Discussion paper issued without formal editing

FOR PARTICIPANTS ONLY
20 February 2019
ENGLISH ONLY

UNITED NATIONS
CENTRE FOR REGIONAL DEVELOPMENT

In collaboration with

Ministry of the Natural Resources and Environment (MONRE), Thailand and Ministry of the Environment, Government of Japan

NINTH REGIONAL 3R FORUM IN ASIA AND THE PACIFIC, 4-6 MARCH 2019, BANGKOK, THAILAND

Circular economy towards sufficiency economy ~ Case of P.R.China

(Background Paper for Plenary Session 1 of the Programme)

Final Draft

This background paper has been prepared Prof. Jinhui Li and Dr. Xianlai Zeng, for the Ninth Regional 3R Forum in Asia and the Pacific. The views expressed herein are those of the author only and do not necessarily reflect the views of the United Nations.

Circular Economy towards Sufficiency Economy: Case of P. R. China

Xianlai Zeng and Jinhui Li

TSINGHUA UNIVERSITY | E-MAIL: XLZENG@TSINGHUA.EDU.CN

Foreword

Anthropogenic activity is leaving a pervasive and persistent signature on Earth so that some metal cycles have been significantly modified over the past century. Global sustainability is declining in an unprecedented rate due to severe resource depletion and serious environmental degradation. The United Nations in 2015 set out a transformational agenda for a sustainable 21st Century with the adoption of 17 Sustainable Development Goals (SDGs) to protect the earth and its inhabitants. For example, SDG 12: Sustainable consumption and production focuses on improved utilization of our over-stressed and critical resources, doing more with less, and adoption of circular rather than linear economies. This is very important as increasing consumer demands from an ascending population with the rising aspirations for a better future have led to concerns over the security of supply and accessibility of many elements within the Periodic Table that are consumed in chemical processes and manufacturing.

One of humankind's biggest challenges over the 21st century is how to provide adequate resources for civilization. Most geological resources extracted so far have been transformed into products and finally to waste, i.e., a linear economy. A circular economy will put much concern on chemistry to make the innovative products, using the renewable feedstock in an eco-design manner. Furthermore, substances of products are made from will increasingly be handled as a secondary resource and not simply disposed of as waste. A circular economy is recognized as an effective approach to alleviate and even solve global issues and chemical processes are a

fundamental part of this. This background paper provides P.R. China's circular economy of urban mining in ELV recycling.

This background paper was written by Dr. Xianlai Zeng and supervised by Prof. Jinhui Li. It was completed when Xianlai Zeng worked as Fulbright fellow in Yale University. We acknowledged the support by Asia Research Centre in Tsinghua University (2018-B1), and Fulbright Visiting Research Scholars Program & the P.R. China Scholarship Council (201706210655).

Abbreviations and Acronyms

ASR	automotive shredder residues
CT	cargo truck
E-waste	electrical and electronic waste
ELV	end-of-life vehicle
EoL	end-of-life
EPR	extended producer responsibility
EV	electric vehicle
PV	passenger vehicle
RV	refit vehicle
SDGs	sustainable development goals

An Executive Summary

Resource shortage and environmental pollution is driving circular economy as a unique solution to improve the economy quality. P.R. China since 2000s has pushed the circular economy in various fields with cleaner production and urban mining. Currently, P.R. China is devoted to establishing the ecological civilization. To review the adventure of circular economy and find the lessons will be of vital necessity for the smooth way forward.

At present, the vehicle industry is one of the economy pillars in global economy. P.R. China is the largest producer and consumer of vehicle. Its recycling is becoming an important part of circular economy. P.R. China's ELV will reach 55 Mt in 2030 and 88 Mt in 2050, with the leading by Guangdong and Shandong. The stocked resource of Fe, plastic, Cu, and Al will rise to 41.75, 4.23, 1.09, and 3.25 Mt in 2030 and 65.94, 6.73, 1.73, and 5.14 in 2050, respectively.

To cover the close-loop of vehicle along the whole life cycle, lots of regulations and recycling process have been enabled to ELV recycling. Since 1949 P.R. China's ELV industry can be roughly classified for three phases. Nowadays, P.R. China owned 603 licensed recyclers and 2,358 collection points. Only around one thirds ELVs have entered the informal market with some unproper treatment, one thirds in formal recycling, and one thirds in stock not collected.

The main experience was extracted here: the most effective regulatory core is the economic incentives to ensure the high collection rate; P.R. China needed to develop its own approach to handle the ELV, not simply duplicate other countries' experience;

and the management information system, including reception, reporting, auditing, and funding subsidy, is quite helpful to support the ELV recycling.

At the way forward, the integrated framework of circular economy for ELV management should be built, and the revision of Administrative Measures on the Recovery of ELV needs to be promptly enforced. To green the vehicle industry, cost internalization and EPR principle should be strengthened for producer of vehicle. The ELV recycling industry needs to update their recycling and recovery process.

Contents

Chapter 1: Introduction

In recent years, circular economy is regarded as a spectacular solution for transcending the problems created by the linear economy model of industrial productive and economic growth. It is an industrial system focused on closing the loop for material and energy flows and contributing to long-term sustainability for the environment and resource utilization. While the anthroposphere is consisted of lithosphere, pedosphere, hydrosphere, atmosphere, biosphere, and technosphere[1], circular economy has been rapidly reforming the whole anthroposphere through manufacturing, producing, consumption, and recycling.

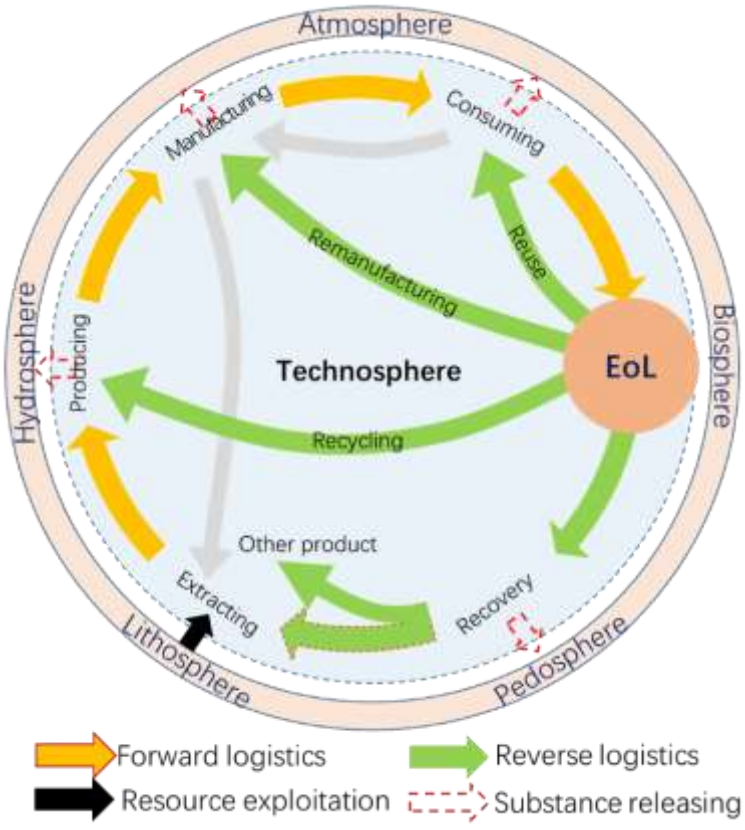


Figure 1. Circular economy approach in the resource (material) flow framework[2]

Aiming at improving economic sufficiency, the core approaches of circular economy

are comprised of cleaner production and urban mining. In P.R. China urban mining or waste recycling is the most typical practices to elevate the resource recycling and resource efficiency. When the product reaches the end-of-life (EoL), reuse, remanufacturing, recycling and recovery (or called 4Rs) can be chosen for the urban mining with the approaches: reuse for consuming, disassembling for remanufacturing, dismantling for recycling, and recovery for new product or material (Figure 1).

Urban mining in P.R. China has experienced a rapid evolution from backyard informal recycling (before 2005) and industrial park (2006-2010) to urban mining demonstration base (2011-2015) and circular economy park (2016-). Driven by environmental protection and resource governance since 2000, circular economy operation has shifted from microscopic company to macroscopic region. Consequently, sufficiency economy has been significantly pushed with the rapid modernization, green, and normalization of urban mining industry.

P.R. China is one of the largest consumers of vehicle and generators of end-of-life vehicle (ELV) in the world. In this report, we chose ELV management as a case to illustrate the circular economy and urban mining practice. In order to tackle the environmental problems and resource recycling of ELVs, P.R. China have attempted to develop different technical route and policy frameworks in order to secure proper management system for ELVs. The existing ELV experience show some successes and drawbacks towards sufficiency economy. Therefore, it is interesting to look into a number of ELV experience presently running, in order to gain knowledge of flaws and virtues from these experiences.

Chapter 2: P.R. China's ELV Generation and Characteristics

2.1 ELV Generation

ELV, like e-waste, is deprived of urban metabolism, which could be described by Weibull lifespan distribution. But some vehicles have a mandatory lifespan given by the national law. Therefore, ELC generation will be much harder to determine than e-waste. In P.R. China, vehicle can be mainly divided into six types: passenger vehicle (PV, e.g., private, civil, new-registration), cargo truck (CT, e.g., private, civil, new-registration), car (e.g., <1L, 1-1.6L, >1.6L in capacity), refit vehicle (RV), electric vehicle (EV), and tractor.

Rapid urbanization and economic growth have resulted in the significant increase of ELV generation. From the weight point, in 2010, the total ELV was nearly 10 million metric tons (Mt), but it reached 30 Mt in 2018, and will reach 55 Mt in 2030, 72 Mt in 2040, and 88 Mt in 2050. CT and car contribute in much more weight than others. Before the year 2030s, CT is higher than car, and later car will take the leading role in ELV weight generation (Figure 2A).

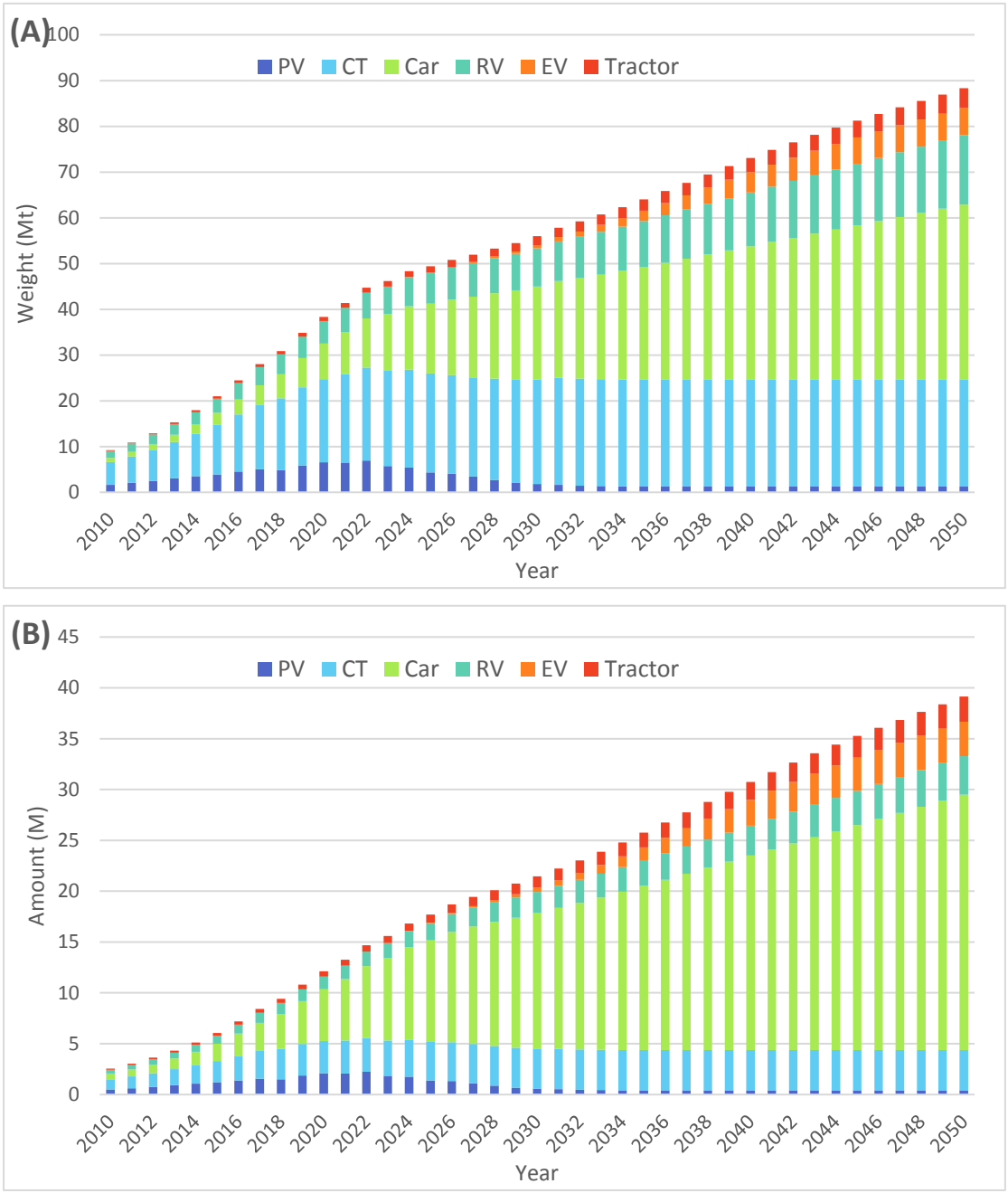


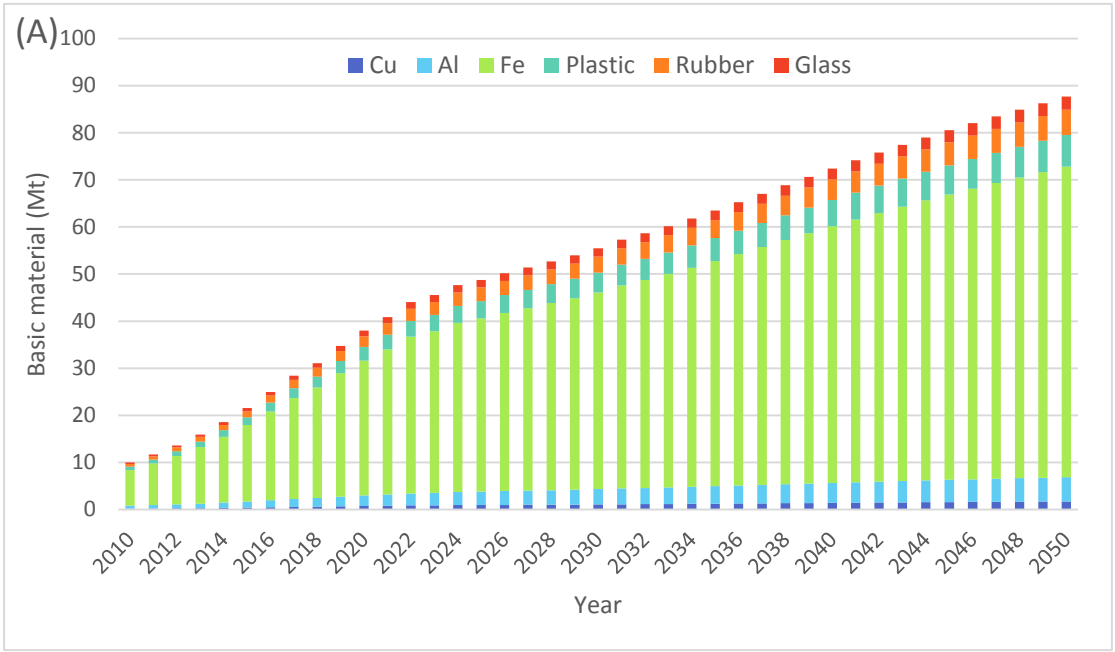
Figure 2 The projected ELV generation in P.R. China from 2010 to 2050. Data source from Zeng et al. (2019)[3]

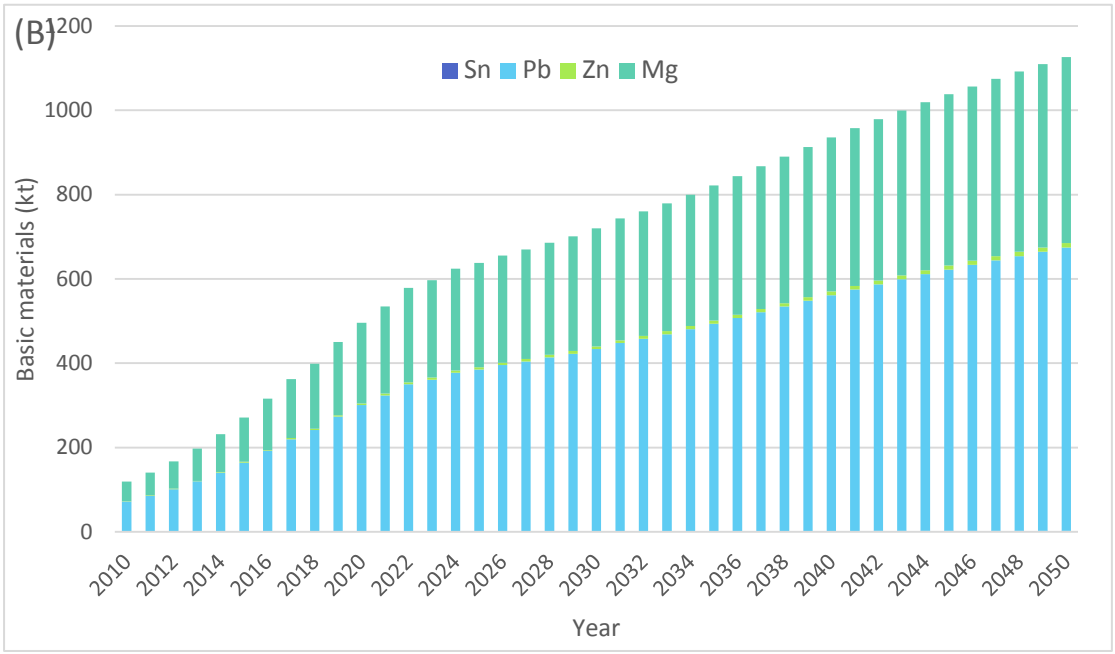
But in amount, there was only 2.5 million-unit ELV, but it will surpass 10 million unit in 2020, 20 million unit in 2030, 30 million unit in 2040, and 39 million unit in 2050. From the year of 2020, the annual increasing amount will be 1 million unit. Meanwhile, car will be leading in total amount, followed by CT, EV, tractor, and PV.

2.2 ELV Characteristics of Environment and Resource

Waste in nature has double characteristics of environmental risk and resource recycling, which makes its recycling much more complicated than virgin mining of natural resources. From the perspective, ELV has massive toxic materials, including spent oil, solvents, ozone depleting substances, and heavy metals (e.g., Lead, cadmium, mercury) belonging to hazardous waste. After recycling, there was still around 200-300kg automotive shredder residues (ASR), imposing a severe environmental risk.

The amount of most resources including basic materials, precious metals and rare earth encased in ELV has been constantly growing since 2010 and can be expected to continue to grow. In 2010, the amounts were approximately 7.56, 0.72, 0.19, and 0.62 Mt for Fe, plastic, Cu, and Al, respectively, but they will rise to 41.75, 4.23, 1.09, and 3.25 Mt in 2030, and 65.94, 6.73, 1.73, and 5.14 in 2050, respectively (Figure 3). Meanwhile, the amount of Au, Ag, and W will increase around 8-, 12-, and 12-fold from 2010 to 2050. The Co will grow from 0 to 260 t in 2050, which can be attributed to the dramatic and continuing boom in EV production and consumption.


(A)
Cu
Al
Fe
Plastic
Rubber
Glass
Basic material (Mt)
Year


(B)
Sn
Pb
Zn
Mg
Basic materials (kt)
Year

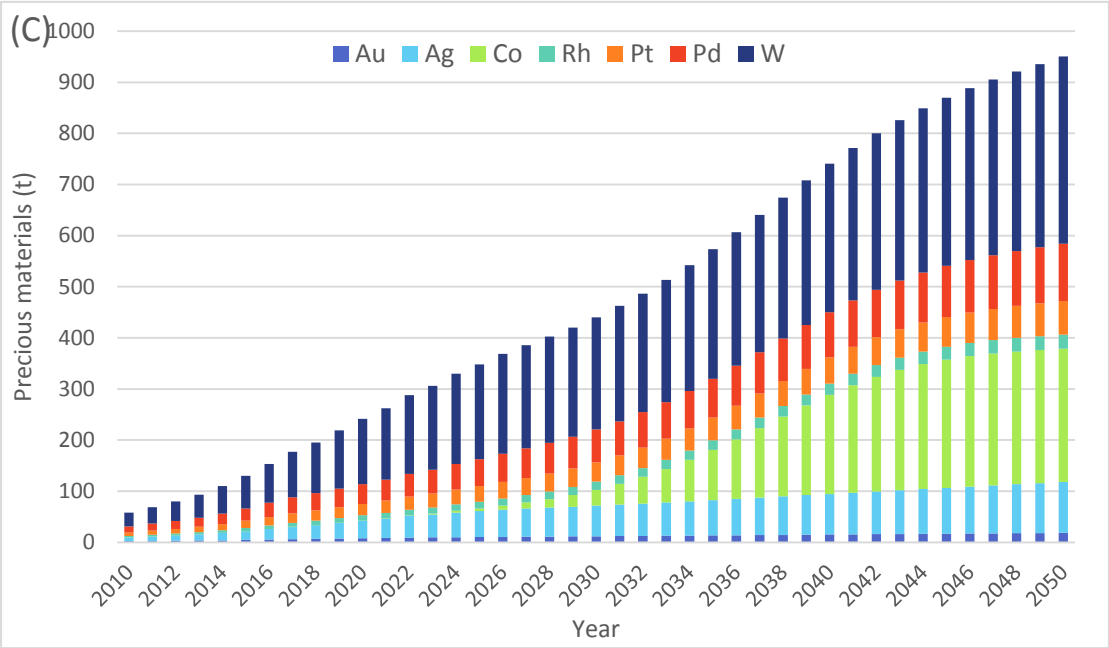


Figure 3 Resource evolution in the ELV from 2010 to 2050

In the perspective of geographic distribution, Guangdong and Shandong are the leading provinces to ELV generation with over 600,000 unit in 2020. The eastern area is suffering from the huge pressure of resource recycling and environmental protection.

Figure 4 ELVs generation distribution in P.R. China (×1,000 unit). Data source from Liu et al. (2011)[4].

Chapter 3: Policy and Technology Drivers behind Circular Economic Approach

3.1 Introduction

Policy and technology are the core to maintain the sustainable development of circular economy industry. To improve the sound management of ELV, many regulation, policy, and recycling process have been enabled.[5]

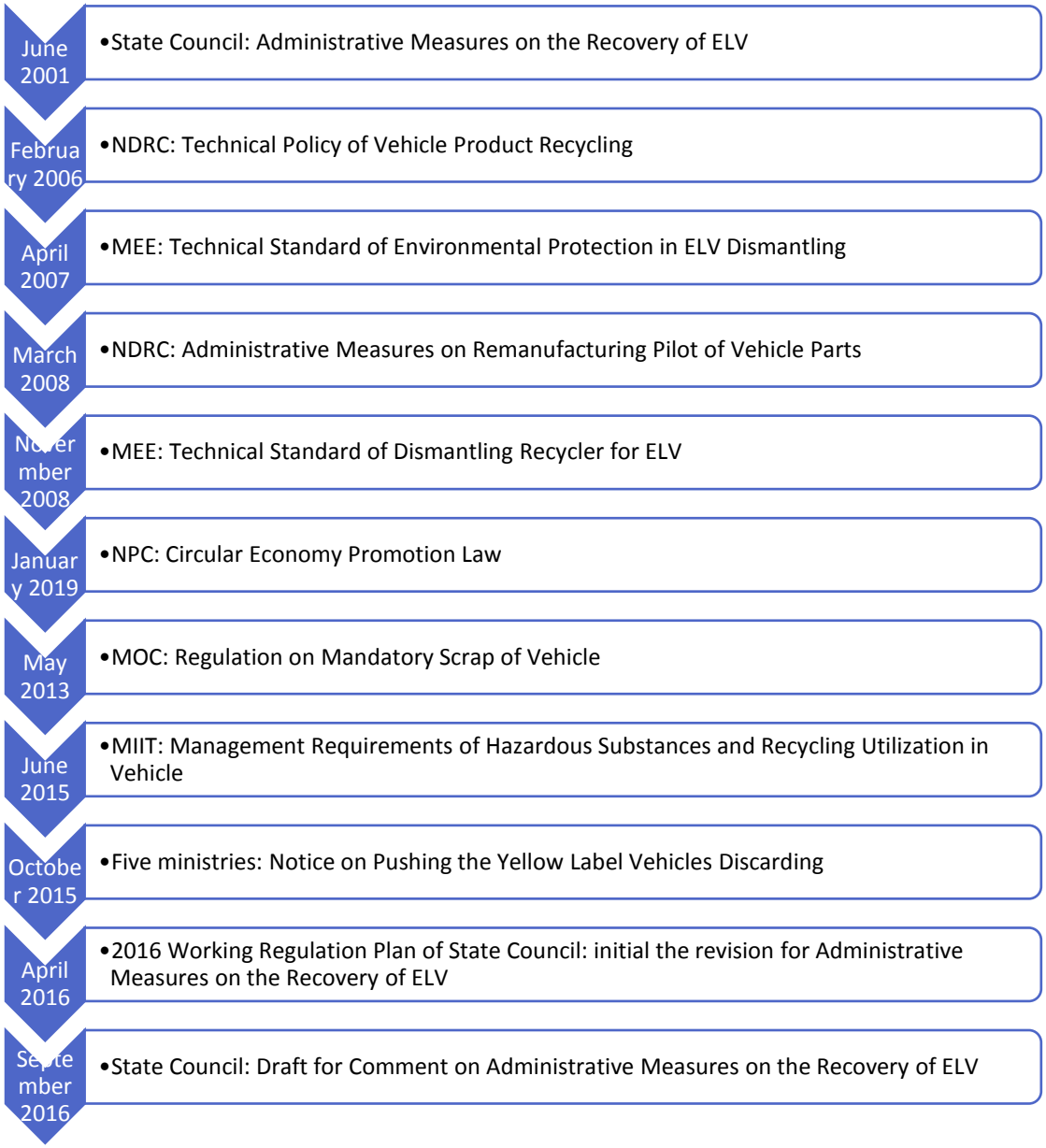


Figure 5 The management system of ELV in regulations, standard, and measures

To cover the closed-loop of vehicle along the whole life cycle, multilevel government and several ministries have been involved in ELV management. Ministry of Ecology and Environment, National Development and Reform Commission, and Ministry of Public Security are the main bodies to enforce the laws and regulations, given in Figure 5.

3.2 Collection and importation

Collection or reception is recognized as the most key procedure for ELV sound recycling. Previous experience and studies indicate economic incentive can motivate the consumer in collection.[6] But the normal obsolescence willingness was not greatly inspired. Taking one Santana car produced in 1999 as the instance, the consumer could obtain CNY 7,000 for collection fee and old-for-new subsidy. But he can obtain at least CNY 10,000 when he sold it in second-hand market. Moreover, the vehicle type with old-for-new subsidy is very less and to the subsidy is very complicated with the application and confirmation. The newly revised Administrative Measures on the Recovery of ELV has considered it to elevate the subsidy, which will be possibly implemented in 2019.

Old scrap importation was one main source of raw materials supply. P.R. China was the largest importer of metal scrap and plastic scrap. But in recent years, the illegal importation of hazardous material along the metal scrap occurred frequently and caused some disaster for local environment and public health. In July 2017, Chinese government enforced the solid waste importation phase out policy. Very soon, the importation of metal scrap and plastics scrap from ELV recycling will become extinct.

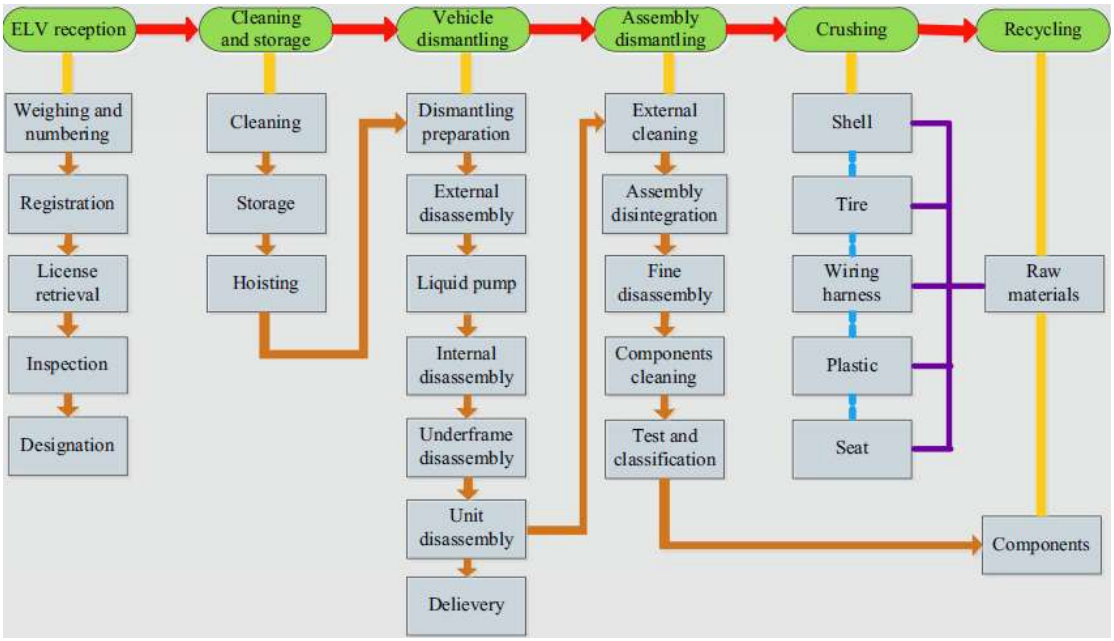


Figure 6 ELV recycling flow diagram in P.R. China. © Springer-Verlag Berlin Heidelberg 2016

Therefore, the domestic ELVs dismantling are the main source of resource recycling. When one vehicle reached the EoL, the consumer should register for write-off, that is to remove the operating list from the government, and then submit their ELV to obtain the collection proof. Next, the license plate should be retrieved to finalize all the write-off operation (Figure 6). The recycling enterprises collected the ELV and then dismantled it using the special process to obtain some valuable materials and parts. The consumer of vehicle can achieve the economic benefit of the obsolescence subsidy from government.

3.3 Reuse

In theory, the selection of reuse, remanufacturing, recycling, and recovery is relied on the fatigue of material of product.[7] ELV is generated by the two situations: one is when the car is worn out after a lifespan of ten to fifteen years, and another one is when the

car is declared as total loss after a major accident. Some collected vehicle does not reach the EoL and can work in a well function. It can enter into the second-hand market if it meets the basic requirement. The lifespan will be extended, which hopefully improves the circular economy.

3.4 Remanufacturing

The dismantling, most disassembling, is very indispensable for ELV recycling with two reasons: one is the parts and components after dismantling can enter into second-hand market, and the other is to remove the hazardous components for avoiding the potential risk. It can be mainly classified two types as step dismantling and whole crushing for the aim of parts remanufacturing and material recycling, respectively. In P.R. China the former type is much popular to maximize the economic and environmental benefit.[8, 9]

The dismantling process has been updated from torch scrapping in workshop to half-automatic line. The dismantled products such as engine, gearbox, and steering are recognized as the main objects for remanufacturing (Figures 6 & 7). After the feasible upgrading, they can be fixed a new car to fulfill their functions.

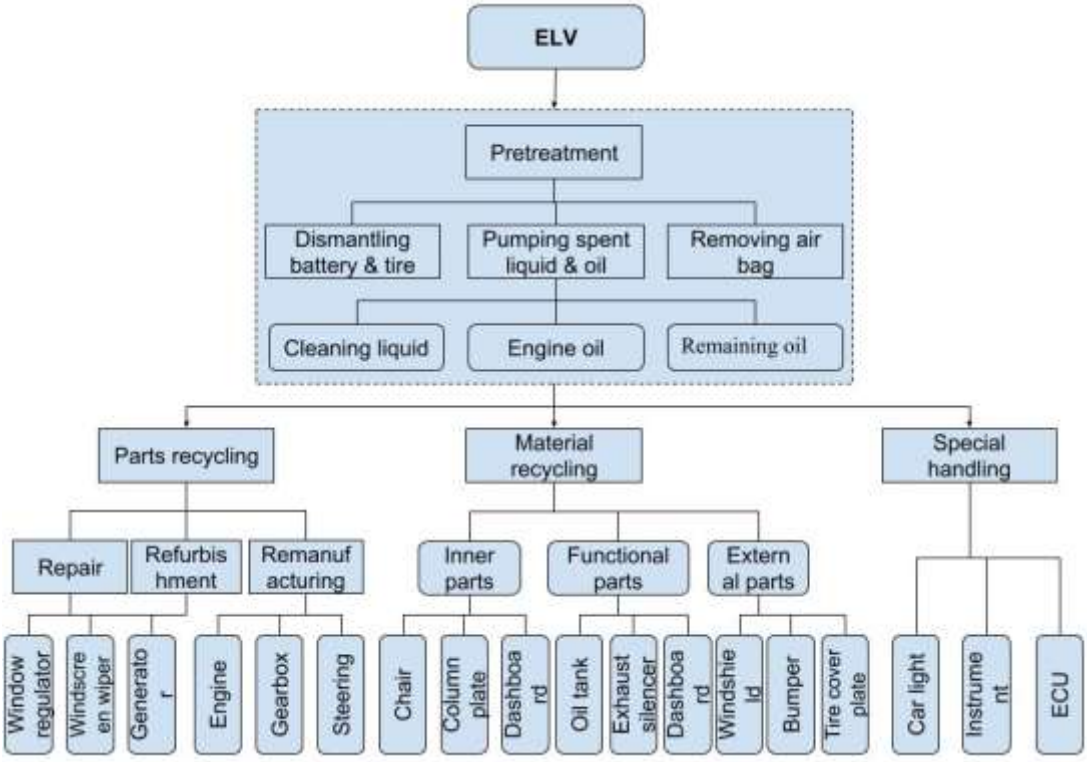
3.5 Recycling

The dismantled products without remanufacturing could be recycled. Generally, the recycling process employed the mechanical treatment: crushing and separation by magnetic and air to obtain the metallic powder and non-metallic powder (Figure 7). The process is very similar with e-waste recycling owing to their product-style structure.

Additionally, environmental requirement should be met to fit for national regulation and standard on air, water, and noise.

3.6 Recovery

At the final recovery, two approaches were adopted for the two materials from the above handling. One is the scrap metals like iron, copper, and aluminum. They can be deeply recovered using the pyro-metallurgical technology in smelter plant (Figure 7). The metal ingot will enter the new logistic of products. The other is the recycling automotive shredder residues (ASRs), about weigh share of 15-25% in one ELV. They contain some metals, plastic, tire, wirng, and plenty of hazardous materials. But the plastic and tire are the concern of the disposal. In light of the high calorific value as 15-30MJ/kg, ASR could be disposed of for energy recovery using the pyrolysis and gasification.[10, 11] Both energy recovery and volume reduction can be achieved together.



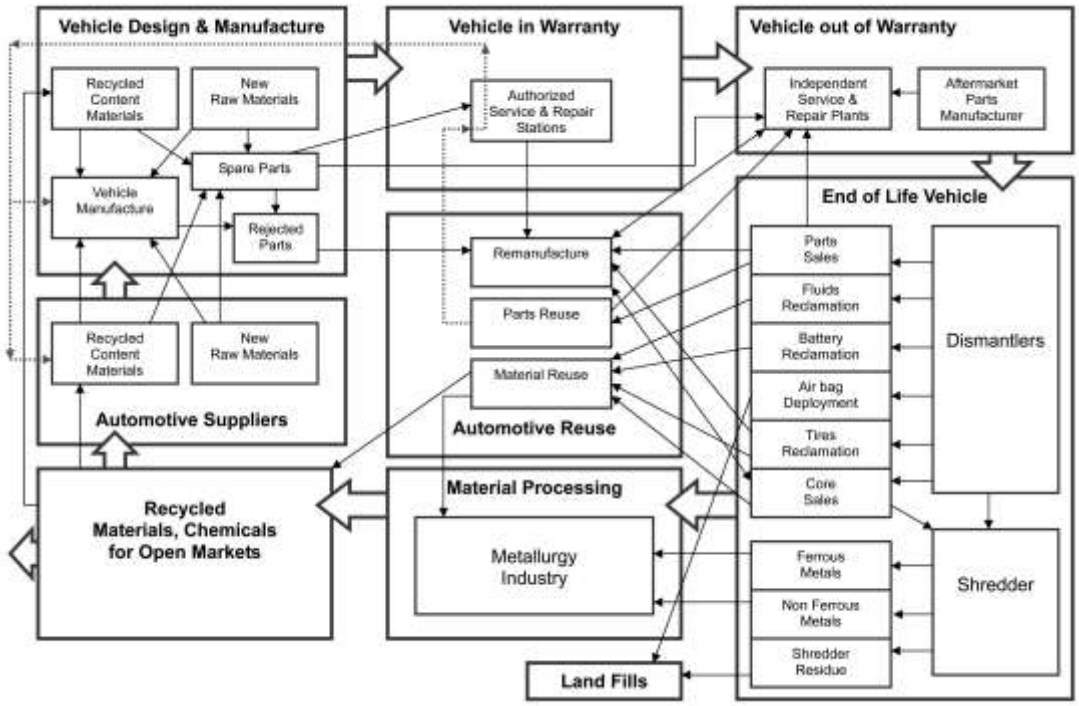


Figure 7 The dismantling and recycling process for ELV management in P.R. China[12] ©

TMS 2005

Chapter 4: Critical Experience and Lessons Learned from Circular Economy Adventure

4.1 P.R. China's Adventure of ELV Management

Since 1949 P.R. China's ELV management has evolved with the industry development and economy growing. With sixty years, P.R. China has established the nearly full-fledged country in vehicle industry across one-hundred-year route of some developed countries, and become the largest producer of vehicle in the world.[13] Three phases can be roughly classified and addressed here in detail.

(1) Initial phase (before 1982)

There were only decades thousands vehicle in the 1950s and reached around 2 million in 1980s. Very few ELV was generated so that there were no ELV recycling industry at this phase.

(2) Rapid development phase (1982-2001)

Vehicle industry started a rapid build-up. The registered amount of vehicle grew from 2.16 million in 1982 to 18.45 million in 2001. The obsolescence and updating have been accelerated. In 2000, 580,000 was obsoleted more 150,000 than the total amount of four year in 1986-1989. In 1983, P.R. China established the leading group of national old vehicle upgrading and regulated to add the collection and dismantling points for speeding up the vehicle industry updating. In 1990s, P.R. China also regulated that the collected ELV should be in time dismantled and recycled, and that the five assemblies with engines, steering, transmissions, axles, and frames, should be treated as iron scrap, not sell for reuse. The national amount of ELV recycling enterprises

should be controlled no more than 400 and their total recycling capacity was not less than 900. In these phase, ELV recycling industry maintained a rapid expansion. However, there was no adequate regulation and the dismantling level was much outdated only using manual dismantling.[14]

(3) Formalizing the recycling phase (2001-)

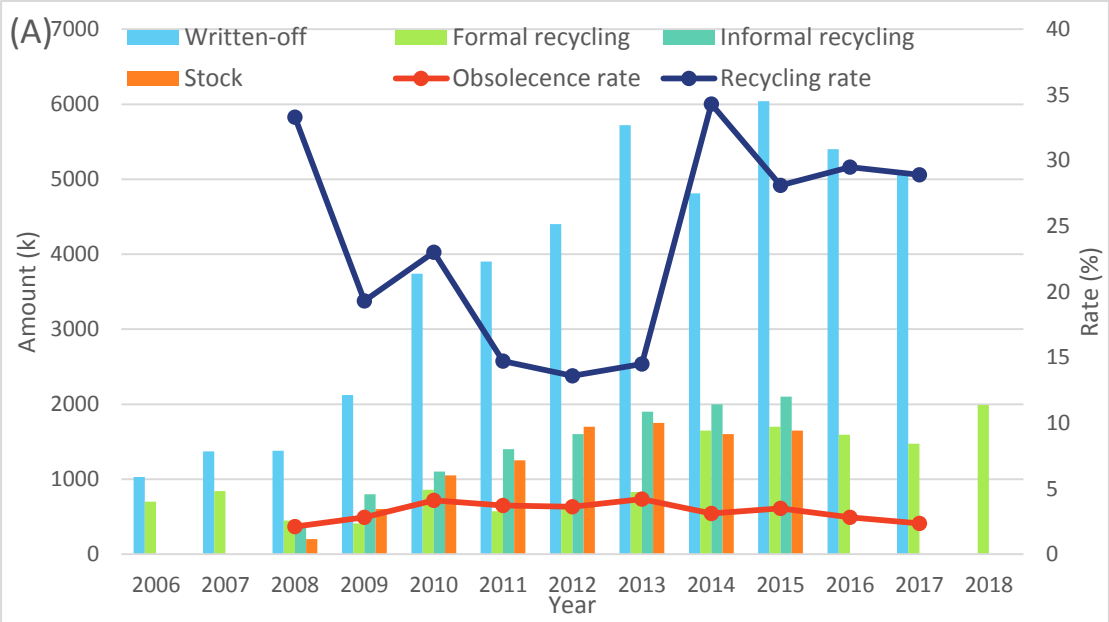
After 2000, massive ELVs generated and went beyond the recycling capacity. A couple of no licensed recyclers just dismantled ELVs to assembly the vehicle using the recycled parts or components. The informal dismantling has resulted in a serious disorder of ELV recycling industry. In June 2001, the State Council promulgated Administrative Measures on the Recovery of ELV (Figure 5). The responsibility of consumer, recycler, and government have been regulated. In the phase, numerous regulations and policies were implemented. The ELV recycling process was upgrading from manual dismantling to automatic disassembling.

4.2 P.R. China's Performance of ELV Recycling

The written-off amount of vehicle has increased from 1 million in 2006 to 6 million in 2015. But the obsolescence rate was only 2-4%, far bellower than the data of many developed countries. The majority vehicles are still in operation, indicating a coming peak of ELV generation in the near future. The formal recycling with dismantling ranges from 0.5 to 2 million unit in the year of 2006-2018. Its recycling rate was no more than 35% (Figure 6).

Only a small fraction of all ELV recycling enterprises was organized in an industry association. In 2004 about 10% of ELVs had been dismantled while the others were

still in use illegally.[12] The informal recycling amount evenly surpassed 1.5 million unit each year, which was higher than the formal recycling amount (Figure 6). This suggested that around one thirds ELVs have entered the informal market with some unproper treatment, one thirds in formal recycling, and one thirds in stock not collected. A recycling market for ELVs was initially established in 2010s owing to the high resource content and reusable parts from them. However, major environmental impacts occur from improper recycling of non-recycled parts, which contain or are contaminated by spent oils, solvents, heavy metals, organic toxics, and ozone depleting substances.[15]



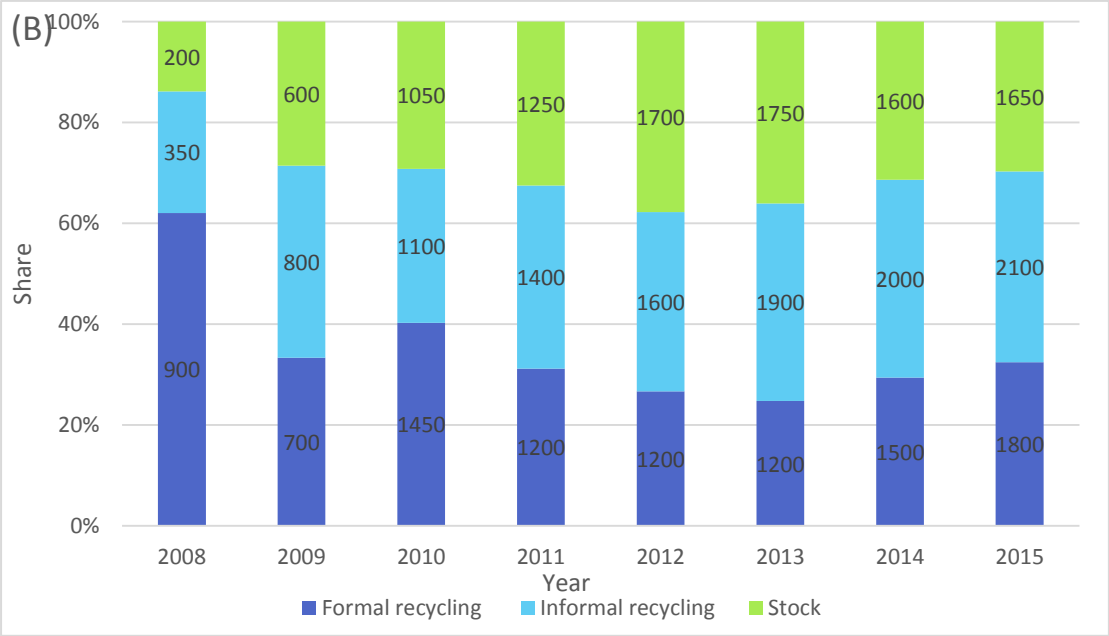


Figure 6 (A) Flow of vehicle in the year of 2008-2015; (B) Share of dealing with. Data source from P.R. China Vehicle Yearbook.

The formal recycling was fulfilled by the licensed recycler and collection point. In recent year P.R. China had around 500 licensed recyclers and over 2,000 collection points (Figure 7). In 2015, there was 603 licensed recyclers and 2,358 collection points, covering the over 80% of county - level administrative regions with the 28,000 employees for the industry.

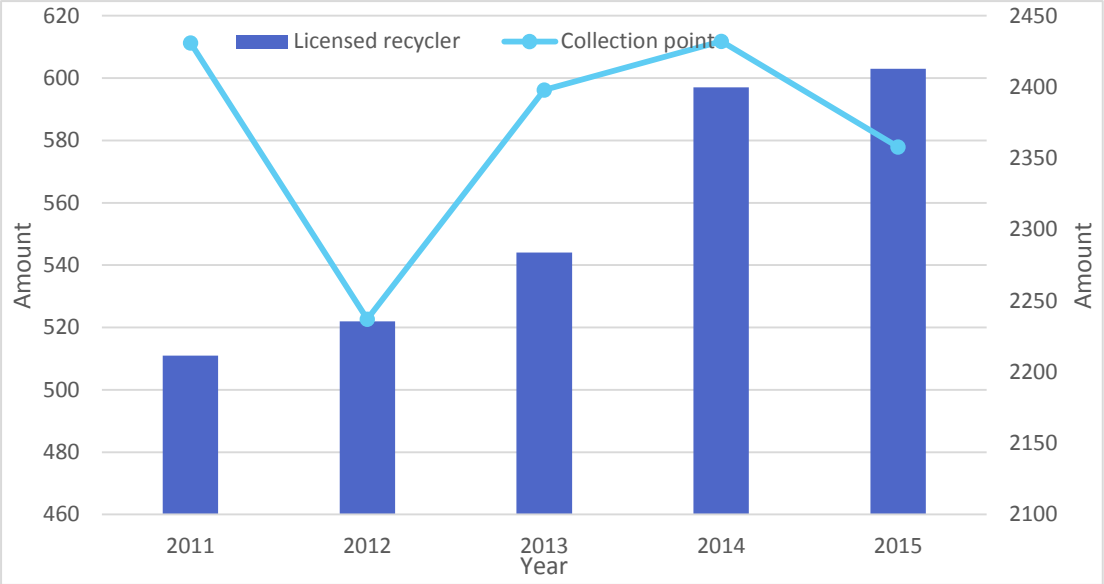


Figure 7 Recycling enterprises amount and collection point in P.R. China

At the perspective of economic profit, we chose one enterprise to examine the cost and benefit analysis. Cost is comprised of the fee in raw, fuel & power, depreciation, human resources cost, equipment repairing, management, and sale. The total cost was about 8.96 million CNY. The economic benefit items cover the selling income of steel, copper, aluminum, lead, zinc, and non-metallic resource. Their total was 12.29 million CNY. Therefore, the profit would be 3.33 million CNY each year (Table 1).

Table 1 The total cost and benefit of one ELVs recycling enterprise operation (million CNY)

Cost		Benefit	
Item	Value	Item	Value
Raw and auxiliary material Fuel and power consumption	7.00	Steel	5.829
Depreciation	0.38	Copper	2.208

Human resources cost	0.35	Aluminum	2.672
Equipment repairing	0.20	Lead	0.304
Management	0.53	Zinc	0.219
Sales cost	0.50	Non-metal	1.239
Sum	8.96	**Sum**	12.29

Note: data source from Xia et al. (2016)[16].

4.2 Main Experience

The solution to ELV problem is relied on the three determinant factors involving in (1) waste prevention; (2) increase of reuse, recycling and recovery of ELVs; (3) improvement of environmental performance of recycling facilities.[17] Thus, how to promote the collection is the first important and proper dismantling is the most key process to enable the high-efficiency recycling. Based on the recent 20 years adventure, main experience is given here:

(1) the most effective regulatory core is the economic incentives to ensure the high collection rate.

(2) P.R. China needed to develop its own approach to handle the ELV, not simply duplicate other countries' experience.

(3) The management information system, including reception, reporting, auditing, and funding subsidy, is quite helpful to support the ELV recycling.

4.3 Critical Lessons

(1) Multi-ministries involving is not beneficial for ELV management. Ministry of Public Security is charged of written-off registration and sale-monitoring of ELV dismantling. Ministry of Commerce and State Administration for Market Regulation are charged of governing the recycling enterprises. And Ministry of Ecology and Environment is charged of the environmental protection along the life cycle of vehicle.

(2) Singular economic benefit cannot make the formal recycling enterprise survive as the informal sector. The collection fee of formal enterprise is far lower than the one of informal sector so that massive ELVs flow to the informal recycling. To raise the price of written-off over ELV sale and tighten up the administration[18] should work together.

(3) Vehicle manufacturers in P.R. China are rarely involved in recycling ELVs, and they seldom provide dismantling information for recycling enterprises.[19] The extended producer responsibility (EPR) implementation in P.R. China is not smooth and lacks very close relationship between the producers and the recycler.[20]

(4) Low recycling technology has declined the recycling efficiency. Current recycling ELV is only relied on simple dismantling and the deep recovery for the high-grade product is still adequate. The upgrading of closed-loop supply chain needs to be enabled in near future.

Chapter 5: The Way Forward

Previous adventure indicates the excellent cover for the closed-loop supply chain by the technology and regulation is the significant core to maintain a high-efficient circular economy. P.R. China's establishing ecological civilization and UN Sustainable Development Goal 2030 are obliging a rapid upgrading of ELV recycling. The experience and lessons impose the following aspects should be paid with higher attention in the way forward.

(1) The integrated framework of circular economy for ELV management should be initially built and supervised by the high government like State Council. Vehicle industry is one of the most important pillars in current P.R. China's economy. The leading government can coordinate many stakeholders of the ministries in a high sufficiency.

(2) The revision of Administrative Measures on the Recovery of ELV needs to be promptly enforced. This revised regulation since 2017 has been discussed and will take effect in this year. The economic incentive and the process formalization will be improved and maintained to avoid the flow of ELV into the informal market.

(3) The collection and recycling network for ELVs should be more effective and standardized. The reverse logistics with reuse, remanufacturing, recycling, and recovery should be supervised by the standard system. Material science and play a significantly role in establishing the standard.

(4) To green the vehicle industry, cost internalization and EPR principle should be strengthened for producer of vehicle. The responsibility awareness could be well linked

with the final collection and recycling. One is more producers will be better involved in the recycling system, and the other is to push green design and manufacturing.

(5) The ELV recycling industry is confronting the technology and pollution control upgrading. The development of large-scale enterprises and combinations of recycling and remanufacturing should be the new trend.

References

(1) Bonneuil, C.; Fressoz, J.-B., *The shock of the Anthropocene: The earth, history and us*. Verso Books: Brooklyn, NY, 2016.

(2) Zeng, X.; Li, J., Urban Mining and Its Resources Adjustment: Characteristics, Sustainability, and Extraction. *SCIENTIA SINICA Terrae* **2018,** *48*, (3), 288-298.

(3) Zeng, X.; Ali, S. H.; Tian, J.; Li, J., Anthropogenic mineral supply has potential to meet Chinese resource demand by 2050. *Nature Geoscience* **2019**.

(4) Liu, J.; QIao, Q.; Chang, L., Forecast on the amount of end-of-life vehicles in province and municipalities in China. *Regeration Resource and Circular Economy* **2011**, (03), 31-33.

(5) Chen, M.; Zhang, F., End-of-Life vehicle recovery in china: Consideration and innovation following the EU ELV directive. *JOM* **2009,** *61*, (3), 45-52.

(6) Zeng, X.; Duan, H.; Wang, F.; Li, J., Examining environmental management of e-waste: China's experience and lessons. *Renewable and Sustainable Energy Reviews* **2017,** *72*, 1076-1082.

(7) Zeng, X.; Yang, C.; Chiang, J. F.; Li, J., Innovating e-waste management: From macroscopic to microscopic scales. *Science of the Total Environment* **2017,** *575*, 1-5.

(8) Li, W.; Bai, H.; Yin, J.; Xu, H., Life cycle assessment of end-of-life vehicle recycling processes in China—take Corolla taxis for example. *Journal of Cleaner Production* **2016,** *117*, 176-187.

(9) Tian, J.; Chen, M., Assessing the economics of processing end-of-life vehicles through manual dismantling. *Waste Management* **2016,** *56*, 384-395.

(10) Chen, M., Automotive product recycling: material efficiency and key technologies. *China*

Mechanical Engineering **2018,** *29*, (21), 2615-2625.

(11) Ni, F. Generic Research on Recycling of Automobile Shredder Residue through Pyrolysis And Gasification. Master, Shanghai Jiao Tong University, Shanghai, 2015.

(12) Chen, M., End-of-life vehicle recycling in China: Now and the future. *JOM* **2005,** *57*, (10), 20-26.

(13) Dong, Y.; Xu, Y.; Pang, T.; Zou, P., Research on Development Strategy for China's Powerful Automobile Industry. *China Engineering Science* **2018,** *20*, (01), 37-44.

(14) Li, J.; Yu, K.; Gao, P., Recycling and pollution control of the End of Life Vehicles in China. *J Mater Cycles Waste Manag* **2014,** *16*, (1), 31-38.

(15) Sakai, S.-i.; Yoshida, H.; Hiratsuka, J.; Vandecasteele, C.; Kohlmeyer, R.; Rotter, V. S.; Passarini, F.; Santini, A.; Peeler, M.; Li, J.; Oh, G.-J.; Chi, N. K.; Bastian, L.; Moore, S.; Kajiwara, N.; Takigami, H.; Itai, T.; Takahashi, S.; Tanabe, S.; Tomoda, K.; Hirakawa, T.; Hirai, Y.; Asari, M.; Yano, J., An international comparative study of end-of-life vehicle (ELV) recycling systems. *J Mater Cycles Waste Manag* **2014,** *16*, (1), 1-20.

(16) Xia, X.; Li, J.; Tian, H.; Zhou, Z.; Li, H.; Tian, G.; Chu, J., The construction and cost-benefit analysis of end-of-life vehicle disassembly plant: a typical case in China. *Clean Technol Envir* **2016**, 1-13.

(17) Kim, N. Exlporing Determinant Factors for Effective End-of-Life Vehicle Policy: Experiences from European end-of-life vehicle systems. Lund University, KFS AB, Lund, Sweden, 2002.

(18) Chen, Y.; Yang, Y.; Hu, S.; Xie, L.; Yang, Y.; Huang, W.; Chen, Z., Analysis and Countermeasures for the Status Quo of the Recycling and Utilization of End-of-Life Vehicles in

China. *China Engineering Science* **2018,** *20*, (01), 113-119.

(19) Wang, J.; Chen, M., Management status of end-of-life vehicles and development strategies of used automotive electronic control components recycling industry in China. *Waste Manage Res* **2012,** *30*, (11), 1198-1207.

(20) Wang, L.; Chen, M., Policies and perspective on end-of-life vehicles in China. *Journal of Cleaner Production* **2013,** *44*, 168-176.