# Feasibility Analysis of Recycling and Disposal of Spent Lithium-ion Batteries in China

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**Abstract.** Lithium-ion battery (LIB) is significantly changing the landscape of human life. The feasibility of recycling and disposal of spent LIBs was proposed based on the study of their forecasted demand and distribution characteristics in China. The yearly processing capacity of recycling and disposal facilities of spent LIBs on a nationwide scale were estimated to be at least 50 kilotons. The recycling and disposal facilities should be established in the southeastern coast areas of China, which generated high-density spent LIBs. Beijing was chosen as a city case study to discuss the demand forecasting and present one detailed construction planning of spent LIBs recycling. The obtained thoughts and results can contribute to the recycling and disposal facilities of other Chinese megacities.

**Keywords:** spent lithium-ion batteries; recycling; disposal; feasibility; China

## Introduction

In recent years, consumer eletronics in China is experiencing rapid development due to advances in science and technology, which has brought about higher requirements for the battery industry. Driven by market demand, the lithium-ion batteries (LIBs) emerged as the fastest-growing new batteries with the most market prospects because of its light weight, small size, high energy density, high operating voltage, wide temperature range, long cycle life and good safety performance.[1, 2] Currently, LIBs have been widely used in notebook computers, mobile phones, digital cameras, electric bicycles, medical equipment, the Earth's satellites and many other aspects. Recently as electric vehicles come onto the market, the application of LIBs on these vehicles is also developing rapidly, and the low-weight and high-power LIB is expected to be one of the best batteries for future electric vehicles.[3, 4]

Spent LIBs with a high recycling value typically contain 5% to 15% cobalt, 2% to 7% lithium and 0.5% to 2% nickel.[5] In addition, spent LIBs also contain toxic substances, such as lithium hexafluorophosphate, which will do harm to the environment and ecology.[6] With the extensive application of LIBs, the recycling of valuable metals in spent LIBs will have both social and economic significance to reduce the negative impact on the environment.[7-9] China is the world's largest manufacturing base and the second largest producer and exporter for LIBs. In 2013, the output of LIBs in China was 33.7 billion watts, creating more than 65 billion yuan sales revenue.[10] Huge production and sales will bring about large quantities of spent LIBs, and China is expected to become the world's biggest producer of spent LIBs.[11]

Given the increasing number of domestic spent LIBs, the Resource Conservation and Environmental Protection Division of China's National Development and Reform Commission is planning to incorporate lithium-ion batteries into *Waste Electrical and Electronic Products Catalog*[12] and has proposed a draft version which has been open to the public to solicit opinions. At present, there is no regulation on recycling spent LIBs in China. The draft regulation made by the National Development and Reform Commission comments will pave the way for the formulation of relevant policies on recycling spent LIBs. Therefore, the feasibility study of recycling and disposal of spent LIBs will be imperative for future policymaking in China.

## Layout Analysis of Recycling and Disposal of Spent LIBs in China

**Demand Forecasting**. In recent years, with economic development, China's LIB production has grown rapidly. During the year 2013, the national annual production of LIB has reached a total number of 4.77 billion and is expected to increase to 8.58 billion by 2020 (Fig. 1). Based on the data above, there were 57.2 kilotons LIBs abandoned during 2013 in China, which is expected to rise at a rate of 14.2 percent according to the prediction, reaching 272.5 kilotons in 2020 (Table 1).[11] According to the forecasts above, currently it is quite necessary to recycle and dispose spent LIBs separately in China.

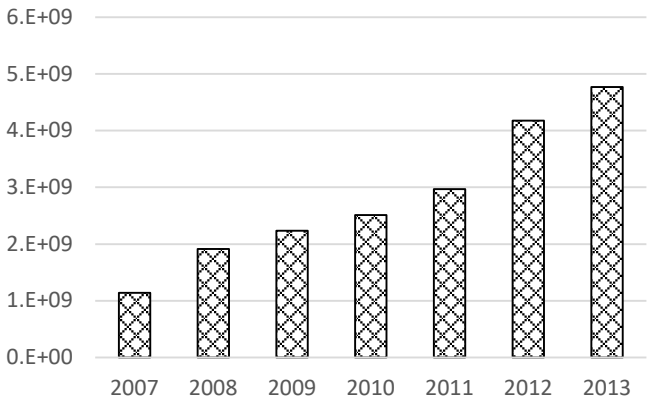


**Fig.1 Production of LIBs from 2007 to 2013 in China. Data source from Macrochina[13].**

**Table 1. Spent LIBs generation from 2013 to 2020 in China**

| Year | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Output /kiloton | 57.2 | 87.4 | 124.6 | 138.9 | 185.3 | 211.1 | 241.8 | 272.5 |

**Construction Planning**. Assuming that the annual treatment capacity of each facility is designed to be 5 kilotons, 17 treatment facilities will be needed on a nationwide scale currently and the national output value of spent LIB disposal will reach approximately 4.3 billion yuan. Based on the fact that LIBs are mainly produced in the southeast coastal provinces in recent years (Fig. 2), the first batch of factories are suggested to be established in coastal re-gions including Guangdong, Jiangsu, Beijing-Tianjin region and Fujian (Fig. 2). By 2020, a second batch of facilities are supposed to be added and the processing capacity of each facility be improved, with the value of production expected to reach about 13.6 billion yuan.

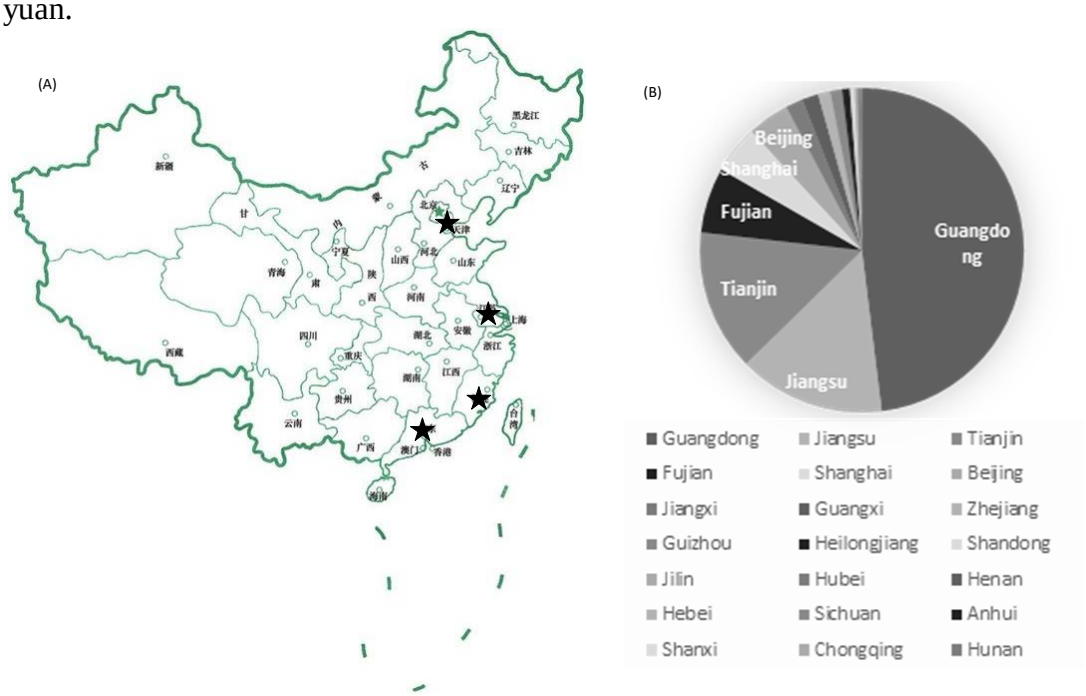


**Fig. 2 (A) Distribution of the first batch of treatment facilities in China; (B) Output of LIBs of major provinces in China**

## Case Study: Disposal Demand and Feasibility analysis in Beijing

Beijing is one of the biggest cities in China with its large quantity of usage and waste generation of LIBs. Meanwhile, as the capital of China, Beijing should take the leader in the field of recycling and disposing spent LIBs separately. In this part, the analysis of Beijing serves as an example to illustrate the specific analysis methods, which can be applied to other megacities.

**Spent LIBs Generation in Beijing.** For the past few years, with economic development and increasingly frequent import and export trade, there have been fluctuations of LIB production in Beijing, and the sales volume of LIBs has been growing rapidly (Fig. 3).

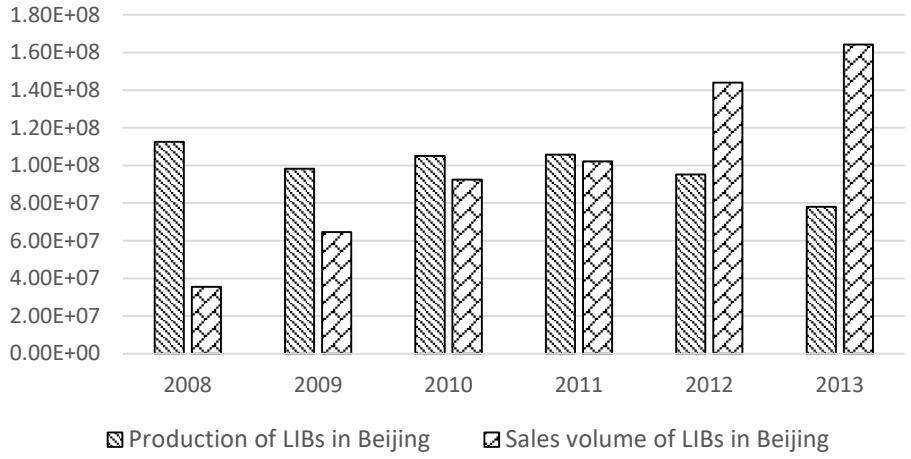


**Fig. 3 Production and sales volume of LIBs from 2008 to 2013 in Beijing (including import and export). Data source from Macrochina[13].**

Based on the relevant data, there were 2.9 kilotons LIBs abandoned during 2013 in Beijing, and the number is expected to rise at a rate of about 26.7 percent according to forecasts, reaching 14.6 kilotons in 2020. (Table 2)

**Table 2. Spent LIBs generation and recycling from 2013 to 2020 in Beijing**

| Year | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Generation amont (kiloton) | 2.9 | 4.2 | 6.0 | 6.7 | 9.0 | 10.7 | 12.6 | 14.6 |
| Recycling amount (kiloton) | 0.9 | 1.3 | 1.8 | 2.0 | 2.9 | 3.7 | 4.7 | 5.7 |

**Disposal Demand in Beijing.** At present, a proportion of spent LIBs generated in Beijing entered the recycling steam of waste electrical and electronic equipment with mobile phones, laptops and other products while the other part get into the formal spent LIB recycling system.[8, 14] According to the forecasts, the amount of spent LIBs in Beijing which finally enter the formal recycling system will increase at the rate of 30.6% from 2014 to 2020, reaching 5.7 kilotons in 2020 (Table 2).

**Construction Planning for Beijing.** The current processing rate of spent LIBs, defined with the ratio of the processing amount in licensed companies to overall collecting amount, is quite low, for the majority of spent LIBs are recycled along with other waste batteries to be stacked or put into the secondary market, workshops or other places. With further standardized collecting channels and enhanced rate of recycling, the processing rate will gradually increase. If the processing rate are calculated as 80%, the current disposal demand of spent LIBs is estimated to be 1.02 kilotons with an economic scale of up to 45 million yuan, and by 2020 the disposal demand is predicted to rise to 4.5 kilotons with the economic scale reaching 236 million yuan. Based on the disposal demand and economies of scale, Beijing currently needs to establish one enterprise with at least 1000 tons' processing capacity for the recycling and disposal of spent LIBs. By 2020, a second phase of construction will be needed and the processing capacity will need to be increased to 4.5 kilotons (Table 3).

Regarding other regions of the country, the same analytical method can be adopt to determine whether special treatment facilities should be established.

**Table 3 Disposal demand and construction planning of spent LIBs in Beijing**

| Index | | 2014 | 2020 |
|---|---|---|---|
| **Total** | Spent LIBs generation（kiloton） | 4200 | 14600 |
| **Recycling** | Recovery quantity（kiloton） | 1300 | 5700 |
| | Processing rate（%） | 80 | 80 |
| **Disposal** | Disposal demand（kiloton） | 1020 | 4500 |
| **Scale** | Economies of scale（million yuan） | 45 | 236 |

## Conclusions

As is shown in the analysis above which is based on demand forecasts, currently it is of necessity to recycle and dispose spent LIBs separately in China.

**Current Annual Capacity at Least 50 Kilotons in China.** According to the national disposal demand fore-casts of spent LIBs, the current construction scale of LIB treatment facilities (annual capacity) should be at least than 50 kilotons and the number of the facilities should be 17. By 2020, the scale of construction of LIB treatment facilities (annual capacity) should be at least 250 kilotons, with increased number of facilities in accordance with the specific circumstances.

**Facilities Concentrated in Southeastern Coastal Areas.** The recycling and disposal facilities should be es-tablished mainly in the southeastern coastal areas of China, particularly in Guangdong, Jiangsu, Beijing-Tianjin region, Fujian and other key areas. The distribution of the processing facilities should be determined according to the local genetaion of spent LIBs on the premise that facilities in areas where levels of spent LIBs are highly ensured.

**Construction in Megacities Based on Local Conditions.** Megacities with higher density of LIB products should determine whether special treatment facilities need to be established according to local disposal de-mand. For example, according to demand forecasts, Beijing currently only need to build one spent LIB treatment facility with an annual possessing capacity of 1.0 kilotons.

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## References

[1] TechNavio, Global Rechargeable Battery Market 2011-2015. (2012) p 37.

[2] B. Scrosati, J. Garche, (2010) Lithium batteries: Status, prospects and future. J. Power Sources 195(9) (2010) 2419-2430.

[3] X. Zeng, J. Li, Implications for the carrying capacity of lithium reserve in China. Resour. Conserv. Recy. 80(0) (2013) 58-63.

[4] K. Richa, C.W. Babbitt, G. Gaustad, X. Wang, A future perspective on lithium-ion battery waste flows from electric vehicles. Resour. Conserv. Recy. 83(0) (2014) 63-76.

[5] X. Zeng, J. Li, Spent rechargeable lithium batteries in e-waste: composition and its implications. Front. Environ. Sci. Eng. 8(5) (2014) 792-796.

[6] D.H.P. Kang, M. Chen, O.A. Ogunseitan, Potential environmental and human health impacts of rechargeable lithium batteries in electronic waste. Environ. Sci. Technol. 47(10) (2013) 5495-5503.

[7] J. Li, P. Shi, Z. Wang, Y. Chen, C.C. Chang, A combined recovery process of metals in spent lithium-ion batteries. Chemosphere 77(8) (2009) 1132-0036.

[8] X. Zeng, J. Li, N. Singh, Recycling of spent lithium-ion battery: A critical review. Crit. Rev. Environ. Sci. Technol. 44(10) (2014) 1129-1165.

[9] X. Zeng, J. Li, Innovative application of ionic liquid to separate Al and cathode materials from spent high-power lithium-ion batteries. J. Hazard. Mater. 271(2014) 50-56.

[10] Ministry of Industry and Information Technology of China. Operation of Chinese Lithium Ion Battery Industry in 2013. The Journal of New Industrialization 6 (2014) 6-7.

[11] X. Zeng, J. Li, Y. Ren Y Prediction of various discarded lithium batteries in China. IEEE I. Symp. Sust. Sys. (2012) pp 1-4.

[12] X. Zeng, J. Li, ALN Stevels, L. Liu, Perspective of electronic waste management in China based on a legislation comparison between China and the EU. J. Clean Prod. 51(0) (2013) 80-87.

[13] Information on http://www.macrochina.com.cn/english/

[14] X. Zeng, J. Li, L. Liu, Solving spent lithium-ion battery problems in China: opportunities and challenges. Renew. Sust. Energ. Rev. (2014) under review.