and causes greenhouse gas emission [20]. (7) For chemical pollution: the mining of lithium and cobalt consumes freshwater and may cause water pollution. Polluted water may accumulate in the reservoirs, but measures are taken to improve the situation [21]. (8) For atmospheric aerosol loading: both organic and inorganic aerosols are found during the using stage of electric vehicles. (9) For ocean acidification: the conducting liquid inside lithium-ion batteries usually contains cyclic organic carbonates, HF and phosphoric acid. The CO2 emissions caused by battery manufacturing and electricity generation stages have increased [22].

As is shown above, some planetary boundaries, including biogeochemical nitrogen and phosphorous cycle, ocean acidification, ozone depletion, biodiversity loss, chemical pollution and atmospheric aerosol loading, have limited impacts caused by the metal mining of lithium-ion battery production. As for climate change, although many evidences show that the mining of metals such as lithium mainly consumes fossil fuels which can cause greenhouse gas emissions, the impact caused by lithium-ion battery production is not the major driver of the global climate change. In another word, metal mining for electric vehicles is not pushing the climate change boundaries as hard as other drivers. For freshwater change, metal mining may extract water from nearby aquifers and streams or even pollute freshwater, but lots of studies show that the water treatment and cascading practices are preventing serious freshwater problems caused by metal mining.

When it comes to land use change, reports above have emphasized the extensive land damage and deforestation due to large scale of metal mining, and the land pollution problem caused by mining is also severe. Resulting from the gas and liquid leakage during metal mining as well as the abandoned mines, freshwater systems are easily polluted and biodiversity around the area also decreases, which means the land use change also causes problems in other planetary boundaries. Given these facts, land use change is chosen to be the targeted environmental area for the main study to further review the specific impacts in details, aiming to find possible optimization suggestions.

Main Study

The Land Use Change Caused by Iron Mining. Even though iron is mainly used in construction and industrial manufactory sectors, the demand of iron for batteries in electric vehicles is actually increasing. One reason is that batteries such as lithium iron phosphate batteries (LFP), using iron as cathode in the lithium-ion batteries, have longer lifecycle and are more stable. Another reason is that iron can be a possible alternative for cobalt, the mining of which is very unsustainable [6]. Studies conducted by Simmons et al. emphasizes that the surface mining of iron can displace soil, kill vegetation, eliminate local landscapes and also affect eco system services [23]. Sonter et al. also...
points out that the iron mining expands very quickly that has influenced the plantation forestry for the production of charcoal [24]. Very severely in Brazil, the survey conducted by Sonter et al. shows that iron mining has caused 1670 km² forest loss between 2005 and 2015, which is around 9% of the Amazon [25]. Despite the land use changes caused by iron mines, the mining-supporting infrastructure, expanding living areas for mining workers and the mining supply chains also increase the indirect land use change.

As has been asserted by Zhang et al., factors such as land fragmentation, community displacement, transportation networks and potential conflicts between farm fields and mining areas can accelerate the land use change caused by metal mining for lithium-ion batteries [26]. A study of Durán et al. shows that around 7% of iron mines are located inside of protected areas and about 27% are located within 10 kilometers of the protected areas. Due to the fact that at least 14% of the protected lands are putting into threats by iron mining activities, the land use change caused by iron mining will be more and more serious as the electric vehicles keep developing [27].

**The Land Use Change Caused by Lithium Mining.** Because nearly all kinds of lithium-ion batteries contain lithium salts, lithium is one of the major raw materials for lithium-ion batteries of electric vehicles. According to Desjardins, the cost for lithium carbonate production in China is 20000 dollars per ton, while it is 10000 dollars per ton in the rest places around the world. Desjardins also predicts that if the production of lithium-ion batteries in electric vehicles increases by 1%, the global demand for lithium will increase about 70000 tons correspondingly [28].

Regarding the mining activities of lithium for battery production, about 90% of lithium is mined from brines in so-called “lithium triangle”, a desert-type area located around Bolivia, Chile and Argentina. The mining processes are simple, but large scale of saline water is evaporated due to the ineffectiveness of the processes. Although these mining activities do not cause serious direct land use change to the area, the lithium mining accelerates the speed of dissertation of the area and the land there become more and more barren [17].

The global lithium stock layout, including brines and hard rock. Grosjean et al. estimates that brines located in “lithium triangle” contain around 26.9 million tons lithium, and the other lithium stock can be found in hard rock resources around the world. Currently Australia, China and Canada are exploiting hard rock for lithium production, and the demand for hard rock mining is increasing [29]. Due to the fact that mining hard rocks requires traditional mining methods in most cases which is opposite to mining brines, the land use change caused by lithium mining will become more and more severe overtime.

**The Land Use Change Caused by Nickel Mining.** Compared with traditional lithium cobalt oxide batteries (LCO) with LiCoO₂ as main cathode material, lithium nickel cobalt manganese oxide batteries (NCM) are more and more popular because their cheap price, energy capacity and stable thermal features. Studies also show that the lithium-ion batteries which contain more nickel tend to have higher reversible capacity [30]. To increase energy capacity of batteries and deal with shortage and high cost of cobalt, increasing amount of nickel is used in the second generation of lithium-ion batteries [31].

El's predicts that more than 85000 tons of nickel will be used for the production of electric vehicles in 2020, and more than 1.1 million tons in 2030 [32]. Many electric vehicle companies, such as Tesla, the nickel resources used for lithium-ion battery production come only from [28]. The increasing demand for nickel as well as the focused unique nickel mining sites can worsen the land use change dramatically. Some researchers even conducted quantitative study to link the nickel mining and land use change. Nakajima et al. evaluate that the global land use change caused by nickel mining is about 1.9 km² in 2005, while the changed area jumps to 34 km² in 2010. They calculate that the land use for nickel mining in this time period changes from 1.13 m² per ton of nickel to 1.47 m² per ton of nickel. To make the damage worse, the land use change impacts are concentrated in the areas with rich biodiversity, such as Indonesia and Philippines [16].

**The Land Use Change Caused by Cobalt and Manganese Mining.** For the mining of cobalt, the Democratic Republic of Congo is the largest supplier in the world, where to concentration of cobalt
can reach 22467mg/kg [33]. According to a report from CRU International Ltd., approximately 40% of the mined cobalt is used for the production of rechargeable batteries in 2015, and the ratio is expected to grow to 55% in 2019. The report also estimates that the cobalt consumed directly for electric vehicle production will go up from 136 kilotons to 222 kilotons between 2010 and 2015 [34].

The intensive mining described above can influence soil pH, increase metal concentration and affect natural soil for vegetation in the mined area. In fact, all stages of the mining activities will cause damage to natural land use, such as mine exploration, construction, extraction and closure. As cobalt is one of the most expensive raw material for the production of lithium-ion batteries, mining companies are willing to open up more new mines to make fortune and even relocate the local inhabitants for cobalt mining [35]. The increasing price and demand for cobalt will encourage cobalt mining activities, which can be a danger to the local land use in the cobalt-rich area.

Manganese is also one of the major raw material for lithium-ion battery production. The main problem for manganese mining is that the mining technique is not clean and causes damages on land use change. Pattanayak et al. find that the 10000 km² of forest around the rich manganese mines around Orissa in India is lost from 1999 to 2003 due to heavily manganese mining and unproper mining methods [36]. Because of the severe land damage, the quantity and quality of the forests are difficult to recover even if lots of investment and care, which means the land use change caused by manganese mining is unreversed in the area.

Discussion

Social Problems Related to Metal Mining and Land Use Change

One of the unavoidable facts about electric vehicles is that the demand for electric vehicle production will keep increasing as electric vehicles are believed to be a sustainable alternative to traditional combustion engine vehicles. With this trend, the demand for lithium-ion battery production will also go up in the near future, and as a result the transportation industry need tremendous amount of the above metals as raw materials. Given that the global stock for all these metals are nearly unchangeable, the mining for metals can be not only a production technical problem, but also social and economic problem. For example, as cobalt is a relatively rare and expensive metal, the increasing of its price may trigger the demand for other possible alternative metals or new materials. This trend will push the research investment and encourage the mining activities for other metals, which means the possible change of mining and metal market.

Rapid changes can happen related to resource exploitation and therefore change the pressures of the socio-technical system related to land use change caused by mining activities. To be more specific, one country which is the main supplier of a decreasingly-demanded metal may stop mining, and the new mines for increasingly-demanded metals will be opened in other countries. This means the land use affected areas will be shifted from the former metal concentrated locations to other new areas and enlarge the global land use change resulting from lithium-ion battery production. In this case, the global land use system in the future will be more complex than a local mining problem, and will develop into regional level or even global level as more and more electric vehicles are produced.

The metal mining activities for lithium-ion batteries not only affect normal land in the local area, a serious problem is that lots of metal mining sites are actually located in the agricultural lands, rich eco-system areas and even global protected areas. As the above study shows, more than 14% of global protected areas for their high ecological value are inside or around the metal mining areas. The lack of environmental protection awareness of mining activity managers is one of the reasons for this kind of land use damage. Many of current mining activities only focus on the metal availability and the economic worth of the metal product, the possible terrible results such as deforestation and biodiversity loss are often overlooked. Especially, if the mining activities are linked with large income due to the demand for metals to product electric vehicles, the conflicts always occur between
the precious environmental values of the natural ecosystem and the possibility to create job opportunities and increase overall income.

A problem which is difficult to concur is that mines and metal resources are impossible to be moved, which results in that the mining of metals is always concentrated in the areas where metal ores are found. The over-exploitation in these areas have caused the decreasing of land quality, and the construction and operation of different mines also disturbed the natural system around the mines. If the newly opened mining land intrudes on land intended for agricultural and forestry, the conflicts also lead to more new land requirement. As have been pointed out in cobalt mining, people around the mines are forced to relocate due to the opening of new mines. This is not just a land use change problem related to mining, but also a social problem of local people’s livelihood and the development of new urban areas for the relocated residence.

Possible Management Methods

Based on the facts and data collected in the results and the problems analysed above, several possible management methods are put forward to ease the land use change and the corresponding social problems caused by metal mining for lithium-ion batteries in electric vehicles.

More Comprehensive Mine Planning. With the continually demand increasing trend for lithium-ion batteries in electric vehicles, the land intended for agriculture, grasslands, forestry and urban usage will start to reduce with the increasing mining activities. In order to avoid spreading land use change caused by this trend, sustainable mine planning strategies are needed to consider the entire life cycle of the targeted mine, including the metal exploration, mine design, mining activity operation, mine closure and natural system rehabilitation. Strategically, the assessment of current ecosystem status around the targeted mine, the land rehabilitation possibilities and long-term environmental effects caused by the mining activities must be carry out before actual operation. If necessary, a cost benefit analysis considering environmental aspects is needed to make a balance between huge potential economic income and the possible social and environmental problems.

In order to have an efficient and comprehensive mine planning, different stakeholders related to electric vehicle production, lithium-ion battery production and actual mining operation should cooperate together to find a way to reduce potential impacts as much as possible. During the sustainable mine planning processes, different scenario studies should be compared in order to ease the pressure brought by mining to the land use change boundary. More specifically, aspects such as mine ore extraction, resource efficiency, topsoil usage etc. should be considered to make mining a temporary pressure to land use change.

Promotion of Recycling. Regarding the increasing demand for electric vehicles and metal raw material resources, the recycling of the lithium-ion batteries can be an important method to reduce mining activities and the pressure onto the land use system. Processes such as pre-treatment, metal-extraction and by-product production should be conducted to reuse the metal inside of lithium-ion batteries. Due to the liquid and other harmful material in the batteries, the processes require supervision and control to prevent unnecessary leakage or accidents resulting in secondary pollution. In order to facilitate the battery recycling, consumer laws for returning used electric vehicles and the recycling system of lithium-ion batteries should be established. Stakeholders including government and manufacturers should be also involves in the recycling system, and producer responsibility should be emphasized.

To strengthen the importance of lithium-ion batteries, evidence can be found in some scientific studies to show that battery recycling can reduce the land use and natural resource impacts. The scenario study conducted by Dewulf et al. compares the land use demand of cobalt and nickel recovered lithium-ion battery production with the virgin production. The result shows that the recycling of lithium-ion batteries can save about 51.3% of the land required for these two metals, which means metal recycling can save half of the land use for mining [37].

Design and Technique Changes in Lithium-ion Battery. The above results have shown the limit cobalt resources, high prices and large area of damaged land. These facts are calling for the efforts to
decrease cobalt ratio in lithium-ion batteries used in electric vehicles and replace it by other possible materials. Hoping to decrease the overall metal usage in lithium-ion batteries, phosphorous can be key element for the technique development. For example, by adding chemical phosphorus-sulfur compound into the electrolyte liquid between metal electrodes in the battery, the lithium can be covered by a thin coat resulted from the reaction between metals and phosphorus-sulfur electrolyte liquid to prevent lithium from reacting with water and improve the battery function [38]. With careful design and improved technique optimization, the environmental problems caused by unproper operation or unclean processes can be avoided to some degree, so as to reduce the land use change and related social problems.

**Reclaim and Restore the Land.** In the final stage of metal mining, how to treat the end-of-life mines should be planned carefully in order to minimize the land use damage. Land restoration, which is a human involvement for the remediation of degraded landscapes, should be the vital aspect. Environmental impact assessment tools should be integrated to study the schemes to reclaim mining sites and re-establish the working environmental for agriculture and forestry, or restore the natural ecosystem. For different kinds of landscape resources in the mining closure areas, specific restoration framework including landscape element plan and design should be worked out for each kind of landscape resources. The effect of land reclaim and restoration should not be overlooked. A study on manganese mining in Ghana shows that there is a 12.1% increase of land use change in the area due to the manganese mining activities between 1986 and 1996. After introducing continuous reclamation of mined land and reversion of used land, there is only 0.67% increase of land use change in the same area between 1996 and 2006 [39].

**Limitations of the Study**

Admittedly, there are two main aspects that increases the uncertainty of this paper. Firstly, regarding the literature review conducted in this study, there is a lack of close relationship between the land use change and lithium-ion battery production for electric vehicles. As a result, the facts collected in the paper are based on general mining practices to some degree, which may add uncertainty of the study. Secondly, metal mining activities actually have various purposes, part of which are for lithium-ion battery production for electric vehicles. This fact makes it difficult to provide concise results to link the land use change used by mining activities with the production of lithium-ion batteries. Although the metals required in lithium-ion battery production need mining activity regardless of the need in other industry, the consumption of metal ores and the speed of mine expansion will certainly be lower when only lithium-ion battery production for electric vehicles are considered.

**Summary**

In order to move further than researches discussing environmental problems of electric vehicles in a general manner, this paper conducted a “two-stage” review. In the first stage, literature discussing how lithium-ion battery production for electric vehicles pushes the nine planetary boundaries. After the comparison, the land use change caused by metal mining for these batteries is identified to be one of the key environmental areas that has severe impacts. In the second stage, detailed land use impacts caused by lithium-ion battery production for electric vehicles are reviewed, and then related social problems are identified.

The main study shows the increasing trend of metal demands for lithium-ion battery production will continue in the near future. The spreading and over-exploited mines have brought direct damages to the local natural resources and global protected areas, because many metal mines are located inside or around the places with high biological value. As different kinds of metals are located in different places around the world, the variation of the demand for any metal will trigger land use change in other places. Due to the link between all the raw materials, the metal market changes and land use changes caused by demand changes, technical renovation or material replacement can result in
complicated problems to the society. The controversy between environmental value and potential job opportunities and economic income is more and more obvious as more lands are required for lithium-ion battery production.

In order to slow down the land use changes and try to solve the related social problems, sustainable mining planning and environmental impact assessment tools should be implemented based on Lifecycle Assessment theories. To minimize the land use change, a comprehensive recycling system for lithium-ion batteries in electric vehicles should be put forward, and residents should be encouraged to get involved in the recycling practice. By technology optimization, metals which have worse impacts on land use can be reduced or replaced, so as to avoid terrible consequence from the beginning. To remediate the already damaged land and ease the environmental impacts, mining closure, rehabilitation and restoration are also needed to secure an ecologically sustainable future for the socio-technical system of electric vehicles and lithium-ion battery production.

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