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STUDY OF LARGE FORMAT EV LITHIUM-ION BATTERY  
RECYCLING IN CHINA

PREPARED FOR



FINAL REPORT  
December 2018

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# STUDY OF LARGE FORMAT EV LITHIUM-ION BATTERY RECYCLING IN CHINA

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## Presentation Outline

- The Li-ion battery recycling market in China
- Li-ion battery recycling regulations in China
- Lithium ion battery recycling value chain
- Lithium ion battery recycling processes
- Li-ion battery recycling cost & revenues
- 11 major recyclers profile
- Conclusions



# TABLE OF CONTENTS

- The Li-ion battery recycling market in China
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- Lithium ion battery recycling processes
- Li-ion battery recycling cost & revenues
- 11 major recyclers profile
- Conclusions

# OBJECTIVES

- ④ Chinese xEV battery recycling company volumes and footprints including any plans for expansion into North America
- ④ Summary of the partnerships / interactions between recyclers and other entities in the value chain, vertical integration etc.
- ④ Large format lithium ion battery recycling technologies that exist today in China and the comparative value they are able to extract from xEV batteries. Volumes, form of process (by) products and down-stream customers types (industry)
- ④ Ecosystem details for major recycling streams – Consumer, LFP large format and NMC large format – difference in economics
- ④ Subsidies on collection, processing or capital
- ④ New technologies that are being developed by Chinese xEV battery recycling companies Including any technology uncertainties and environmental concerns
- ④ Barriers to commercializing industrial scale, cost positive recycling processes developed in China in North America
- ④ Impacts that battery chemistry changes in lithium-ion xEV batteries have on various lithium-ion battery recycling technologies currently used in China
- ④ Chinese pack dismantling practices and associated costs – 3rd party or recycler dismantled?
- ④ Rough allocation of total EOL (End Of Life) costs between transport/ dismantling/ recycling
- ④ Five largest contributors to logistics costs in China
- ④ Regulatory factors in China (including environmental, technological and logistics) impacting the recycling ecosystem for xEV batteries
- ④ Interviews with 14 leading large format xEV lithium-ion battery recyclers in China

## CHINESE COMPANIES INVOLVED IN LITHIUM ION BATTERY RECYCLING

	Company included in the scope of the survey	Others involved in Li-ion battery recycling
<b>Recyclers</b>	<b>BRUNP</b>	Shanghai Jinqiao Group
	<b>GEM</b>	Taisen Recycling Group
		TES-AMM Suzhou
		Huanwu Nanjing
		Jiangmen Litong
		Tele Recycle
<b>Metal suppliers</b>	Jiangxi Ganfeng	Hanrui Cobalt
	<b>Huayou Cobalt</b>	Jinchuan science & technology co
<b>Battery component suppliers</b>	Ningbo Shanshan	<b>Guangdong Guanghua Sci-Tech Co. Ltd (JHD)</b>
<b>Li-ion battery / lead acid manufacturers</b>	Narada	BYD
	Chaowei Power (Chilwee)	CALB
	Camel Group	<b>Highpower International (1)</b>
		BAK
		Hefei Guoxuan High Tech Co
		CNAC Lithium Battery
<b>OEM</b>		Shandong Green new Energy
		BAIC

*In Red: Company white listed by the MIT*

*Other company involved in Battery recycling in China: Fangyuan Environmental Protection, Xien Technology, Jinyuan New Materials, Henan Electric Power Research Institute - (1) Ganzhou Highpower Technology is the affiliate involved in the recycling*

# METHODOLOGY

Contacts details in Excel files  
~100 contacts

Contacts with more than 50 people – 14 detail interviews

Company	M	First Name	Last name	Title
CATL – BRUNP	Mr	Robert	Galyen	CATL
BRUNP	Mr	Hagel	Yuhaijun	Battery Recycling Leader
CAMEL GROUP CO., LTD.	Mr	Jocelyn	Lau	Waste Director Li-ion batteries Recycling Dep.
Chaowei Power Holdings Limited	Mrs	Grace	Wen	manager of international market
GEM Co Ltd	Mr	Yuan	King	Battery recycling dept manager
Jiangxi Ganfeng Lithium Co Ltd	Mrs	Huoqing	Liao	Export & Sales manager Lithium Salts and Li Metal
Huayou Cobalt	Mr	Hayden	Qian	International Raw Materials Procurement Manager
Li Tong	Mr	Br	Shawn	BD manager
Narada Power Source Co.	Mr	Guo	Lei	Product Manager
Narada Power Source Co.	Mr	Jimmy	Zhang	Director of Energy Storage (ESS) Business
NINGBO SHANSHAN CO., LTD.	Mrs	Zara	Zhou	Marketing & Sales Manager
OnTo Technology LLC	Mr	Steve E.	Sloop	President
Taisen Recycling Group	Mr	Jaiden	Wu	CEO
CIAPS, TIANJIN INSTITUTE OF POWER SOURCE	Mr	JIQIANG	Wang	President
Guangdong Guanghua Sci-Tech Co	Mr	Darren	Chen	Overseas Division Manager

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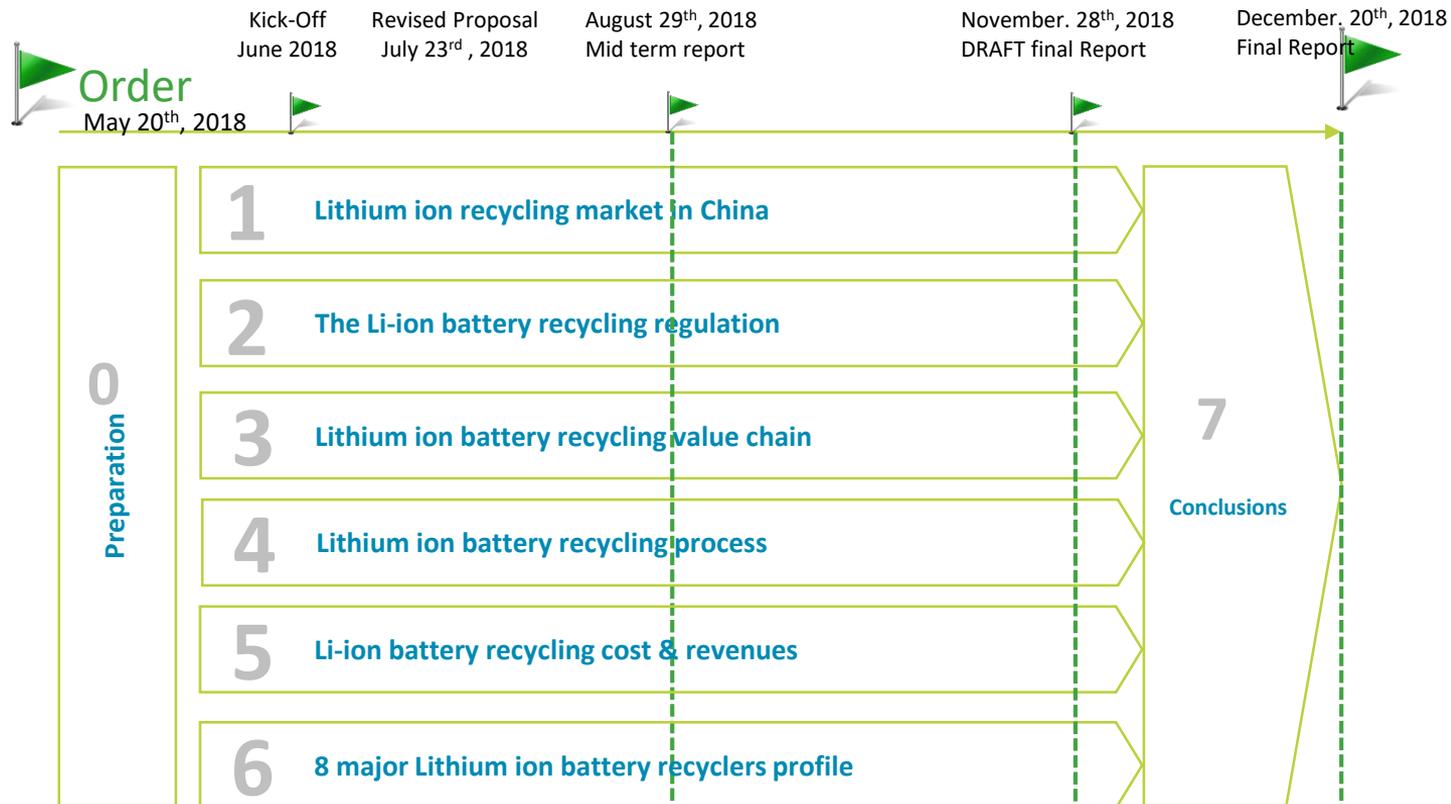


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# PROJECT SCHEDULE & PLANNING



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# 1- Li-ion battery recycling market in China



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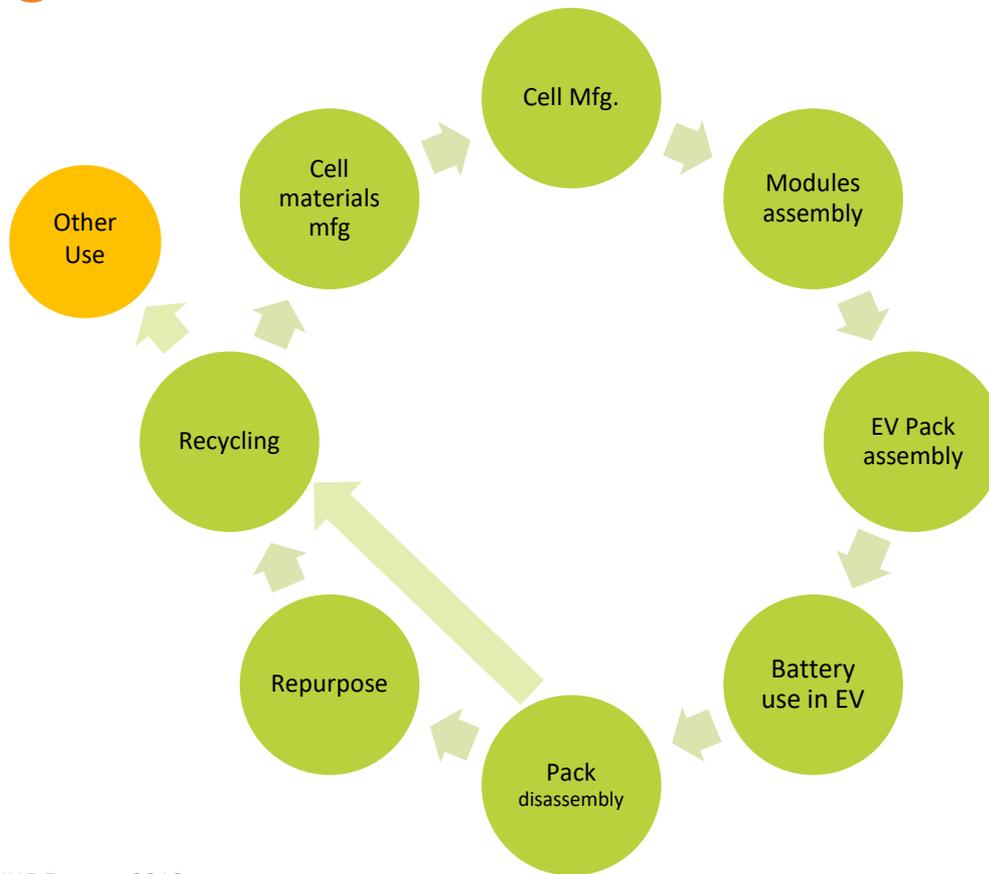


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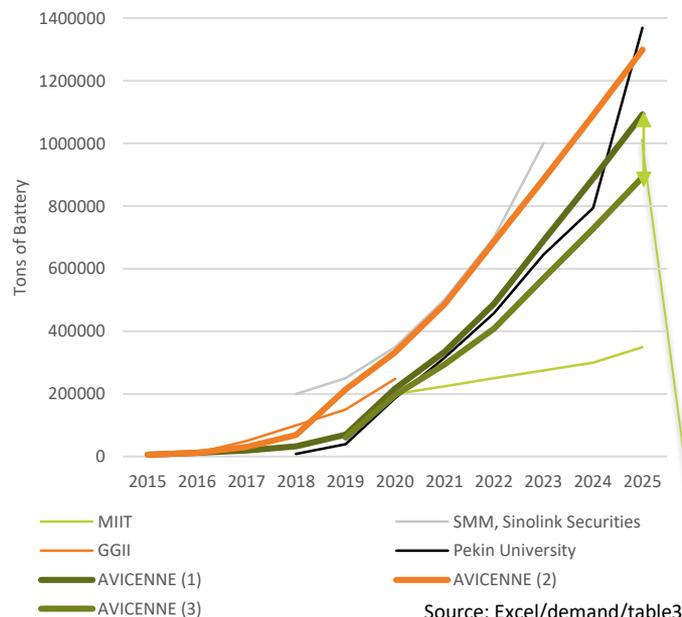
# LITHIUM ION REPURPOSE & RECYCLING STEPS



Source: AVICENNE Energy, 2018

# BATTERY RECYCLING MARKET IN CHINA

The NEV<sup>(1)</sup> lithium ion battery pack to be recycled, including mfg. Scrap will reach 200 kT in 2019-2020 and 400 kT in 2020-2021



- (1) NEV: New Electric Vehicle (EV + PHEV)  
 (2) Sources: GGII: Gaogong Industry Research Institute, SMM: Shanghai Metals Market, Avicenne Energy 2018

## Rationales

- 1 Explosive growth of new energy vehicles in China will pose a great challenge to battery recycling
- 2 Today, manufacturing scrap portion is quite significant but percentage will decrease rapidly and will become a non significant part as the portion of End Of Life batteries increase.
- 3 Ministry of Industry and Information Technology said it expects retired batteries will together weigh around 200,000 Tons by 2020.
- 4 The China Automotive Technology and Research Center estimated that figure would reach 350,000 Tons by 2025.
- 5 According to China Securities Journal, the battery recycling segment is a new gold mine thanks to its market size, which stands at 5 billion yuan (\$788 million) this year, and is expected to double by 2020. Chinese Institutes has the same figures
- 6 We identified more than 35 players in the Li-ion battery recycling business. There are probably more.
- 7 Estimated lithium ion battery recycling capacity: 100 000 Tons in 2018, 500 000 Tons in 2020 and > 1 million Tons in 2025.

- (1) Scenario 1 – Battery life time: 6 years
- (2) Scenario 2 – Battery life time: 5 years
- (3) Scenario 1 + considering 20 GWh annual market in 2025 for 2<sup>nd</sup> life batteries used for ESS, back-up for Telecom, etc... (50% of the total ESS market) ; 20GWh will represent roughly 20% of the end-Of-Life batteries.

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# KEYS TO SUCCESS IN RECYCLING IN CHINA

## Established

- 📌 LCO small cell collection to demonstrate processes
- 📌 Auto pack collection companies established and selling black mass to recyclers
- 📌 Black mass pricing established value for OEM and/or collection companies
- 📌 Many companies established in recycling value chain, most majors with good business models, ability to capitalize expansions and connections in the value chain appear to be headed toward profitability
- 📌 Recycling process demonstrating key metals extraction in order to capture metals value to markets, including reuse in batteries
- 📌 Recycling costs for battery packs expected to be profitable for NMC and LFP systems when volumes exceed 20,000 metric tons per year
- 📌 Today pilot lines are not profitable; volumes are too low; no financial data for nowadays pilot lines
- 📌 Regulatory direction, support and path established for managing changing automotive electrification landscape

## Remaining Unknowns

- 📌 Uncertainty of supply of LCO cells with regulations limiting imports of spent batteries – will loophole of device import close?
- 📌 LFP near breakeven for recyclers with \$0 cost for LFP black mass – will government subsidize, drive shift to NMC or remain a cost to OEM?
- 📌 Effectiveness of lobbying by the recycling value chain – OEM to recycler for subsidies for LFP and capitalization
- 📌 Pilot production process continues validation and to show cost improvement with scale
- 📌 Some industry consolidation expected and seeing a few companies that are not profitable or see path to profitability to exit
- 📌 Additional white listed companies and pending additional recycling regulations?



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# 2- Li-ion battery recycling regulation

# CHINA LITHIUM ION BATTERY REGULATION

## Regulation continues to evolve and are not complete

- 📌 Process started in mid-1990s as the “problem” was starting to be defined with consumer batteries – review of 1996 – 2018 progress in the appendix
- 📌 2018 was a year of many changes to the regulatory and white listed landscape for Lithium Ion Batteries, the China Government took many steps to manage key issues that remain:
  - 📌 **Interim Measures on Traction Battery Recycling (February 2018)** – direct translation of summary in appendix
  - 📌 **Interim Administrative Measures on the Traceability of Traction Battery Recycling (July 2018)**
  - 📌 **White List of five NEV battery recycling enterprises which meet the requirements of the “Standard Requirements for the Comprehensive Utilization of Decommissioned NEV Power Batteries”. (July 2018)**
  - 📌 **Implementation of Pilot Projects on Traction Battery Recycling (July 2018)**
- 📌 China Industry Minister did not complete the comprehensive new battery recycling rules that were expected by year end 2018.
- 📌 Some programs like white listing, economic uncertainty for many chemistries and the pilot projects suggest further evolution will be needed for lithium ion battery recycling regulations in China.

# THE LI-ION BATTERY RECYCLING REGULATION

## Regulatory Environment still has lots of remaining issues

- ④ Low professional standards (not true for all the players), poor safety, low barriers to entry, and unscrupulous dismantling in domestic power battery recycling enterprises
- ④ The relevant technical specifications are not yet perfect, the recycling system has not yet been established
- ④ The lack of power battery recycling penalties mechanism (some rules are in place but no penalties if company do not follow the rules)
- ④ Today the business is not profitable
  - ④ **Volumes are not meeting process economics and LFP systems are not profitable ; NMC pack recycling will be profitable**
  - ④ **Understanding business models of recyclers was difficult (timing wise) as they seem to be presently lobbying government for subsidies and thus reluctant to share 'positive' business models**
- ④ The urgent need to develop incentives for the implementation of battery recycling regulations, the establishment of a clear reward and punishment mechanism.
- ④ Most of the lithium batteries to be recovered in the current stage have no economic value and enterprises are not enthusiastic about recycling.
- ④ Today, no government incentive for collection / transportation or recycling EV batteries.
- ④ It is expected that “White listed” companies will get incentives at least to recycle LFP packs (not decided yet) – **But, our survey demonstrates that both LFP and NMC pack recycling could be profitable in the future.**

# CHINESE RECYCLING REGULATION

- ① China will make manufacturers of electric vehicles (EV) responsible for setting up facilities to collect and recycle spent batteries, as part of its efforts to tackle mounting waste in the sector, **new interim rules published on February 2018.**
- ① EV manufacturers have to set up recycling channels and service outlets where old batteries can be collected, stored and transferred to specialist recyclers
- ① Together with battery makers and their sales units, carmakers must also set up a “traceability” system enabling the identification of owners of discarded batteries
- ① Dr. Zhang Tongzhu and Mr. Hu Jian are responsible for the battery recycling standard system in China
- ① China’s industry ministry urged the sector to introduce standardized designs and raise technology to “international” levels by 2020. **It plans to publish comprehensive new battery recycling rules before the end of 2018 – not issued yet.**
- ① While carmakers are technically liable for recycling batteries, in practice they sign deals with suppliers to recycle batteries on their behalf. The OEM will have to pay for the collection and any recycling costs.
- ① **On January , 2018, China banned the import of 24 recyclable materials, including plastic, paper, and e-waste such as batteries.** However, China imported large volume of used batteries as components of phones, laptops and other electronic devices. (not included in the scope of the survey)

# RECYCLING POLICY/INCENTIVES

- ④ China is launching an electric car battery recycling standard as old batteries are expected to come back in high numbers as EV adoption ramps up in the country.
- ④ The Ministry of Industry and Information Technology has already pushed a standard for tracking the entire life cycle of batteries in electric vehicles, but it is now establishing a new scheme with automakers to recycle the batteries at the end of life.
- ④ The ministry also promised to draw up policies to support battery recycling, making full use of existing tax incentives and creating innovative new financing methods.
- ④ The ministry has already published draft rules to create a “[traceability management platform](#)” aimed at tracking the entire life cycle of electric car batteries from production to disposal.
- ④ Feb 2018, “interim” rules: (take effect in August 1st, 2018)
  - ④ manufacturers of electric vehicles (EV) are responsible for setting up facilities to collect and recycle spent batteries
  - ④ The carmakers must also establish a maintenance service network allowing members of the public to repair or exchange their old batteries conveniently
  - ④ Together with battery makers and their sales units, carmakers must also set up a “traceability” system enabling the identification of owners of discarded batteries
  - ④ battery makers are also encouraged to adopt standardized and easily dismantled product designs, to help automate the recycling process. They must also provide technical training for car makers to store and dismantle old batteries
  - ④ The guidelines encourage battery-makers to strengthen cooperation with companies that can make a better and rational use of used batteries removed from new energy cars. Today, Guidelines are not subject to penalties or incentives.

# INTERIM ADMINISTRATIVE MEASURES ON THE TRACEABILITY OF TRACTION BATTERY RECYCLING

Issued by the Ministry of Industry and Information Technology (MIIT) on 03.07.2018)

- 1 In accordance with the “Interim Measures on Traction Battery Recycling” released this February, MIIT issued in July 2018 the “Interim Measures on the Traceability of Traction Battery Recycling”. The document announced the establishment of an administrative platform (<http://www.evmam-tbrat.com/>) where information concerning traction batteries will be collected.
- 2 Battery producers, automakers, vehicle recycling and scrapping enterprises, enterprises in the business of battery cascade utilization as well as battery recycling enterprises are responsible for uploading information on the batteries. Provincial Industry and Information Departments will be responsible for supervision and monitoring and for tracing the batteries in conjunction with relevant authorities at the same level. This regulation shall come into effect on 1 August 2018.

## ENTERPRISE WHITE LIST (FIRST BATCH) IN LINE WITH THE "STANDARD CONDITIONS FOR THE COMPREHENSIVE UTILIZATION OF DECOMMISSIONED NEV POWER BATTERIES"

(issued by MIIT on 27.07.2018)

- ① On 27 July 2018, MIIT announced a White List of five NEV battery recycling enterprises which meet the requirements of the "Standard Requirements for the Comprehensive Utilization of Decommissioned NEV Power Batteries".
- ① Besides Huayou Cobalt, Ganzhou Highpower Technology and JHD, the list also lists GEM and Brunp, which have close ties to BYD and CATL, China's largest traction battery manufacturers.
- ① These enterprises were chosen based on their scale, their rate of automatization, low energy consumption, environmental protection standards, efficient utilization of resources, and clean and high efficient technology. Going forward, they will receive strengthened support from the government.
- ① **It's very important to be "white listed" because only those company will get subsidies from the government**
- ① **To be white listed and chosen by the government, it is crucial to have good relationship with the government. Huge importance of lobbying.**

Number	Province	Enterprise
1	Zhejiang	Huayou Cobalt
2	Jiangxi	Ganzhou Highpower Technology
3	Hubei	GEM
4	Hunan	Brunp
5	Guangdong	JHD

- ① Brunp told AVICENNE that 3 other companies are now selected

# IMPLEMENTATION OF PILOT PROJECTS ON TRACTION BATTERY “RECYCLING” (MOSTLY BASED ON 2<sup>ND</sup> LIFE USE)

Jointly issued by MIIT, the Ministry of Science and Technology (MoST), MEE, MoT, the Ministry of Commerce (MofCoM), SAMR, and the National Energy Administration (NEA) on 25.07.2018)

- ④ Chinese call this project a « recycling » project but it is related to 2<sup>nd</sup> life: EV battery pack to be used by Telecom back-up batteries.
- ④ On 25 July 2018, MIIT jointly with MoST, MEE, MoT, MofCom, SAMR and NEA announced 17 pilot areas for the implementation of a traction battery recycling system: the Jing-Jin-Ji region, Shanxi Province, Shanghai City, Jiangsu Province, Zhejiang Province, Anhui Province, Jiangxi Province, Henan Province, Hubei Province, Hunan Province, Guangdong Province, Guangxi Zhuang Autonomous Region, Sichuan Province, Gansu Province, Qinghai Province, Ningbo City, and Xiamen City.
- ④ The pilot projects are part of an ongoing effort to build a system for recycling traction batteries by 2020 and to explore innovative cooperation mechanisms. This involves
  - ④ setting up production lines, efficient retrieval of batteries,
  - ④ the commercialization of the recycling system,
  - ④ developing benchmark recycling companies,
  - ④ key recycling technologies,
  - ④ relevant standards and supporting policies.
- ④ This project is not related to Recycler white list release.
- ④ The pilot phase will last for no longer than two years. China Tower Co., Ltd. will be in the lead to integrate the pilot projects, to report on them, to develop a battery cascade utilization demonstration project, and to establish an industry association.



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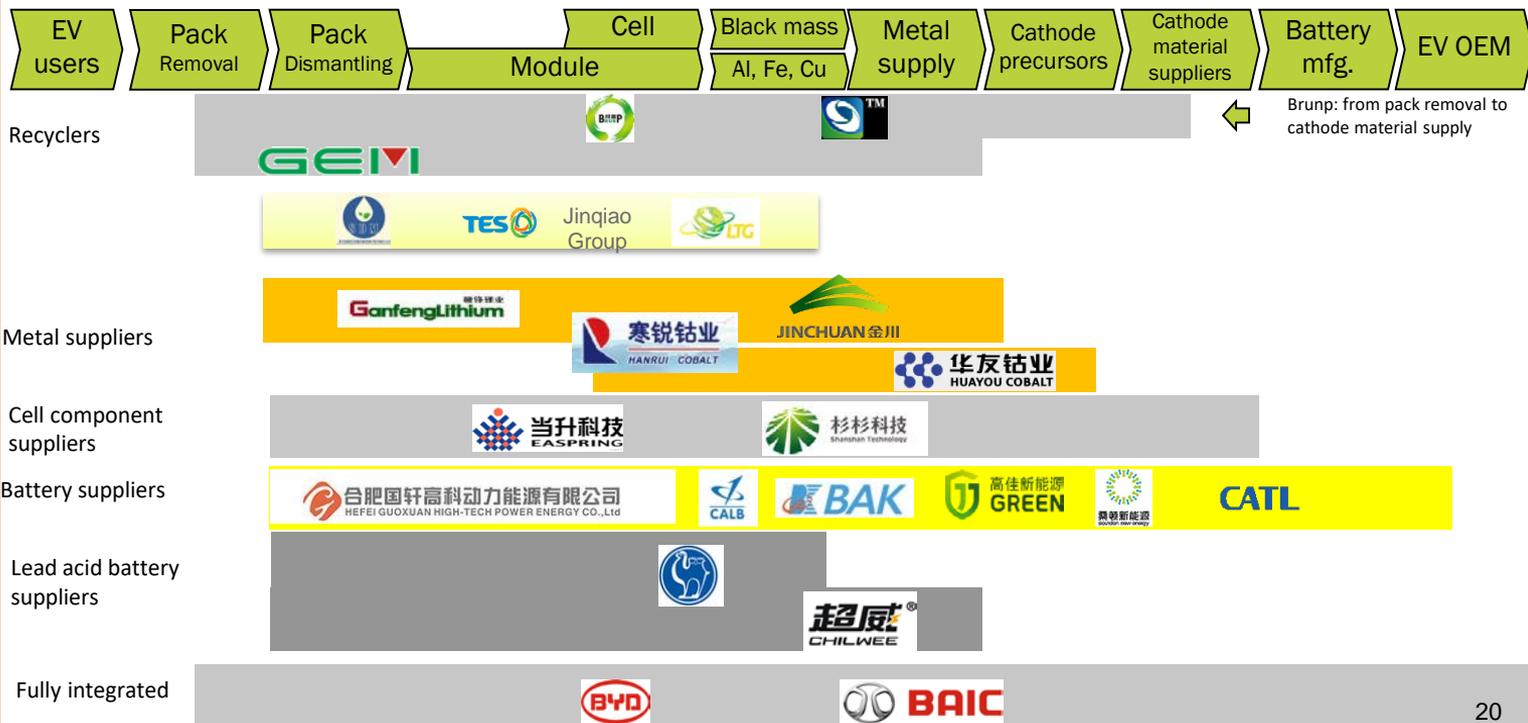
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# 3- Li-ion battery recycling value chain

# THE LI-ION BATTERY RECYCLING VALUE CHAIN IN CHINA

Recycling attracts lot of different players from metal suppliers, cathode suppliers, cell mfg., lead acid battery mfg., OEM and E-waste recyclers



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# 4- Li-ion battery recycling process

# RECYCLING PROCESS IN CHINA

- 🕒 Most of the companies are still at a pilot scale
- 🕒 They all except Taisen have the same process steps (Process Map Next Page):
  - 🕒 Manual dismantling of the pack
  - 🕒 Then, module dismantling or direct smelting
  - 🕒 Standard process in China:
    - 🕒 Soaking in salt solution
    - 🕒 electrical discharge
  - 🕒 Mechanical separation
  - 🕒 Leaching
  - 🕒 Refining with hydro metallurgical process
- 🕒 Special process from Taisen Recycling Group: they do not discharge the cell or the module before crushing: During the crushing process, they do not need to soak the battery into salt water to discharge the battery because the crushing process leaching by water. Meaning crushing under water to prevent fire or short circuit or heat. Taisen claims that their process 100% safe and the water is reused for crushing.

# RECYCLING PROCESS

## Pre-treatment

- ② Module dismantling + discharging + purely mechanical separation which results in a black mass.
- ② Module dismantling + discharging + incineration + mechanical separation which results in a black mass.
- ② Direct smelting which results in an alloy containing Co and Ni and a slag containing Li

## Refining

- ② Metal recovery: Leaching (either of the black mass and/or the alloy or slag) followed by various hydro-metallurgical steps such as extraction/precipitation to produce salts or precursor materials for the manufacture of active cathode materials
- ② Regeneration of cathode materials

①

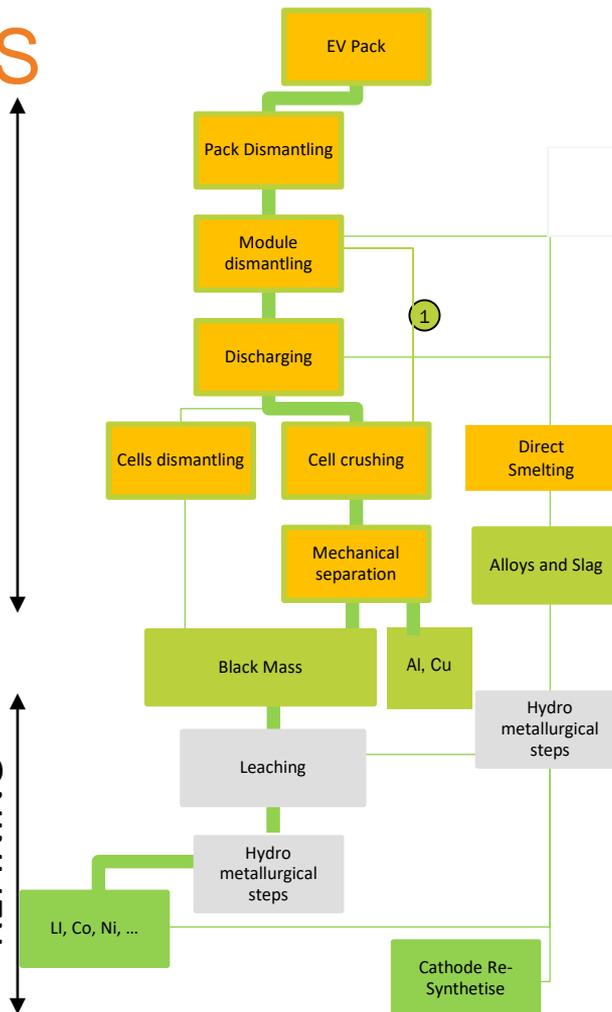
Taisen developed a process where they do not discharge the cell before crushing process leaching by water

Most of the time, they have to batch process for different chemistries (Source: GEM, Ganfeng Lithium, Narada, )

Sources: AVICENNE ENERGY 2018, Interviews

PRE-TREATMENT

REFINING





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# 5- Li-ion battery recycling cost & revenues

# BATTERY RECYCLING COST & VALUE OF THE RECYCLED WASTE

## General comments

- 🔗 Today, as volume are small, it is difficult to make profit with Li-ion battery recycling
- 🔗 Recycler claim that they need subsidies to make profit with recycling
- 🔗 Some Universities research and our data show that Lithium ion recycling could be profitable (both LFP and NMC)
- 🔗 With the increase of the volume, Lithium ion battery recyclers will make profit, especially with NMC technology.
- 🔗 Battery recycler is buying the old NMC pack, cell or black mass at a price indexed on the Co price, this pricing/value was established by companies to cover cost of dis. EVs and sending battery packs to recycler, in most cases different companies than recycler
- 🔗 One Ton of old NMC battery pack price= 50-60% of the Co content (50-60% x 40 kg Co x USD 50/Ton = USD 1,000 to 1,200 /Ton (assuming 40 kg of Co / Ton of battery)
  - 🔗 Co at 50,000 \$/Ton
  - 🔗 NMC 111 black mass at US\$ 2,750 \$/Ton
  - 🔗 NMC 532 or 622 black mass at 1,375 \$/Ton
  - 🔗 NMC 111 EV pack at roughly US\$ 1,200 / Ton
- 🔗 For LFP, it will be also possible for recycler to make a profit, mostly thanks to Li & Cu value. To be profitable, recycler will not have to pay for LFP pack in the near future in China, however collection step will be at a loss..

LFP

NMC  
&  
LFP

Materials extracted from one Ton of lithium-iron-phosphate battery waste stood at 8,110 yuan (US\$ 1,273), but the cost of recycling them would be 8,540 yuan (US\$ 1,341). *“Because policies are not enforced and there is no clear incentive mechanism, lithium battery recycling is not profitable.”* (Zhang Tianren, chairman of the battery maker Tianneng Power, Oct 2017)

Companies are unwilling to participate in it due to the high cost and little profit of battery dismantling. A company using mechanical and hydro metallurgical recovery technology to recycle ferric phosphate lithium battery revealed that it costs 8,540 yuan to recycle a Ton of used ferric phosphate lithium battery while only gains 8,110 yuan profit (recycled materials value), with a loss of 430 yuan.

In the other hand, researchers from Peking University and Industrial Innovation Centre in Shenzhen (1) analyse that *“the recycling of spent power battery is profitable, therefore, there is no need for government to take no additional economic incentives, like subsidies or tax reduction. Driven by interests, the entrepreneurs would automatically take on the recycling and strenuously maximize the recovery rate. However, if the added economic incentives were given, some companies were inclined to take informal measures, like subsidies deception, which is unfavorable to the market competition instead.”*

# BATTERY RECYCLING COST & VALUE

## Definitions & assumptions

Details in Excel Table

### Battery recycling value calculation (NMC 111)

(NMC 111 example)

Cobalt	40
Nickel	36
Lithium Carbonate	77
Iron	
Aluminium	88
Copper	125

Source: Excel/value/table 5

Metal content (kg) in 1 Ton of  
EV battery pack (Li, Ni, Co, Cu,  
Al, Fe)

Recovery efficiency<sup>(1)</sup> (%)

Cobalt	90%
Nickel	90%
Lithium Carbonate	85%
Iron	50%
Aluminium	90%
Copper	90%

Source: Excel/value/table 6

X

Cobalt	50
Nickel	13
Lithium Carbonate	15
Iron	0.1
Aluminium	2
Copper	7.5

Source: Excel/value/table 7

Metal  
Price  
(\$/kg)

Metal recovery in 1 Ton of  
EV battery (kg)  
(Li, Ni, Co, Cu, Al, Fe)

Cobalt	36
Nickel	33
Lithium Carbonate	67
Iron	
Aluminium	79
Copper	112

Source: Excel/value/table 6

X

Value recovered  
from metals  
(\$/Ton of battery pack)

Cobalt	1,796
Nickel	426
Lithium Carbonate	1,029
Iron	~0
Aluminium	158
Copper	844

Source: Excel/value/table 9

Total metal recovery per  
Ton of NMC 111 battery  
pack: US\$ 4,254 / Ton

(1) Recovery efficiency: quantity of metal Recover / total quantity of metal in the pack

# BATTERY RECYCLING VALUE IN CHINA

## Assumptions & rationales

- ① Recovery The value extracted from battery recycling is highly dependent on
  - ① Metal pricing
  - ① efficiency
  - ① Recycler then may provide precursor or cathode active material (in that case they get the value of metal recovery but all the cathode value chain will remain the same – No recycler has established significant precursor or cathode capability, to date, only small volume pilots for precursors. – Future question is Cathode production too specialized for recyclers to produce competitively?)

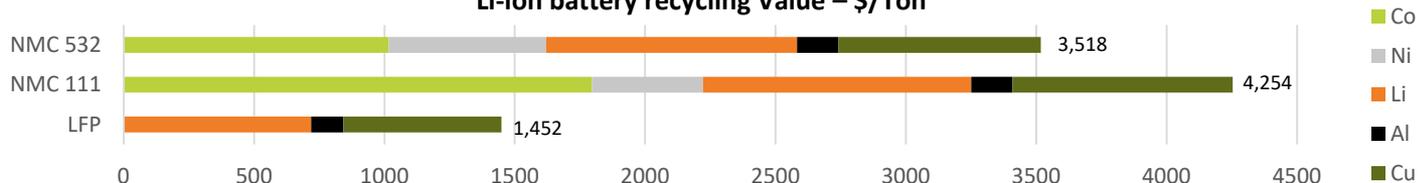
### ① Average data used for calculation (see also excel file for details)

Kg of metal/Ton of pack	Average Metal content in 1 Ton of EV battery			Recovery efficiency	Average Metal Price		Average Metal Value		
	LFP	NMC 111	NMC 532		RMB/Ton	\$/kg	\$/Ton	NMC 111 \$/Ton	NMC 532 \$/Ton
Cobalt	-	40	23	90%	333,333	50		1,796	1,017
Nickel		36	52	90%	86,667	13		426	604
Lithium Carbonate	54	77	72	85%	100,000	15	719	1,029	962
Iron	80			50%	667	0.1	4	~ 0	~ 0
Aluminium	65	88	88	90%	13,333	2	124	158	158
Copper	85	125	115	90%	50,000	7.5	606	844	776
							1,452	4,254	3,518

Source: Excel/value/table 5      value/table 6      value/table 7      TOTAL      value/table 8      value/table 9

Some of those data are very volatile but you can directly change it in the excel file

Li-ion battery recycling Value – \$/Ton



Source: AVICENNE Energy, 2018

STUDY OF LARGE FORMAT EV  
LITHIUM-ION BATTERY  
RECYCLING IN CHINA

PREPARED FOR



FINAL REPORT  
December 2018

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# BATTERY RECYCLING COST

## Definitions & assumptions

EV Pack



Lithium Carbonate,  
Ni, Co, Al, Cu...

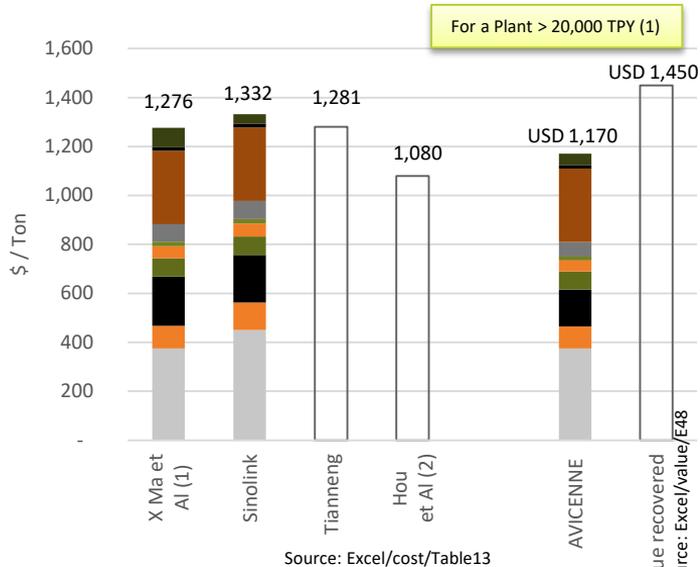
### Battery cost split:

-  Material recovery (used battery pack cost paid by the recycler to the OEM): Will be 0 for LFP pack and indexed on Cobalt price for NMC: on average, recyclers have to pay RMB 7,500/Ton (USD 1,100-1,200 /Ton) for NMC 111 battery pack
-  Collect & storage: paid by the recycler
-  Transportation, paid by the recycler
-  Pack Dismantling cost; made by the recycler
-  Pre-treatment cost
-  Refining cost

# BATTERY RECYCLING COST IN CHINA

## LFP recycling cost

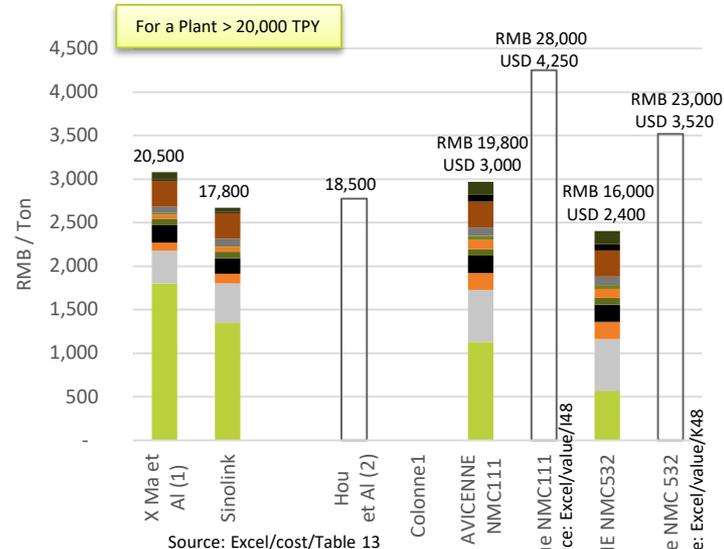
RMB 7,800/Ton – USD 1,170 \$/Ton



- Material recovery
- Accessory material
- Energy
- Dismantling
- Pretreatment
- Environmental
- Handling expenses
- Labor charge
- Transportation
- Maintenance
- Depreciation

## NMC111 recycling cost

RMB 19,800/Ton – USD 3,000 \$/Ton



- Material recovery
- Accessory material
- Energy
- Dismantling
- Pretreatment
- Environmental
- Handling expenses
- Labor charge
- Transportation
- Maintenance
- Depreciation

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(1) All the players explain us that today it is impossible to make profit because volume are too small. They told us that the minimum capacity to make profit is in the range of 15,000 to 20,000 Tons of battery packs or about 50,000 NEV battery.

Source: Avicenne Energy, 2018

# COST & REVENUE OF RECYCLING IN CHINA

STUDY OF LARGE FORMAT EV  
LITHIUM-ION BATTERY  
RECYCLING IN CHINA

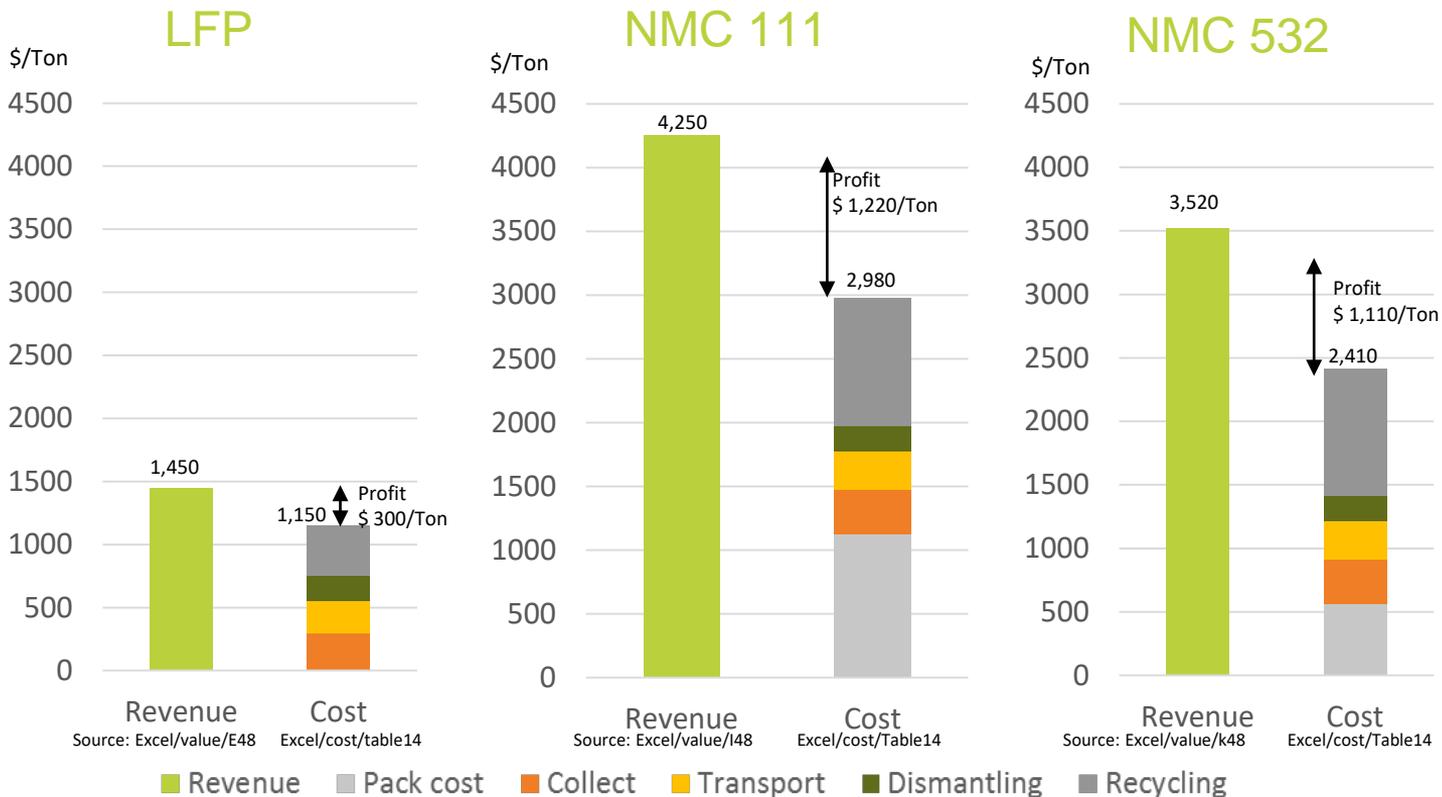
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For > 20,000 Tons of battery pack recycled / year



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RECYCLING IN CHINA

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# 6- Major recyclers profile

# MAJOR RECYCLERS IN CHINA

8 companies were pre-selected for the survey, but some other players included as they seemed important during the survey

Only Li-ion batteries (from electronic devices & xEV)

Companies	Capacity in 2018 (Tons)	Capacity in 2020 (Tons)	Capacity in 2025 (Tons)	Core Business
<b>BRUNP</b>	10,000 (4) (90% electronic devices, 80% LCO & 20% NMC)	40,000 (75% of NMC, 25% LCO)	100,000 (95% NMC, NCA)	
<b>GEM</b>	30,000 Focus on NMC	300,000	300,000	E-waste Recycler
<b>Huayou Cobalt Co</b>	5,000 (focus on NMC)	Not decided yet		Co supplier
Ganfeng Lithium	20,000 (LFP)	30,000 (50% LFP – 50% NMC)	40,000	Li supplier
Shanshan	0	10,000 (focus on NMC)	50,000	Cathode, anode & electrolyte supplier
Narada	Pilot (LFP)	20,000 (LFP)	40,000 (75% LFP – 25% NMC)	Lead acid batteries
Camel	5,000 (LFP & NMC)	20,000–50,000 mainly NMC	300,000	Lead acid batteries
Chaowei Power	Pilot (NMC)	Not decided yet	Range of 10,000 (3)	Lead acid batteries
<b>High Power Li</b>	5,000	Not decided yet		NiMH, Li-ion supplier
<b>Guanghua Sci-Tech</b>	12,000 (50% NMC, 50% LFP)	120,000 (LFP 75% - NMC 25%)		Chemicals
Taisen	10,000 (1) EV (40%): 60% of NCM 40% of LFP / Electronic (60%) : 100% LCO	30,000 (2) (75% EV: 50% NMC-50% LFP)		Li-ion battery recycler
Jinchuan science	5,000	Not decided yet		Ni & Co supplier

Pre-selected for the survey

In Red: White listed by MIIT – (1) additional 30,000 Tons in Korea – (2) + 50,000 in Korea (3) depending on the profitability; not sure yet (4) Source: interview with Mr. Yu Haijun, Brunp VP

Source: AVICENNE ENERGY 2018

# OTHER RECYCLERS IN CHINA

We identified more than 35 companies with projects in Li-ion battery recycling

Companies	Capacity in 2018 (Tons)	Capacity in 2020 (Tons)	Capacity in 2025 (Tons)	Core Business
Shanghai Jinqiao	Pilot	Not decided yet		E-waste recycler
Beijing Easpring	Pilot	Not decided yet		Cathode supplier
Shenzhen BAK	10,000	Not decided yet		Li-ion battery supplier
TES-AMM Suzhou	Pilot (25 Tons)	Not decided yet		E-waste recycler
Nanjing Huanwu Resource Recycling Technology Co	6,000	Not decided yet		E-waste recycler
Jiangmen Li Tong				E-waste recycler
Beijing Saidemei	10,000	Not decided yet		
BAIC	10,000	Not decided yet		
Soundon New Energy	Pilote	100,000		Environmental technology
Shandong Gao Jia New Energy Co (Green Energy)	Pilote	20,000		Battery supplier
.... And more (see excel table)				
<b>TOTAL</b>	<b>~ 150,000</b>	<b>~ 500,000</b>	<b>~ 1,000,000</b>	

# MAJOR RECYCLERS IN CHINA

## Inbounds / outbounds / international projects

Only Li-ion batteries (from electronic devices & xEV)

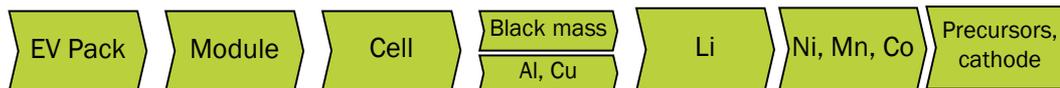
Companies	Capacity in 2018 (Tons)	Inbound	Outbound	International and US project?
<b>BRUNP</b>	10,000	EV	Precursors, LCO, NCM	Not yet
<b>GEM</b>	30,000	EV Packs	Li, Co, Ni, Al and Cu	No
Huayou Cobalt Co	5,000	Cells	Li, Co, Cu, Ni, and precursors	No
Ganfeng Lithium	20,000	EV Packs	Li, Co, Ni, Al and Cu	No
Shanshan	0	EV packs or cells ?	Cathode materials	No
Narada	Pilot	EV, E-buses packs	Cu & Lithium today (LFP only)	No
Camel	5,000	EV pack	Cu, black mass	No
Chaowei Power	Pilot	Stop for now	Stop for now	No
<b>High Power Li</b>	5,000	Packs	?	No
<b>Guanghua Sci-Tech</b>	12,000	Packs	Ni & Co sulfate, Li carbonate	Yes, in Korea
Taisen	10,000 (1)	Packs	Lithium Carbonate, Ni & Co sulfate	Yes (Korea, Vietnam,
Jinchuan science	5,000	?	?	?

*In Red: White listed by MIIT*

*Source: AVICENNE ENERGY 2018*

# RECYCLER MAJOR BUSINESS MODELS

We identify 5 major business models



From EV Pack to precursors & cathode materials  
Value: Cu, Al, Ni, Co, Li, Mn (1)

BRUNP, GEM, ShanShan,

From EV Pack to metals  
Value: Cu, Al, Ni, Co, Li, Mn (1)

GEM, Ganfeng LITHIUM, Highpower,  
Taisen,

From LFP EV Pack to Li  
Value: Cu, Li

Narada

From EV Pack to Al, Cu & Black mass  
Value: Cu, Black Mass

Camel, Li Tong, TES,

From cell to metals  
Value: Cu, Al, Ni, Co, Li,

Huayou Cobalt,

Then, players may decide to go further and manufacture Precursor or cathode active material ; in that case, they have their supply chain secured but do not have any advantage in term of Metal pricing or raw material cost (except the cost related to logistic). At this point in the value chain materials coming from recycling are considered the same as materials coming from mining. The current recyclers would need to invest capital to be capable to produce which would offset some of the additional profits. So, no impact on recycling profit expected in next 10 years as quantities are minimal, only at pilot stage so far, needs demonstration at scale and decisions by recyclers to produce precursors and cathodes.

(1) to be used internally for cathode active material manufacturing or sold



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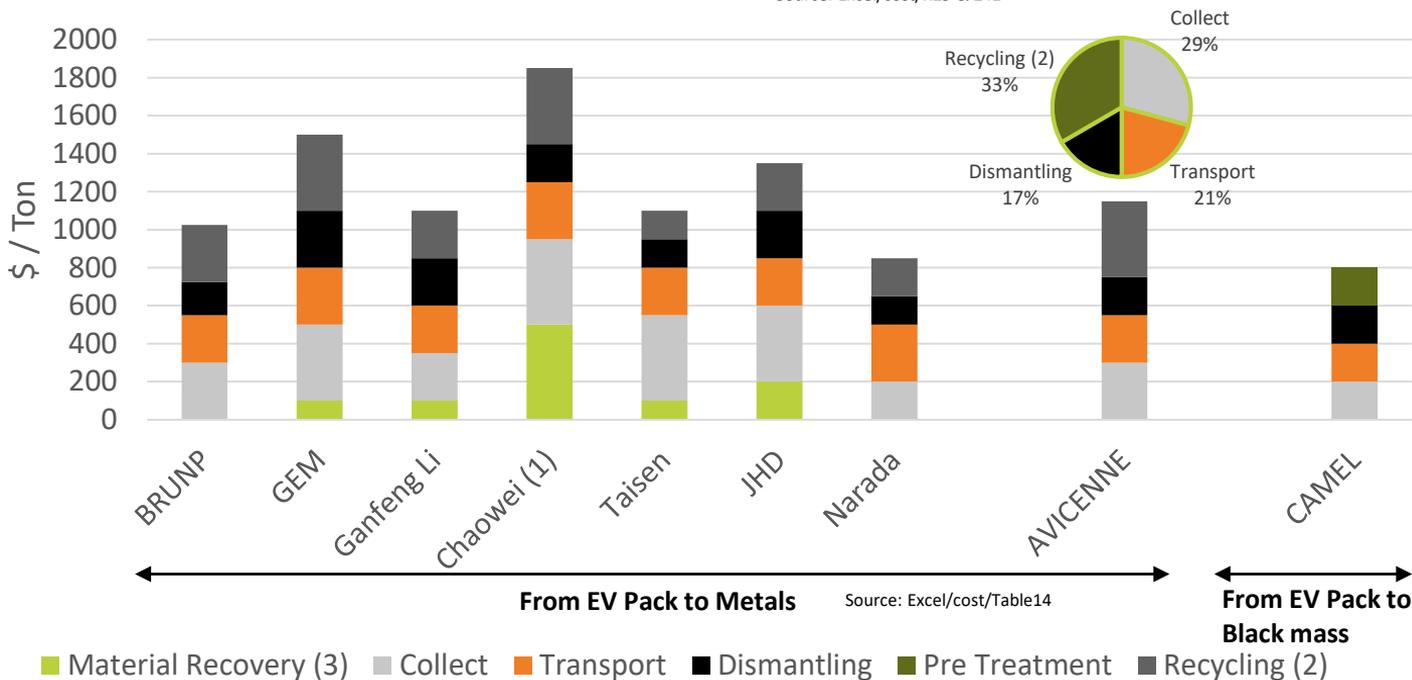
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# LFP RECYCLING COST

LFP recycling cost is estimated at US\$ 1,150 / Ton for high capacity (>20,000 TPY)

## LFP recycling cost: 1,150 \$/Ton

Source: Excel/cost/R19 & Z41



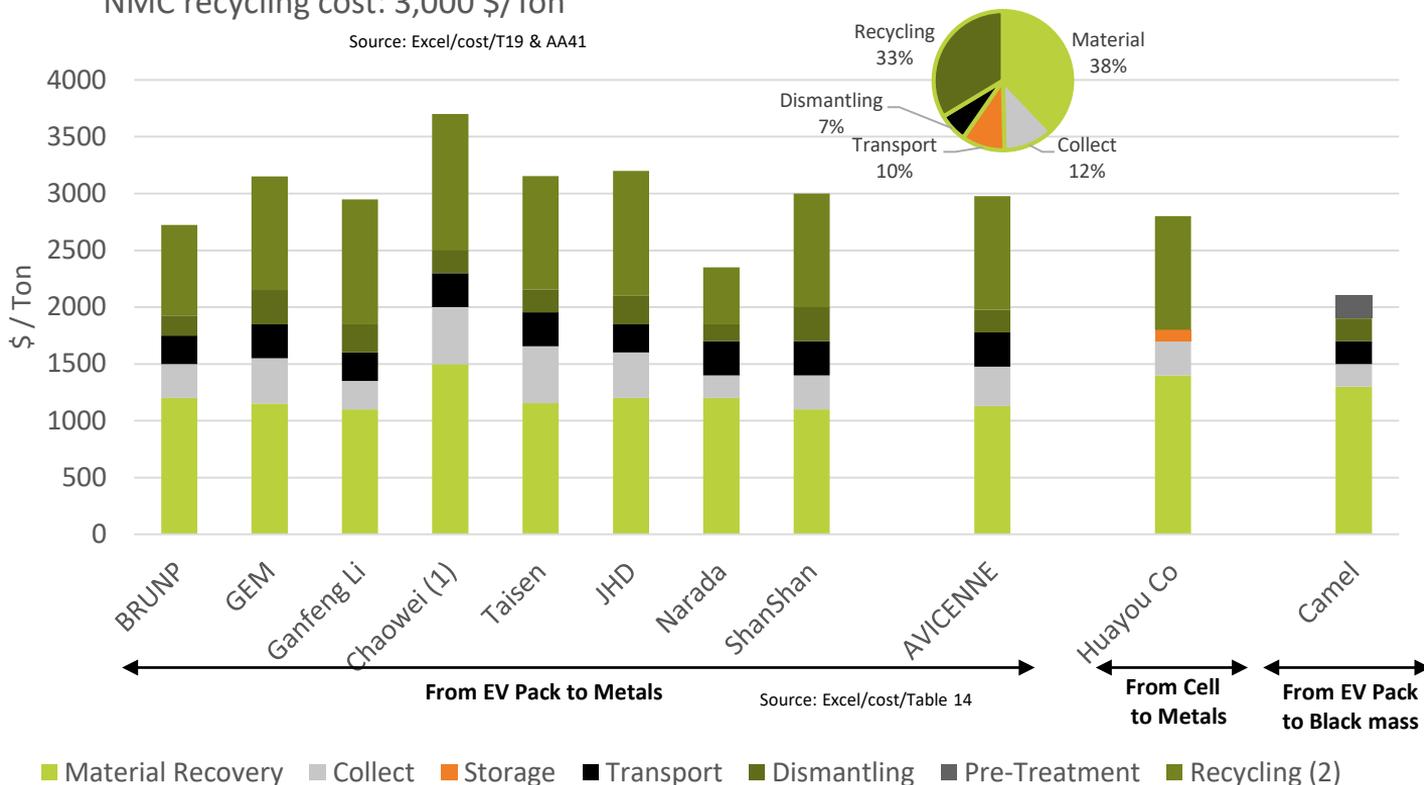
(1) Not anymore in the business (2) Pre treatment & refining (3) Material refers to the price recyclers have to pay to get the End Of Life Pack. – Source: Interviews, AVICENNE Energy 2018

# NMC111 RECYCLING COST

NMC recycling cost is estimated at US\$ 3,000 / Ton for high capacity (>20,000 TPY)

NMC recycling cost: 3,000 \$/Ton

Source: Excel/cost/T19 & AA41



(1) Not anymore in the business (2) Pre treatment & refining – Source: Interviews, AVICENNE Energy 2018

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# RECYCLING VALUE CHAIN

- ❶ Recyclers have to pay the OEM to get the old battery pack. LFP pack is free in most of the case. (Brunp, GEM, Ganfeng Lithium, Camel...). Others (Huayou Cobalt, ShanShan) buy cells from pack dismantlers.
- ❷ Then, the recycler pay to collect, transport, and all recycling processes
- ❸ Outbounds:
  - ❶ Black mass: CAMEL
  - ❶ Metals: GEM, Narada, Ganfeng Lithium, Guanghua Sci-Tech
  - ❶ Salts: Guanghua Sci-Tech, Taisen
  - ❶ Precursors: Huayou Cobalt
  - ❶ LCO, NCM...: Brunp, ShanShan,
  - ❶ Companies producing cathode may of course also supply precursors, salts, metals or black mass.

## Company profile

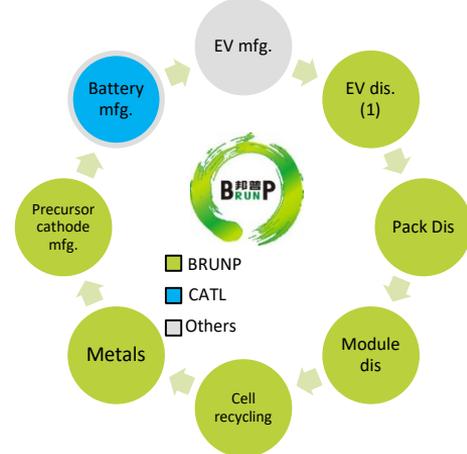
- 1 Founded: 2005
- 2 HQ: Guangdong Brunp Recycling Technology Co., Ltd - Registered capital of RMB 76.8 million.
- 3 Hunan Brunp recycling Technology Co., Ltd., Changsha, Hunan, - registered capital of RMB 60 million.
- 4 BRUNP's battery recycling activities are located in Hunan, whereas their R&D and precursor production are located in Guangdong
- 5 EV dismantling to cell recycling and precursor and cathode supplier

## Recycling capability

- 1 130000 square meters
- 2 >6,000 Tons of waste batteries annually (small cells mostly) – 2017 data
- 3 1,000 Tons HV batteries (Li-ion) in 2018
- 4 Total 2018: 10,000 Tons Li-ion batteries
- 5 White listed by the MIIT as “official Li-ion battery recycler”
- 6 Production (2018): 10,000 Tons of Nickel manganese cobalt hydroxides, NMC, Lithium cobalt oxide, cobalt chloride, nickel sulfate, cobaltous sulfate and cobaltous oxide (x2 compare to 2016)
- 7 Recovery average efficiency claimed by Brunp: more than 98.58%
- 8 Investing ¥1.2 billion (\$178 million) to build a 100,000 Tons waste battery plant in Changsha, Hunan Province, China – (Launch in Q4 2018) – Investment in the range of US\$ 1,800 / Ton
- 9 Process: Mechanical dismantling – Pretreatment – Hydrometallurgy
- 10 > 30 recycling outlets in China

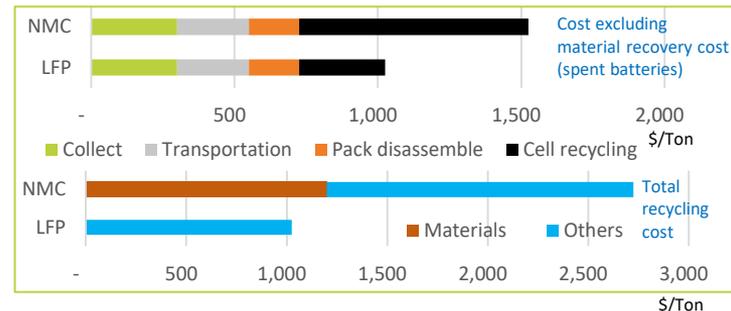
**Inputs**  
Small Li cells,  
Cathode materials<sup>2</sup>

**Outputs**  
Precursors, NCM



## Recycling Costs

For more than 20,000 Tons



## Partnership

- 1 CATL affiliate - the company owns its 66.72% shares
- 2 Major waste suppliers: BMW, BYD Auto,
- 3 May 2018, entered into a partnership with BMW Brilliance (a JV between BMW and Brilliance Auto a Chinese auto maker -in October 2018, BMW group took the full control of this JV: dismantle 100% of their cars (ICE & EV) and to recycle the battery packs.
- 4 Outbounds sold exclusively to CATL and CATL suppliers

(1) dis: disassemble (2) Cathode materials today, Full EV in the future

Source: AVICENNE Energy 2018

# GEM

<http://en.gem.com.cn>

## Company profile

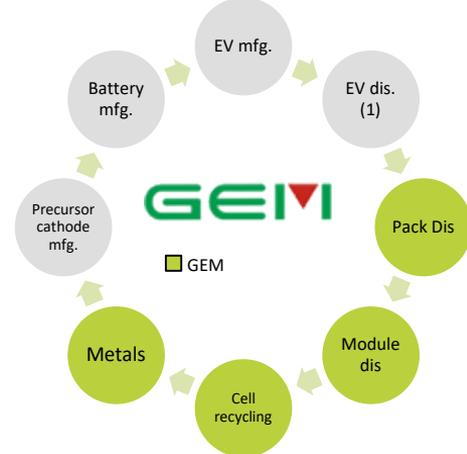
- 🕒 Founded: 2001
- 👥 6,000 employees
- 📊 Shenzhen Stock exchange – Market Cap: 21.3 B CNY (3.2 B USD)
- 💰 Total Revenue: 10.6 Billion CNY – 1.6 Billion USD – 6% profit margin
- 🌱 GEM is the first stock in China in exploiting urban mines, resources recycling field and WEEE recycling industries.

## Recycling capability

- 🕒 Planned Capacity: 300,000 Tons of batteries/y in 2020-2021
- 🕒 16 recycling plant in 2018 (5 for batteries – all kind) in 10 province: Guangdong, Hubei, Jiangxi, Henan, Tianjin, Jiangsu, Shanxi, Inner Mongolia, Zhejiang, Hunan and Durban in South Africa
- 🕒 Recycling = 25% of the revenues
- 🕒 > 4,000 Tons of Cobalt recovered from recycling (not only battery recycling)
- 🕒 Li-ion battery recycling capacity: 30,000 Tons in 2018 (2 times more than 2017)
- 🕒 White listed by the MIIT as “official Li-ion battery recycler”

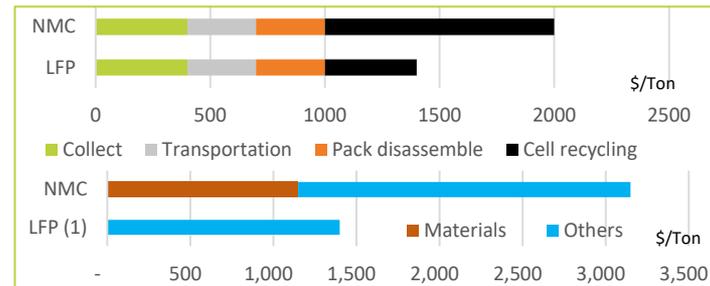
**Inputs**  
EV Packs  
**Outputs**  
Li, Ni, Co, Cu, Al

(1) dis: disassemble



## Recycling Costs

For more than 20,000 tons



## Partnership

(1) Today: 300 \$/Ton to bought LFP used pack

- 🕒 JV with Ecopro (92% GEM-8% Ecopro) to produce NCA precursor (10,000 t/yr)
- 🕒 Battery pack Reuse center (2<sup>nd</sup> life) with Samsung
- 🕒 Cooperation with SAMSUNG to establish the big circular system of power battery
- 🕒 Agreement since 2015 with BYD for battery end of life processing
- 🕒 Agreement with BAIC for Battery collection ; non exclusive

## Company profile

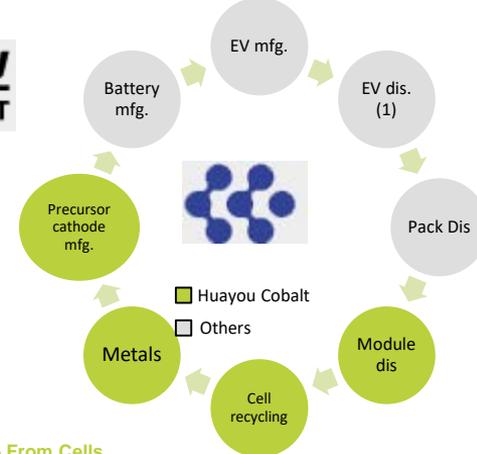
- Founded: 2002
- HQ: Tongxiang Zhejiang Province
- focusing on the nonferrous smelting of cobalt, nickel and copper, and the cobalt new materials deep processing.
- Revenues: RMB 10 Bn
- Market Cap: RMB 43.7 Bn

## Recycling capability

- White listed by the MIIT as “official Li-ion battery recycler”
- 5 000 Tons pilot recycling plant in 2018
- Mostly NMC cells
- 2019: 5,000 Tons
- 2020: increase the capacity (no comment on the additional capacity)
- They built some business models & business plan on a 20,000 Tons of battery recycling capacity
- Focus on NMC, not LFP

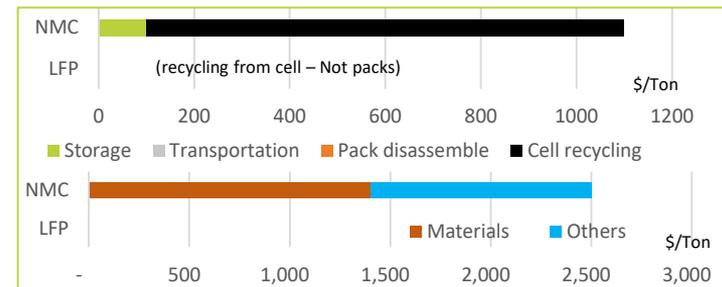
**Inputs**  
NMC Cells, few LFP, NCA

**Outputs**  
Metals, Precursors



## Recycling Costs

For more than 20,000 Tons – From Cells



## Partnership

- Huayou Cobalt and Posco will invest in two joint ventures in China’s Zhejiang province to produce lithium-ion battery materials
- 2 JV with LG: Investment of \$440-million to build a 40,000 t/y lithium-ion battery precursor materials plant and a 40,000 t/y cathode plant, in China, in 2019

## Company profile

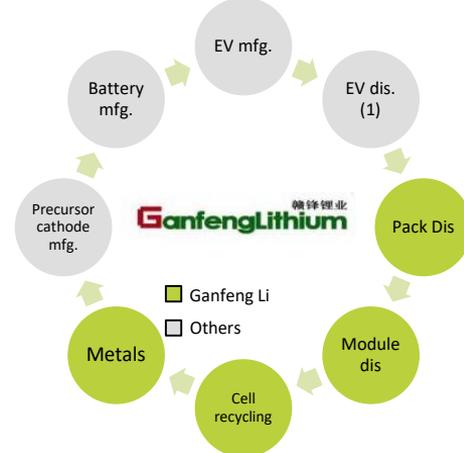
- 🕒 Founded: 2000
- 🕒 listed in China Stock market since 2010.
- 🕒 1,100 employees – 5 production site
- 🕒 Market cap: 34.5 Billion CNY
- 🕒 looking to raise \$1 billion from an initial public offering (IPO) in Hong Kong
- 🕒 Operations include lithium extraction, lithium compounds and metals processing as well as lithium battery production and recycling

## Recycling capability

- 🕒 20,000 Tons of batteries in 2018
- 🕒 In 2017, it was 10,000 Tons
- 🕒 Produce 1,000 Tons of LCE thanks to Li recycled in 2017
- 🕒 Capacity of 30,000 Tons planned for 2020 & more than 40,000 Tons for 2025
- 🕒 First step of investment was a RMB 12 Million investment in 2016 for a 5,000 Tons LFP recycling plant

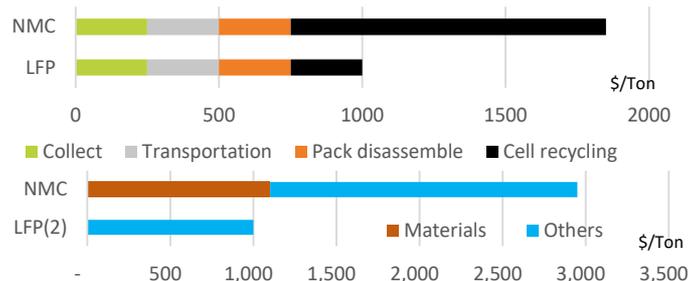
**Inputs**  
xEV Packs

**Outputs**  
Metals, Lithium  
Carbonate



## Recycling Costs

For more than 20,000 tons



(2) Today: 300 \$/ton to bought LFP used pack

## Partnership

- 🕒 Win contract with LG to supply 47,600 Tons LCE in the 2019-2022 period

# SHANSHAN

http://www.shanshan.com



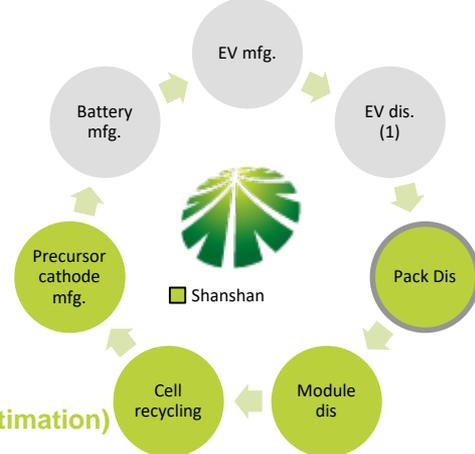
## Company profile

- Founded: 1992
- HQ: Wang Chun industrial Park, Ningbo
- Provides precursors and lithium battery materials in China and internationally
- Revenues: RMB 8.7 Bn – Profit: RMB 1 Bn
- Market Cap: RMB 19.7 Bn
- 4,700 employees

## Recycling capability

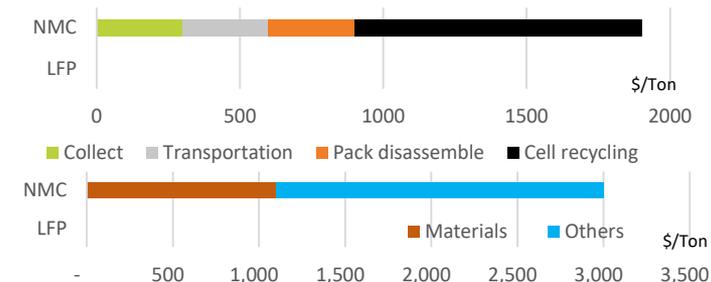
- Last February 2018, Shanshan Energy started building its new lithium-ion battery materials with an annual output by 100,000 Tons and in investing 775 M USD.
  - Inputs**
  - Not decided
  - Outputs**
  - Cathode
- In September 2018, Ningbo Shanshan group charge one of its subsidiary Shanshan Energy to be ready to enter in the Li-ion recycling business: started to build 2 months ago a recycling factory with a future capacity of 50,000 T/y. (2019)
- Inbounds have not be chosen yet: EV pack or only lithium ion cells
- Mainly focus on NMC

(1) dis: disassemble



## Recycling Costs (Estimation)

For more than 20,000 Tons



## Partnership

- Looking for pack dismantler

## Company profile

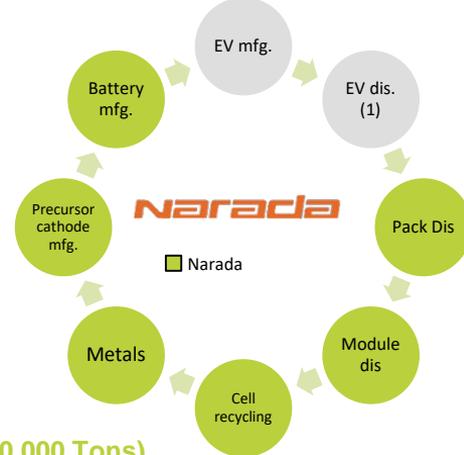
- 1 Founded: 1994
- 1 HQ: Hangzhou/China
- 1 Total revenues: 8,600 Billion RMB - 30% growth in 2017 – Recycling: 3,400 Billion RMB
- 1 Supplier of lead acid & Li-ion industrial batteries
- 1 Narada Power, which makes batteries and complete energy storage systems as well as acting as a project system integrator, is establishing a subsidiary for the recycling of lithium-ion batteries.

## Recycling capability

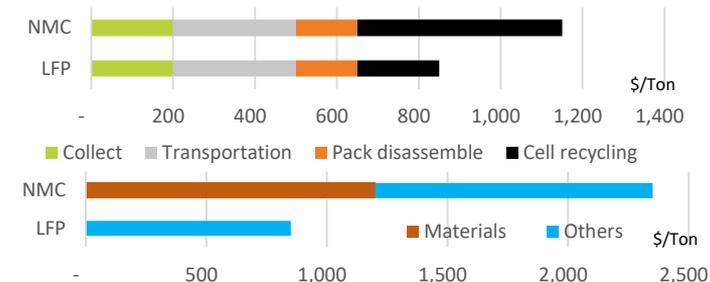
- 1 Anhui Narada Huabo New Material and Technology Co., Ltd. (ANHNMNT)— will be wholly owned by Narada and receive an initial cash injection of CNY100 million (\$15m).
- 1 Today Pilot line (10 Tons)
- 1 20,000 Tons plan for 2020 & 40,000 for 2025
- 1 Start with LFP
- 1 We will start our first pilot NCM recycling line in 2023

**Inputs**  
EV, E-buses packs

**Outputs**  
Li today  
Metals (2023)



## Recycling Costs (> 20,000 Tons)



## Partnership

- 1 Narada has acquired 49% equity in Huabo Technology, a leading player in China's battery recycling industry. It is expected that the capacity of Huabo Technology in lead battery recycling will exceed one million Tons in the future.

## Company profile

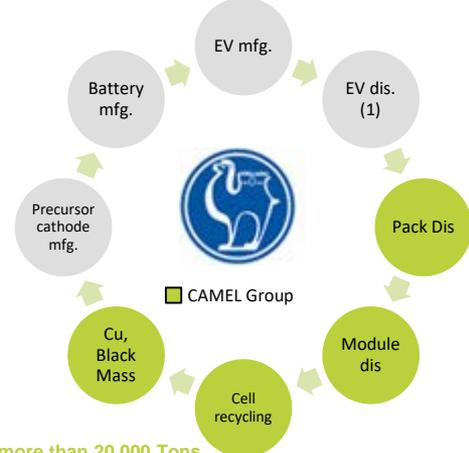
- 🕒 Founded: 1988
- 🕒 HQ: Xiangyang, Hubei
- 🕒 Camel Group Co., Ltd., is a China-based lead-acid battery manufacturer & recycler.
- 🕒 Revenues: RMB 8.65bn
- 🕒 5,700 employees
- 🕒 Market cap: RMB 9.8 bn

## Recycling capability

- 🕒 CNY3 billion will go to technological between 2018 and 2023:
  - 🕒 2018: 5,000 Ton power battery recycling pilot line
  - 🕒 2018-2019: demonstration module that can process 20,000 Tons of power batteries annually
  - 🕒 2020: 50,000 Tons of power batteries annually
  - 🕒 2025: 300 000 Tons/year
- 🕒 Li-ion production capacity: 2 GWh
- 🕒 Annual plastic production: 28,000 Tons
- 🕒 Annual recycling capacity mainly Lead acid: 250,000 Tons
- 🕒 Annual pure sulfuric acid production capacity: 18,000 Tons
- 🕒 have planned to reach 500,000 Tons of recycling lead acid capacity by 2020
- 🕒 Camel Black mass Average sales Price:
  - 🕒 LFP black mass: 8,000 CNY / Ton (1,160 US\$ / Ton)
  - 🕒 NCM black mass : 16,500 CNY / Ton (2,380 US\$ / Ton)

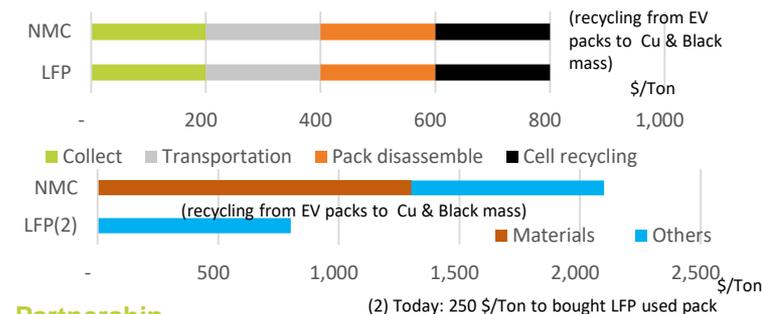
**Inputs**  
EV Pack  
**Outputs**  
Cu, Black mass

(1) dis: disassemble



## Recycling Costs

(EV packs to black mass) for more than 20,000 Tons



## Partnership

- 🕒 CAMEL has struck a deal with the People's Government of Gucheng county, Hubei province, on the company's investment in the power battery's echelon utilization and regeneration industrial park project
- 🕒 Planned to enter in 2020 the leasing vehicle business thanks to a partnership with Xiangyang Yuqing Electric-drive Technology Co., Ltd. to produce EV electrical motors & controllers - Camel New Energy to produce the battery

# CHAOWEI POWER (CHILWEE)

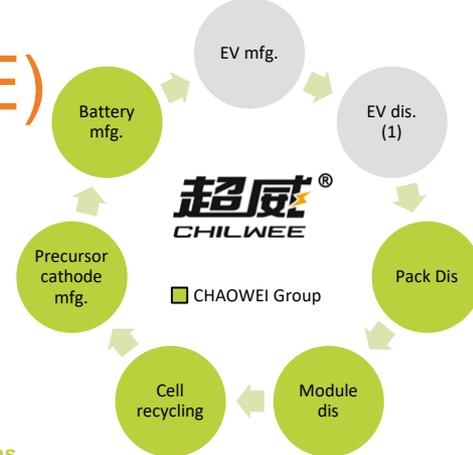
## Company profile

- 1 Founded: 1998 – Revenues: RMB 25 Bn – Profit: 12%
- 1 18,000 employees
- 1 HQ: Changxing County, Zhejiang Province
- 1 Chaowei Power is principally engaged in the manufacturing and sale of lead-acid motive batteries and other related products widely used in electric bikes, electric vehicles and special-purpose electric vehicles.
- 1 the largest manufacturer of traction lead-acid batteries in China, with a market share exceeding 40%.
- 1 Traction LABs make up ~75% of Chaowei's sales – EV LAB: 20% - Li-ion: 5%

## Recycling capability

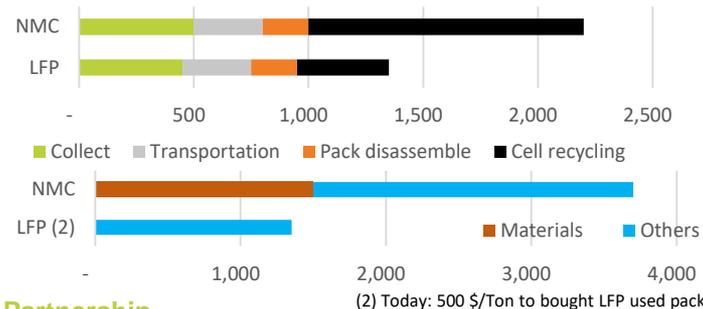
- 1 Regarding recycling we have tried to recycle Li-ion cell and especially NCM (LFP cells do not contain any high value component to recycle! We are not interested to recycle it)
  - Inputs STOP
  - Outputs STOP
- 1 We have tried several smelting processes in our laboratory then we have tried at a pilot scale....
- 1 We have stop since this date to recycle in house....due to economic reasons...NCM recycling business is not profitable today!
- 1 Our company has more than 200 collecting centers in China, we are able to recycle more than 30,000 GWh/year of lead acid batteries
- 1 Maybe in 5 years from now if the market is profitable we will invest in Li-ion recycling (at least 10,000 Tons if profitable)

(1) dis: disassemble



## Recycling Costs

For more than 20,000 Tons

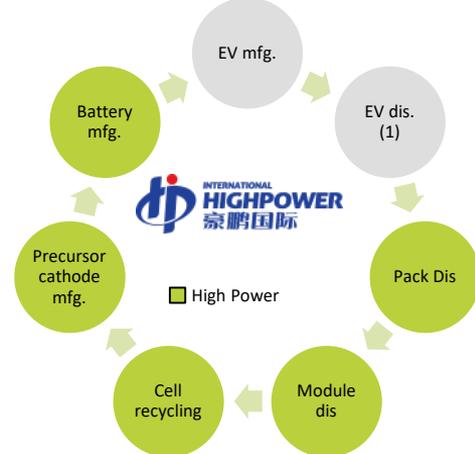


## Partnership

- 1 in 2016, we have worked with the US in partnership with Stanford University on the development of our lithium-ion battery

## Company profile

- 📌 Founded: 2001 – Revenues: RMB 25 Bn – Profit: 12%
- 📌 HQ: Shenzhen, Guangdong, China
- 📌 Manufacture and sales of Ni-MH and Li-ion rechargeable batteries, as well as energy storage systems and used battery recycling.
- 📌 In June 2008, Highpower was listed in NASDAQ, USA
- 📌 Market Cap: \$ 46.7 Million
- 📌 US\$ 244.2 Million in 2017
- 📌 One of the most important NiMH battery supplier



## Recycling Costs

For more than 20,000 Tons

- 📌 No recycling today
- 📌 Seems that they are not that much involved in Recycling (Source: Bob Fischer, member of HighPower Board)

## Recycling capability

- 📌 White listed as official Lithium ion battery recycler by the MIIT
- 📌 Recycling capacity: No public announcement yet
- 📌 Affiliate for Recycling: GZHP
- 📌 Recycling of NiMH and Li-ion battery
- 📌 Process: used batteries are primarily separated by physical deconstruction the batteries and pyrometallurgical process. The Li-ion battery scrap is treated with a hydrometallurgical process. The pretreated battery powder is smelted into a metal salt product using Highpower's patented technology.

**Inputs**  
Battery Pack  
**Outputs**  
??

## Partnership

- 📌 Cooperation agreement with eTrust power (subsidiaries of CITIC group), supplier of Li-ion battery (Prod capacity: 3GWh in 2018, 20GWh in 2021, 50 GWh in 2030)

# GUANGDONG GUANGHUA SCI-TECH CO., LTD

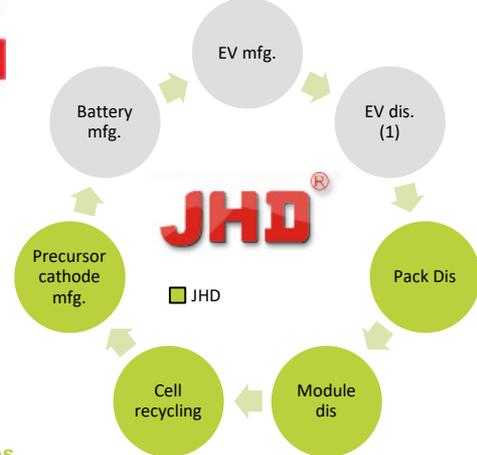
## Company profile

- Founded: 1980 – Revenues: RMB 25 Bn – Profit: 12%
- HQ: Jiangyan, Guangdong Province
- Guangdong Guanghua Sci-Tech Co., Ltd Power is principally engaged in the manufacturing and sale of specialty chemicals: electronics chemicals (Copper oxide, Copper sulfate, Copper nitrate, Nickel sulfanate, Nickel sulfate), Food additives (Citrate, Phosphate, Carbonate salt), Pharmaceutical, ceramics...
- 730 employees, US\$ 200 Million revenues

## Recycling capability

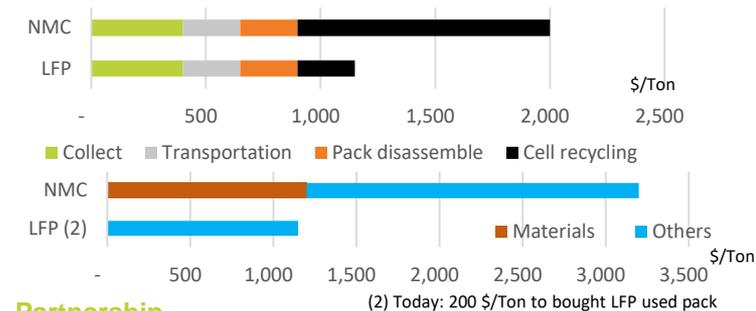
- White listed as official Lithium ion battery recycler by the MIIT
  - Recycling capacity: 1 plant 1,000 Tons/month – 12,000 Tons planned for 2018 – 50% LFP – 50% NMC
  - 2020: 2 additional plant for a total of 120,000 Tons/y
  - Plan to open a recycling factory in Korea
- Inputs**  
Battery Pack
- Outputs**  
Ni & Co Sulfate  
Li Carbonate

(1) dis: disassemble



## Recycling Costs

For more than 20,000 Tons



## Partnership

- JHD & BAIC sign an agreement to cooperate on 2<sup>nd</sup> use and recycling of used batteries. (Nov 2018)
- Penglong Auto (affiliate of BAIC) will invest in JHD battery 2<sup>nd</sup> use unit based in Zhuhai and a battery recycling unit.
- JHD signs strategic cooperation Agreement with Nanjing Golden Dragon Bus (Nov 2018)

# TAISEN RECYCLING GROUP



泰森循环科技  
TAISEN XUNHUAN

<http://www.tai-sen.cn>  
<https://www.taisen-recytech.com/>

## Company profile

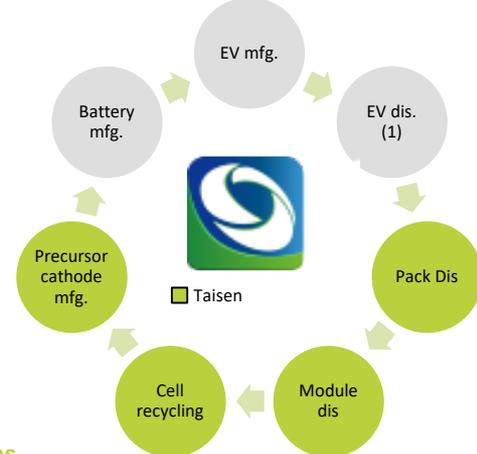
- 📌 Founded: 2014
- 📌 HQ: Hunan Province of China
- 📌 Recycling of cell phone battery, laptop battery and electric car related battery
- 📌 150 employees

## Recycling capability

- 📌 The company has a battery dismantling, sorting, crushing, separation production lines and with the annual capacity disposal of waste lithium batteries up to 10,000 Tons in China
- 📌 a lithium iron phosphate waste recycling lithium carbonate production line, with the yearly processing capacity over 5,000 Tons.
- 📌 Taisen Process
  - 📌 crushing process leaching by water
  - 📌 Magnetic separation (-> Fe – 99%)
  - 📌 Gravity separator (-> Al, Cu, black mass) / > 95%
  - 📌 Black mass treated by hydrometallurgical process (-> Li, Ni, Co, Mn) – 35% efficiency
  - 📌 Output: Lithium carbonate, Nickel sulfate, Cobalt Sulfate, NMC precursor powder
- 📌 Investment In Vietnam
- 📌 Investment in Korea
  - 📌 \$ 30 M for 20,000 Tons recycling capacity
  - 📌 Production of 2,400 Tons of Lithium carbonate for South Korean market & 15,000 Tons of Ni Hydroxide for Chinese market
- 📌 6,200 Tons LCE, Cobalt Sulfate, and Nickel Sulfate
- 📌 Investment: 8,400 Tons Cobalt Sulfate production (23.6 M Yuan)

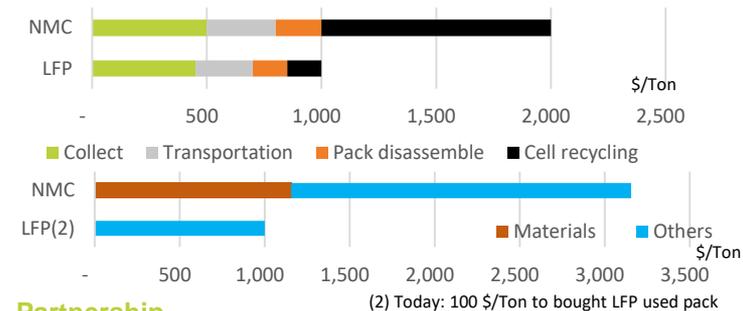
**Inputs**  
Battery Pack  
**Outputs**  
battery material

(1) dis: disassemble



## Recycling Costs

For more than 20,000 Tons



## Partnership

- 📌 JV in Korea (in Pyeongtaek ) called Dr. LiB - Global Alliance: Taisen & South Korean e-waste recycler NH Recytech: capacity to recycle 30,000 Tons of used lithium batteries annually.
- 📌 NH Recytech have long term partnership with LG, Samsung, Mercedes,
- 📌 NH Recytech customers: LG, Samsung, Huawei, Mercedes-Benz
- 📌 Partner with BYD – Collect

## CONCLUSION (1/2)

- 🕒 Chinese xEV battery pack recycling market will increase fast: The lithium ion battery to be recycled will reach 200 kT in 2019-2020 and 400 kT in 2020-2021
- 🕒 Estimated lithium ion battery recycling capacity: 100,000 Tons in 2018, 500,000 Tons in 2020 and > 1 million Tons in 2025.
- 🕒 Lithium ion battery Recycling is really new in China and not yet structured ; it is just the beginning
- 🕒 The relevant technical specifications are not yet finalized – mostly advanced pilots, the recycling system, final regulation and subsidies has not been established
- 🕒 Today, no government incentive for collection / transportation or recycling EV batteries. But, “White listed” companies are likely to get incentives at least to recycle LFP packs (not decided yet) – maybe detailed in next regulation release soon)
- 🕒 At present, the state is in the process of formulating relevant management measures on the above issues.
  - 🕒 Interim Measures on Traction Battery Recycling (February 2018)
  - 🕒 Interim Administrative Measures on the Traceability of Traction Battery Recycling (July 2018)
  - 🕒 White List of five NEV battery recycling enterprises which meet the requirements of the “Standard Requirements for the Comprehensive Utilization of Decommissioned NEV Power Batteries”. (July 2018) : Huayou Cobalt, Ganzhou Highpower Technology, Guangdong Guanghua Sci-Tech Co. Ltd (JHD), GEM, Brunp
  - 🕒 Implementation of Pilot Projects on Traction Battery Recycling (July 2018)
- 🕒 China banned the import of 24 recyclable materials, including plastic, paper, and e-waste such as batteries.
- 🕒 Manufacturers of electric vehicles (EV) responsible for setting up facilities to collect and recycle spent batteries
- 🕒 EV mfg have to set up recycling channels and service outlets where old batteries can be collected, stored and transferred to specialist recyclers. They can of course contract with companies to set up recycling services; The OEM have to pay for the recycling.
- 🕒 We identified more than 30 players involved in the recycling business
- 🕒 Most of the companies are still at a pilot scale
  - 🕒 Manual dismantling of the pack
  - 🕒 All the companies use both pyro & hydro process / Pre -treatment including cell crushing & mechanical separation of Al, Cu & Black mass / Refining of the Lithium, and then Co, and Nickel
- 🕒 Today, as volume are small, it is difficult make profit with Li-ion battery recycling ; But, we forecast that recyclers will make profit as soon as they reach higher capacity (20,000 Tons of battery pack seems to be a first step to make profit, at least recycling NMC batteries, even if they have to pay for getting the NMC pack – (Tipping fee)
- 🕒 Recyclers hope to get incentives from the government to help them reaching higher capacity.

# CONCLUSION (2/2)

❶ Recycler claim that they need subsidies to make profit with recycling

❷ Battery value recovered from recycling – Average sales price on Chinese market in 2018 (1)

❶ OEM can collect US\$ 550-600 of value per ton of packs

❷ The recycler can extract US\$ 3,400 of value (metals)

❸ The total cost of recycling is USD 2,400/Ton

	LFP EV Pack	NMC 111 EV Pack	NMC 532 EV pack	LFP Black mass	NMC 111 black mass	LFP metal value	NMC 111 metal	NMC 532 metal
Average Selling price (\$/Ton)	0 – 200 excel/cost/D5:T5	1,100-1,200 excel/cost/D5:T5	550-600 excel/cost/D5:T5	1,000 -1,100 Source: Camel	2,500 Source: Camel	1,450 excel/value/E48	4,250 excel/value/I48	3,500 excel/value/k48

❶ Average recycling cost in China

Cost \$/Ton	EV Pack	Collect, Storage	Transportation	Dismantling	Recycling	Total
LFP	0	300	250	200	400	1,150
NMC 111	1,150	350	300	200	1,000	3,000
NMC 532	575	350	300	200	1,000	2,400

❶ Major recyclers identified in China:

Data Slide 30 and Excel/cost/Table 14

Companies	Capacity in 2018 (Tons)	Capacity in 2020 (Tons)	Capacity in 2025 (Tons)	Inbounds/ Outbounds	LFP recycling cost	NMC111 recycling cost
<b>BRUNP</b>	10,000	40,000	100,000	EV Pack – Precursors, NMC, LCO	1,025	2,750
<b>GEM</b>	30,000	300,000	300,000	EV Packs - Li, Co, Ni, Al and Cu	1,700	3,150
<b>Huayou Cobalt Co</b>	5,000	Not decided	NA	NMC Cells – Precursor, Metals		2,500
<b>High Power Li</b>	5,000	Not decided	NA	EV Packs - Not decided yet	NA	NA
<b>Guanghua Sci-Tech</b>	12,000	120,000		EV Packs - Li, Co, Ni, Al and Cu	1,400	3,200
Ganfeng Lithium	20,000	30,000	40,000	EV Packs - Metals	1,100	2,950
Camel	5,000	20,000 – 50,000	300,000	EV Packs – Black mass	1,050	2,100
ShanShan	Pilot	50,000		EV Packs – Precursors, Cathode		3,000
Taisen	10,000 (1)	30,000 (2)		EV Packs – Precursors, cathode	1,100	3,150
<b>AVICENNE (2)</b>	<b>20,000</b>	<b>50,000</b>	<b>150,000</b>	<b>EV Packs - Metals</b>	<b>1,150</b>	<b>3,000</b>

(1) NMC pack index on Co price – Co @ 50 000 \$/ton – In Red, company white listed, (2) Avicenne Average estimations

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# WASTE BATTERY POLLUTION PREVENTION AND TECHNOLOGY CONTROL

## First, the general rule

- ④ (I) In order to carry out the Law of the People's Republic of China on Environmental Protection, "Law of the People's Republic of China on Prevention and Control of Environmental Pollution by Solid Wastes" and other relevant laws and regulations, prevent and control environmental pollution, ensure ecological security and human health, guide environmental management and scientific pollution control and lead pollution Prevent technological progress, and promote the use of waste batteries, the development of this technology policy.
- ④ (II) This technical policy is applicable to the prevention and control of mixed waste, substandard products, scrapped products and outdated products arising from the production, transportation, sale, storage, use, maintenance, utilization and remanufacturing of various batteries. Waste batteries under key control include waste lead-acid batteries, lithium-ion batteries, nickel-hydrogen batteries, nickel-cadmium batteries and mercury-containing button cells.
- ④ (III) This technical policy is the guiding document, which mainly includes the pollution prevention and control technology for the collection, transportation, storage, utilization and disposal of waste batteries and the new technologies for encouraging research and development so as to provide technical guidance for the environmental management and pollution prevention and control of waste batteries .
- ④ (D) waste battery pollution prevention and control should follow the closed-loop and green recycling, resource utilization priority, reasonable and safe disposal of the comprehensive prevention and treatment principles.
- ④ (5) To gradually establish an information supervision system for the collection, transportation, storage, utilization and disposal of waste lead batteries, waste energy batteries for new energy vehicles, etc., and encourage the adoption of information technology to build a supervisory system for the entire process of waste batteries.
- ④ (6) Waste batteries that are listed in the national list of hazardous wastes or that are identified as hazardous wastes in accordance with the national standards for the identification and identification of hazardous wastes are managed in accordance with the guidelines for hazardous wastes.

# WASTE BATTERY POLLUTION PREVENTION AND TECHNOLOGY CONTROL

## Second, collect

- ④ (A) Encourage the collection of waste batteries by category in areas with access to resources.
- ④ (B) to encourage battery manufacturing enterprises, waste battery collection enterprises and the use of enterprises and other building waste battery collection system. Encourage battery manufacturers to fulfill producer extended responsibility.
- ④ (III) Encourage waste battery collection enterprises to establish waste battery collection system by using information technologies such as "Internet of Things +" and promote efficient recycling of waste batteries through information disclosure and other means.
- ④ (D) waste battery collection enterprises should establish a marked identification of waste battery collection facilities. Encourage consumers to waste batteries sent to the corresponding waste battery collection network device.
- ④ (E) During the collection process, the structure and shape of waste batteries should be kept intact. It is forbidden to break the waste batteries by themselves. The damaged batteries should be stored separately. This is translated at the cell level only, not modules or packs.

## Third, transport

- ④ (A) waste batteries should take effective packaging measures to prevent leakage of toxic and hazardous substances in transit caused pollution.
- ④ (II) Waste Lithium-ion batteries should be pre-discharged before shipment, independent packaging and other measures to prevent explosion caused by impact or short-circuit caused by environmental risks.
- ④ (3) It is forbidden to dump and discard used batteries during transport.

# WASTE BATTERY POLLUTION PREVENTION AND TECHNOLOGY CONTROL

## Fourth, storage

- ④ (A) Waste batteries should be classified storage, storage in the open air is prohibited. Damaged batteries should be stored separately. (Intent was for damaged cells with potential leakage to be stored in separate areas, potentially with different pollution control and safety requirements – but not defined in mandate). Storage should be regularly cleaned.
- ④ (B) storage of waste lead-acid batteries should prevent leakage of electrolyte. Waste lead-acid batteries should be stored so as to avoid flooding.
- ④ (C) waste lithium-ion batteries should be stored before storage safety testing, dark storage, should control the storage place of the ambient temperature to avoid spontaneous combustion caused by high temperature and other environmental risks.

# WASTE BATTERY POLLUTION PREVENTION AND TECHNOLOGY CONTROL

## Fifth, use

- ② (A) Prohibit artificial, open-air dismantling and crushing waste batteries.
- ② (B) should be selected according to the characteristics of waste batteries dry smelting, hydrometallurgical and other technologies to use waste batteries. Dry-process smelting (direct translation from the Chinese – Pyro-metallurgical) should be carried out in negative pressure facilities, and the unorganized emission of exhaust gas in the treatment process should be strictly controlled.
- ② (C) waste lithium-ion battery should be used (at end of cell life) prior to discharge treatment should be disassembled under low temperature conditions to prevent electrolyte volatilization. The mandates encourages the use of acid-base dissolution - precipitation, high-efficiency extraction, fractional precipitation and other techniques recovery of valuable metals. Or to use high concentrations of ammonia wastewater generated during the process. The mandate encourages the use of distillation, membrane treatment and other technical treatment and reuse of chemicals.
- ② (iv) Waste mercury-containing batteries are encouraged to be recycled by techniques such as vacuum distillation using fractional control.
- ② (E) scrap zinc manganese batteries and waste nickel-cadmium batteries should be broken in a closed device.
- ② (vi) dry-process smelting (Pyro-metallurgical) should be used adsorption, bagging and other technologies to deal with waste gas.
- ② (G) Hydrometallurgical extraction of valuable metals produced wastewater should adopt membrane separation method, adsorption of functional materials and other processing techniques.
- ② (VIII) Wastewater and waste gas emissions from waste lead-acid batteries shall implement the "Emission Standard for Industrial Pollutants for Recycled Copper, Aluminum, Lead and Zinc" (GB 31574). Other Waste Battery Dry Utilization Enterprises' emissions should refer to the implementation of the "Hazardous Waste Incineration Pollution Control Standard" (GB18484), wastewater discharge should meet the "Integrated Wastewater Discharge Standard" (GB 8978) and other corresponding standards.
- ② (IX) The technical policies for the prevention and control of pollution by the use of lead-acid batteries are stipulated in the Technical Policy for the Prevention and Control of the Production and Recycling of Lead-acid Batteries.

# WASTE BATTERY POLLUTION PREVENTION AND TECHNOLOGY CONTROL

## Sixth, disposal

- ③ (A) Waste batteries should be not discarded into domestic waste incineration plant or compost fermentation plant.
- ③ (2) Waste batteries that have not been collected and are not yet used in a cost-effective manner should be classified into landfills for future use.
- ③ (3) Waste batteries should not be disassembled, rolled and other crushing operations prior to and during disposal of waste batteries, so as to ensure the integrity of the waste batteries and reduce and prevent the exudation of harmful substances.

## Seven, encourage the development of new technologies

- ③ (A) high value-added batteries and all-component use of technology.
- ③ (B) intelligent waste battery dismantling, crushing, sorting and other technologies.
- ③ (C) automation, high efficiency and high safety of new energy vehicles power battery module separation, directional recycling and reverse dismantling technology.
- ③ (D) waste lithium-ion battery separator, electrode material utilization technology and electrolyte membrane separation technology.

# CHINA EVOLVING RECYCLING DIRECTIVES

## China 1996-2016 Summary – Waste Management & Research

In view of the serious environmental problems caused by waste LIBs and valuable materials in waste LIBs, China has paid great attention to them, and has actively taken measures to management waste LIBs. The List of Wastes Prohibited for Import based on the Basel Convention is the first legal document related to WEEE management in China, and was released in 1996. Waste batteries are on the list. In 2003, the State Environmental Protection Agency of China, together with nine other government agencies, co-issued a policy on battery recycling called the “Policy on Pollution Prevention Techniques from Waste Batteries.” The policy required that battery industries should take responsibility for collecting waste batteries and for proper labeling (MEP, 2003).

The companies China Mobile, Motorola and Nokia launched a recycling campaign, “Green Box Environmental Program,” in December 2005 to recycle waste mobile phones and accessories (waste LIBs included). Six other cell-phone manufacturers joined the campaign the year after. The campaign collected more than 150 t of phones and LIBs in 300 cities in China (Zeng et al., 2015).

During June 2009 to December 2011, China launched a program called “Old for New” for Household Appliances, which laid a solid foundation for establishing a formal WEEE collection and recycling system in China. In addition, some web-based recycling companies launched the old-for-new service of WEEE. For instance, “Love Recycling Network” has established more than 200 service points in China, built a 5000-member service team to cover the business in many cities in China and recycled more than 20 million units of WEEE containing LIBs since 2011 (Love Recycling, 2017).

In 2012, relevant Chinese government departments issued the “Administrative Measures on the Collection and Using of Waste Electrical and Electronic Equipment Treat Fund,” which stipulates that manufacturers or importers are responsible for the fund collection. This fund is used to enable qualified enterprises for the recycling of WEEE.

Source: <https://journals.sagepub.com/doi/pdf/10.1177/0734242X17744655>

# CHINA EVOLVING RECYCLING DIRECTIVES

## China 1996-2016 Summary – Waste Management & Research (Cont'd)

The Fund has been successfully applied in the recycling of air conditioners, TV sets, refrigerators, washing machines and computers (Yu et al., 2014).

With the soaring increase of small WEEE, the “Directory of Waste Electrical and Electronic Equipment Treatment (2014)” (including LIBs) was introduced in February 2015 and put into effect in March 2016, which means that waste LIBs were officially added to the scope of the Fund (NDRC, 2015). This would increase the enthusiasm of the qualified enterprises of WEEE to collect and recycle waste LIBs. Currently, there were 109 licensed recycling enterprises, which can process 4 Mt of WEEE every year in China (Li et al., 2015).

The New Policy on Pollution Prevention Techniques from Waste Batteries was released by the Ministry of Environmental Protection (MEP) on 26 December 2016, which regulates the collection, transportation, storage, utilization, and treatment of waste LIBs (MEP, 2016). The main contents of this legislation are as follows.

1. Mixed waste, substandard products, waste products, and expired products in the production, transportation, sale, storage, use, maintenance, utilization, remanufacturing, and other processes of all kinds batteries are included in the policy. Waste lead-acid batteries, lithium-ion batteries, nickel hydrogen batteries, nickel cadmium batteries, and mercury containing button cell are focused on.
2. Recycling enterprises are encouraged to use “Internet of Things plus” and other information technology to establish a complete waste battery collection system. Battery manufacturers are encouraged to fulfill the extended producer responsibility. Consumers are encouraged to send waste batteries to the corresponding waste battery collection points.
3. Effective waste battery packing measures should be taken to prevent the leakage of toxic and harmful substances during transportation. Pre-discharging, independent packaging, and other measures for waste LIBs before the transportation are required to prevent environmental risks caused by impact or short circuit explosion. Dumping and discarding waste batteries during transportation is forbidden.

# CHINA EVOLVING RECYCLING DIRECTIVES

## China 1996-2016 Summary – Waste Management & Research (Cont'd)

4. Safety testing and light-resistant storage should be carried out before the storage of waste LIBs. The environmental temperature of the storage place should be controlled to prevent the environmental risks caused by spontaneous combustion.
5. Open burning, simple incineration, and rough extraction of metals from waste batteries are banned. Waste LIBs should be disassembled at low temperature in order to prevent the volatilization of electrolyte. Acid/alkali dissolution-precipitation, efficient extraction, fractional precipitation, and other technologies are encouraged to recover valuable metals from waste LIBs.
6. Waste batteries should be avoided in the domestic waste incineration plant or the composting plant. In the process of landfill disposal of waste batteries, waste batteries should not be disassembled, rolled, and crushed, and the integrity of waste batteries should be ensured to reduce and prevent the leakage of harmful substances.
7. Intelligent dismantling, crushing, sorting, high value-added, and full-components utilization of waste batteries are encouraged. The utilization technology for separators and electrode materials, and the membrane separation technology for electrolytes from waste LIBs should be developed and used. Through many years of effort and development, China has made much progress in waste LIB management. However, China was still lagging behind the developed countries, due to lack of a complete collection system, mature recycling technology, and detailed guidance for both consumers and producers of lithium batteries in China.